XIV LATIN-AMERICAN CONGRESS ON ELECTRICITY GENERATION AND TRANSMISSION

CLAGTEE 2022

BOOK OF ABSTRACTS AND PROCEEDINGS

ISBN: 978-85-64689-02-2
DOI: 10.29327/547386

RIO DE JANEIRO, BRAZIL, NOVEMBER, 29 – DECEMBER 1

ORGANIZATION

PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAÍSO

unesp

UNIVERSIDAD NACIONAL de MAR DEL PLATA

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Book of Abstracts and Proceedings of 14th Latin-American Congress on Electricity Generation and Transmission: CLAGTEE 2022

ISBN 978-85-64689-02-2

DOI 10.29327/547386

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ACKNOWLEDGMENTS

PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA

Title: Book of Abstracts and Proceedings of The 14th Latin-American Congress on Electricity Generation and Transmission – CLAGTEE 2022

JOSÉ LUZ SILVEIRA & CELSO EDUARDO TUNA
FUNDEB – Fundação para o Desenvolvimento de Bauru
DOI 10.29327/547386

ISBN 978-85-64689-02-2

Câmara Brasileira do Livro (CBL)
Guaratinguetá, Novembro, 28th,2022

PREFACE

Rio de Janeiro is a large Brazilian seaside city, famous for the beaches of Copacabana and Ipanema, the 38-meter tall statue of Christ the Redeemer atop Corcovado mountain, named one of the New Seven Wonders of the World, and the Sugar Loaf Mountain, a granite peak with cable cars. The city is also known for the exciting Carnival, with extravagant costumes and samba dancers. It is the best-known Brazilian city abroad, and the second largest metropolis in Brazil (after São Paulo), the sixth largest in America and the thirty-fifth in the world. Its estimated population is 6 800 000 habitants. Classified as a metropolis, it exerts national influence, being one of the main economic, cultural and financial centers of the country. It represents the second largest GDP in the country and it is headquarters to Brazilian oil, mining, and telecommunications companies, including two of the country's major corporations, Petrobras and Vale. Covered by a large number of universities and institutes, it is the second largest research and development center in Brazil, responsible for 19% of the national scientific production.

In this place will take place: the 14th Latin-American Congress on Electricity Generation and Transmission, (November 29th – December 1st, 2022), now recognized as a preeminent event for the community of power systems science and engineering in Latin-American countries. Thirteen previous events were organized by UNESP - São Paulo State University (Brazil), PUCV - Pontifical Catholic University of Valparaiso (Chile) and UNMdP - National University of Mar del Plata (Argentina).

These events enable a valuable exchange of experiences concerning the methodology for the analysis, planning, and operation of power systems, and the introduction of new technologies, theories and knowledge, which could contribute to the improvement of the electric energy generation, transmission and distribution systems.

The program for the Congress covers the presentation and discussion of technical papers prepared by professionals and researchers, accepted by an Editorial Committee; technical conferences given by guest experts from important national and international businesses, manufacturers and/or suppliers of electrical equipment or power plants; and special sessions for discussion of specific subjects concerning to Planning, Development and Interconnection of Electrical Power Systems Networks in the Latin-American countries.

The technical program for the Congress covers a broad range of topics: Conventional Power Plants and components; Alternative Power Plants and Components; Bioenergy and Hydrogen; Electric Power Transmission and Distribution; Energy Planning and Management; Computational Systems and Signals Processing; Environmental and Ecological Issues; Social and Economic Issues.

Finally, I hope that this week in Rio de Janeiro will be productive for everyone involved, and I also hope that participants can exchange experiences, get in touch with new trends in their area and meet other professionals, aiming at the development of technical knowledge and professional, so important today.

Celso Eduardo Tuna

Executive Chairman

November 28th, 2022

DATE: November 29th – December 1st; 2022

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OBJECTIVE

The growing demand for electric energy in the Latin-American countries requires a greater quality of service and efficiency in the area of techno-economic operations. This brings the constant need for improvement in the growth planning and the levels of the operation of the electric energy systems. The economic and technical aspects must be taken into consideration, as well as the environmental impact of implantation of new power plants and the need to introduce new technologies, control systems and safety measures.

Gradually a process of integration among the Latin-American countries has emerged, as the electric energy needs are similar, including the generation facilities, for these countries.

Considering the above mentioned points, UNESP - Sao Paulo State University (Brazil), PUCV - Pontifical Catholic University of Valparaiso (Chile) and UNdMP - National University of Mar del Plata (Argentina) have joined forces in order to create a forum that permits a valuable exchange of experiences concerning the methodology for the analysis of operation, planning, and the introduction of new technologies that could contribute to the improvement of the electric energy generation and transmission systems. This has become a reality with the creation of these Latin-American congresses, which take place in the distinct cities of the Latin-American countries.

HISTORY OF CONGRESS

Considering the above mentioned points, UNESP - Sao Paulo State University (Brazil), PUCV - Pontifical Catholic University of Valparaiso (Chile) and UNdMP - National University of Mar del Plata (Argentina) have joined forces in order to create a forum that permits a valuable exchange of experiences concerning the methodology for the analysis of operation, planning, and the introduction of new technologies that could contribute to the improvement of the electric energy generation and transmission systems. This has become a reality with the creation of these Latin-American congresses, which take place in the distinct cities of the Latin-American countries.

A cronological review about CLAGTEE is presented below:

- The I Congress took place in Viña de Mar, Chile, on October 1993.
- The II Congress took place in Mar del Plata, Argentina, on November 1995.
- The III Congress took place in Campos do Jordão, Brazil, on November 1997.
- The IV Congress took place in Viña del Mar, Chile, on November 2000.
- The V Congress took place in São Pedro City, Brazil, on November 2003.
- The VI Congress was held in Mar del Plata City, Argentina, on November 13th to 17th, 2005.
- The VII Congress took place in Valparaiso City, Chile, on October 22nd to 25th, 2007.

- The VIII Congress was held in Ubatuba, SP Brazil, on October 18th to 22nd, 2009.
- The IX Congress was held in Mar del Plata City, Argentina, on November 6th to 09th, 2011.
- The X Congress took place in Viña de Mar, Chile, on October 6th to 9th, 2013.
- The XI Congress was held in São José dos Campos, Brazil, November 8 to November 11, 2015.
- The XII Congress was held in Mar del Plata City, Argentina, November 12 to November 15, 2017.
- The XIII Congress took place in Santiago, Chile, October 20 to October 23, 2019.
- The XIV Congress will be in Rio de Janeiro, Brazil, November 29th – December 1st, 2022.

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B-1.1-4

Analysis of Power Quality Indicators Considering Intentional Islanding

Cesar Bastamante Soares*, Silvio Giuseppe Di Santo
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The present work intends to demonstrate the possible alterations in the electric energy quality indicators referring to the continuity of supply, considering the insertion of distributed generation in a power grid network. Therefore, the Monte Carlo method was used as a tool, performing random disconnections in the IEEE 37 Node Test Feeder standard network, estimating, through computer simulation, using OpenDSS controlled by Matlab, energy quality indexes related to service continuity, considering the distribution network without the insertion of distributed generation, and with the installation of distributed generation with the possibility of formation of intentional islanding zones. Lastly, a comparison was made between the simulations, verifying improvements in the chosen quality indicators where it was possible to operate in intentional islanding mode. The results found in this study may be used as a basis for real implementations.

Keywords: Estimation of DIC and FIC Indicators, Intentional Islanding, Distributed Generation with Islanding, Islanding Zones.

B-1.3-1

Remote Access Platform to Sonar Data Applied to Ichthyofauna Monitoring in Hydroelectric Power Plants

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This paper presents the requirement gathering, design, proof of concept, and development of a solution for remote activation and automation of hydro-acoustic equipment (SONAR - Sound, Navigation and Ranging). The motivation of the study is the possibility of creating a remote access technology to minimize environmental impacts on the ichthyofauna in the area of direct influence of Hydroelectric Power Plants (HPP). After the promising results of the proof of concept, a prototype was conceived and validated in the field at HPP Jirau on the Madeira River, state of Rondônia, Brazil. The focus was the use of the technological solution in real-time monitoring of the movement of ichthyofauna at fixed points of the structures of the HPP Jirau, such as the spillway, the generating units (GU), and the surface trunk retention structure (Log Boom). The use of SONAR technology with remote access technology made it possible to monitor the movement of the ichthyofauna in these areas over long periods with accurate information. The prototype commissioning phase required system adaptations and hardware and software improvements.

The remote access technology applied to SONAR presented high stability and robustness, being easy to adapt to different applications in different plants in the Brazilian hydroelectric sector, supporting decision-making during operational maneuvers.

Keywords: Environmental impacts, hydroelectric power plant, ichthyofauna, remote access, sonar.

B-1.3-3

A Vibration Analysis Procedure to Monitoring Dam´s Operation Under Varying Loading Conditions

José Vitor Freitas da Silva*, Ubiratan Holanda Bezerra, Hendrick Maxil Zárate Rocha, Renato Lisboa Francês, João Crisóstomo Weyl Albuquerque Costa, Flávio Moreira de Paula, Marcelo Boaventura, Maria Emília de Lima Tostes
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Abstract--This paper presents a vibration analysis procedure by means of modal and harmonic responses, utilizing the Finite Element Method - FEM, and a 3D CAD model of a generic hydroelectric dam. The modal analysis is important to provide characteristics of the structure such as natural frequencies and mode shapes, which indicates how the structure vibrates at a specific frequency. The harmonic response is performed by applying a simulated force to the structure, which results in the Frequency Response Function (FRF), in a range of frequencies of interest. All these parameters are critical for the dam´s structure monitoring and dynamic behavior investigation, to guarantee a safe operation under varying loading conditions. The 3D model is designed using SolidWorks, then it is imported to ANSYS software, which performs the FEM vibration analysis, considering boundary conditions to represent adequately the real behavior of the dam´s structure. The material used is concrete from Ansys`s library. As overall results, from the modal analysis the five most significant modes are taken in discussion, as well the FRF's in the three axes directions. The highest deformation value occurred at 13.33 Hz with 7.223 mm in the z-direction, which is expected, because most forces are in that direction. The paper will discuss these results in more details, to take in consideration external disturbances that may generate resonance phenomenon and collapse the structure, and must be avoided at all costs in order to prevent accidents and maintain structure reliability and safety, protecting employees and nearby residents.

Keywords: dam, finite element, harmonic response, modal, vibration analysis

TOPIC 2 - Alternative Power Plants and Components

B-2.1-3

Quantification of greenhouse gas emission savings in an electric power distribution system with on-grid photovoltaic distributed generation insertion

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This work aimed to quantify the greenhouse gas emission savings due to the decrease in user demand and active losses in the network, in a residential sector of the electric-power-distribution system. Such residential area is located in Mar del Plata city, Argentina, where on-grid photovoltaic generation sources were incorporated. The studied network was modelled by using DIgSILENT software using its real electrical parameters. The system is composed of a main feeder at medium voltage, step-down transformers, and secondary distribution at low voltage with its more than 5000 users and photovoltaic systems, including their daily and seasonal characteristics of consumption and generation, respectively. The network operation analysis was performed for a whole year, 2019, during which the behaviour of different parameters could be quantified in 5 scenarios with different levels of insertion of photovoltaic generation. The focus was placed on the amount of energy that is no longer provided by traditional electric energy sources. It was possible to measure the environmental impact produced based on the obtained results. A constant reduction in emissions was observed as the level of photovoltaic insertion increased. However, this reduction tends to stabilize at a maximum value determined by the adopted grid connection system.

Keywords: electric power distribution system, greenhouse gas emission, on-grid connection, photovoltaic distributed generation, renewable energy sources.

B-2.1-6

Analysis of the use of BAPVs and BIPVs for electric energy generation in buildings in urban Areas

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This work aims to analyze the power generation capacity of photovoltaic panels installed in buildings in the urban environment and its influence on the temperature inside them. This influence can be verified through the variation of the electrical energy consumption of the air conditioning system, since this consumption increases as the temperature inside the building also

increases. The object of study (a building in the urban environment) will be analyzed by means of computer simulation, using Auto-Cad, SketchUp and Energy Plus software, aiming at analyzing the electricity consumption of lighting and air conditioning systems during seasons of the year, considering two different types of photovoltaic systems (Building Applied Photovoltaics - BAPVs and Building Integrated Photovoltaics BIPVs). The obtained results allow the evaluation of the influence of the installation of photovoltaic panels on the environment temperature of the building and, consequently, in the consumption of electric energy.

Keywords: BAPVs, BIPVs, electricity generation, urban areas.

B-2.1-7

Charging Strategies for Electric Vehicles from Renewable Hybrid Systems

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The growing introduction of electric vehicles (EV) creates a new energy demand that can be covered by renewable energies. In this work, a Hybrid Mini Grid connected to the electric utility grid, located in the Amazon Energy Efficiency Center (CEAMAZON), at Federal University of Pará (UFPA), in Belém, Pará, Brazil, was used to analyze EV charging strategies. To that end, initially, CEAMAZON load curves and photovoltaic generation curves were obtained on three days with different weather conditions (sunny day, sunny day with high variability and cloudy day). Therefore, based on CEAMAZON photovoltaic generation and load, it was possible to obtain the energy available for EV charging, considering the hybrid system power delivery limitations, and thus define the best charging powers for EVs. The results show the benefits of storage systems in operational flexibility, in conjunction with the different charging power settings available, as well as the feasibility of recharging.

Keywords: Vehicles (EV), Charging Strategies for EV, Hybrid Systems, Renewable Energies, Photovoltaic Generation.

B-2.1-8

Proposal of Enhancements on Traditional Voltage and Reactive Power Control Practices in Distribution Systems with MV Distributed Generators

Fernanda Caseño Trindade Arioli*, Jéssica Tiemi Takeuchi, Heliton de Oliveira Vilibor, Bárbara Resende Rosado, Tiago Rodarte Ricciardi, Fernanda C. L. Trindade
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The increased integration of distributed generation to distribution power systems diversifies the energy mix and causes major changes in the operation and planning of distribution systems. Such changes are motivated by technical challenges, as sustained overvoltage at customer units,

reduced power factor at the point of connection with the transmission system, and increase in the percentage of technical losses. In this context, this work proposes a set of practices of voltage control and reactive power compensation (Volt-var) in distribution systems in the presence of distributed generation connected at medium voltage level (minigeneration) employing only the traditional Volt-var equipment, capacitor banks and voltage regulators, and the respective functions. It differs from many works from literature that try to integrate communication, new technologies, and elaborated control functions instead of first extracting full value of the traditional equipment and practices. This work is part of an R&D project developed by CPFL Energia and UNICAMP. The results show that, for a single circuit, technical losses decrease 8.2%, and the voltage transgression cost decreases by 96% when the recommended practices are adopted.

Keywords: Distributed generation, distribution systems, power factor violation, Volt-var control, voltage transgression, technical losses.

B-2.1-9

Optimized design of a hybrid wind-solar plant to maximize the energy produced

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When operating individually, solar and wind plants are not able to deliver power continuously due to the intermittent behavior of primary resources. Hybridizing these generators using their complementarity features would significantly contribute to solving this problem by providing more stable and sustainable energy. In this way, the present proposal aims to contribute with a methodology that allows to understand through the Pearson coefficient the complementarity relationship between these sources and to determine the optimized composition of a hybrid plant through the capacity factor. The results indicated that there is a low potential for the implantation of a hybrid plant in the place where the data were collected. In addition, the optimized composition of the hybrid plant was 90% wind and 10% solar.

Keywords: hybrid power plants, complementarity, solar photovoltaic power plant, wind power plant.

B-2.1-10

Experimental Analysis of an Autotransformer Performance Connected to Photovoltaic Systems

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The DC-AC inverters, intended for conditioning the electrical signals generated by the photovoltaic modules, normally present as output, phase-phase and phase-neutral voltages of

380 and 220 V, respectively. Although there are inverters that output 220/127 V phasephase/phase-neutral voltages, their supply in the national market is rare and this factor therefore leads to a higher cost of this equipment. Considering a photovoltaic system installed in regions where the three-phase secondary grid presents phase-phase/phase-neutral voltages of 220/127V, one of the alternatives to reduce the general price of the photovoltaic system is the application of an autotransformer between the inverter and the secondary power distribution grid. This alternative is attractive because the cost of the 380/220 V inverter added to the cost of the 220/127 V autotransformer is normally lower than that of the 220/127 V inverter. In this context, of the connection of an autotransformer composing a photovoltaic system, it is necessary to analyze the losses resulting from its operation, since the energy generation that a photovoltaic system produces is not constant throughout the day. Therefore, there is a need to do experimental tests and observe if, under conditions of load variation, the autotransformer will continue to work in an acceptable range of performance, with minimal losses for energy consumption by the consumer unit to which it is connected or to transfer energy to the electrical secondary distribution grid. The present work proposes, therefore, to estimate the efficiency of a 30 kVA autotransformer from the no-load and electrical resistance experimental tests. The experimental tested results allowed the identification of fixed losses, in the core, and of variables losses, in the windings, for different fractions of generated energy, as well as the fraction of load that corresponds to the maximum efficiency of the autotransformer that composes the photovoltaic system.

Keywords: Autotransformer, Photovoltaic systems, Performance of the autotransformer, Daily performance.

B-2.1-11

Complementarity of Wind and Solar Renewable Sources in the North of Maranhão

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As the global demand for electrical energy arises, the expansion of energy resources has been investigated deeply. In this context, among the Brazilian states, Maranhão has shown an excellent potential for solar and wind energy. These primary energy resources have an intermittent arrangement, negatively affecting the electricity system. Nonetheless, this limitation can be surpassed with the possibility of the use of complementarity between these two resources. This paper investigates the local complementarity between solar irradiation and wind speed in some places in the north of Maranhão. The analyses are made using real data obtained from some specific locals and complementarity index already shown in literature, like Pearson's correlation coefficient. The results can support the idea of hybrid power plants to take advantage of local complementarity.

Keywords: Complementarity, solar energy, solar irradiation, wind energy, wind speed.

B-2.1-13

Analytical Model to Estimate the Influence of Turbulence Intensity on the Capacity Factor of Wind Farms

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The capacity factor is one of the tools to evaluate the performance of wind farms, in addition it serves to select the appropriate wind turbine model for the local wind conditions, in order to optimize the production of electricity. This research presents a new parametric model based on the analytical integral of the characteristics of the parameters of the Weibull distribution of the local wind associated with the intensity of the turbulence. The parameters of the proposed model were optimized with genetic algorithm. The proposed model was validated with data from the SCADA system, and with information available in Wind Atlas and ONS for different wind farms in Brazil. This study was able to systematically estimate the influence of the turbulence intensity as a function of the form factor and the Weibull distribution scale factor related to the rated speed of the wind turbine.

Keywords: Capacity factor, SCADA, Wind farms, Wind energy.

B-2.1-14

Control system for the optimal dispatch of a hybrid photovoltaic-diesel generation

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Brazil is a country with continental dimensions where most of the population is connected to the distribution system and receives energy from several generation plants spread across the national territory. However, a small portion of the population living in remote regions, where the distribution system cannot reach, are isolated and thus need to generate their own energy.The regions are supplied by microgrid, formed mainly by Diesel Generators (DG), which are easy to design, build and operate. However, the consumption of diesel used in these generators is high, the cost of preventive and corrective maintenance is significant and the use of fossil fuel harms the environment. To mitigate these problems, the possibility of using hybrid microgrids, which allow the use of renewable sources to generate clean energy and also reduce the fuel consumption of (DG). However, its association with a renewable generation, such as photovoltaic (PV), directly and without any control, can cause damage to the (DG) and also, in case of the operation of the protection system, leave the microgrid without electricity. This is because, in order to have a greater reduction in fuel, it is necessary that the generation of (DG) be reduced, using more energy from (PV). Such a process is complex to be operated, because the (DG) have a limit range of operation, which should be around 30%. If this limit is not respected, the equipment may have malfunctions in its mechanical set. Thus, this article proposes the development of an algorithm capable of guaranteeing a greater penetration of photovoltaic generation without

exceeding the minimum generation limit of the GMG. The proposed control system is developed and simulated in Matlab Simulnk® software. The configuration and dimensioning of the hybrid system was carried out using the HOMER Energy® software, thus ensuring the best configuration between the generators and an optimal dispatch.

Keywords: Photovoltaic, Diesel Generator, hybrid, optimization, control system, algorithm.

B-2.1-15

Evaluation of an Associated Project by Integrating a Photovoltaic Power Plant with a Wind Complex in Southern Brazil

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The use of renewable sources for electricity generation has been growing every year around the world. However, sources with variable generation characteristics need that the electric power system be designed by the maximum capacity of the power plants, resulting in idle periods. An alternative to improve the use of the power system in these scenarios is the association of plants whose energy resources are complementary in time, as is the case for wind and photovoltaic projects in some regions of Brazil. Thus, this paper aims to analyze the complementarity of wind and solar resources in southern Brazil, in a region where a 300 MW wind complex will be built. Furthermore, assuming the possibility of associating a photovoltaic plant to the wind complex, the feasibility of the project is evaluated through the analysis of the LCOE (Leveled Cost of Energy) under different operating conditions.

Keywords: Associated Projects, Complementarity, Hybrid Systems, Photovoltaic Power Plant, Renewable Energies, Wind Complex.

B-2.1-16

A Fault Supervision Method for Islanded and Converters-Based Microgrids with Integration of Renewable Generation

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The need to supply the rapid increase in global energy consumption through clean and sustainable generation encouraged the development of microgrids as an important part of the smart grid and distributed generation paradigm. The operation of microgrids implies a series of challenges such as energy management strategies and protection systems to ensure a safe and stable operation. The variability of renewable resources and the low inertia of electronic converters produce variable fault currents in microgrids during faults, particularly in island mode operation. For this reason, traditional protection systems based on activation by defined current

levels can fail. In this work, a rule-based supervision algorithm for fault detection and location in islanded microgrids that include renewable generation and storage devices is proposed. The method provides an additional security layer to the traditional protection included in electronic converters by detecting, locating and isolating faults; and thus providing information on the status of devices. It requires voltage and current measurements and is based on comparing measured and predicted variables using line and generations models. The approach is applied to a fault simulation model of an islanded microgrid that includes photovoltaic panels and batteries. Simulations are carried out in different scenarios, which possess different solar radiation levels, battery states of charge, and fault types and locations (e.g. on the different busses, AC or DC). In particular, for failure scenarios with low solar radiation and low battery state of charge, the converter protections do not work, however, the supervision strategy permitted detection, location and isolation of the fault by means of the corresponding circuit brakers.

Keywords: fault detection, fault location, fault isolation, microgrids, renewable generation.

B-2.1-17

Analysis of the PETG material, for the manufacture of wind blades

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Throughout the development of humanity, there have been searches for these new materials that add additional gains and that can have several applications, one class that fit in this research is the polymers. Since their discovery, the use of polymers has increased due to their versatility. Among the main commercially used polyesters, PET stands out the most. And from it, PETG originated, which is a copolymer, and its main application area is 3D printing, this is due to its specific properties, such as ease of extrusion and thermal stability. In view of this information, this work presents a study of the literature, to first verify the properties of PETG, and to corroborate its use in the renewable energy sector, more specifically, in the manufacture of wind blades through FDM printing. Finally, the work brings a conclusion of feasibility and preference for the use of PETG in this blade manufacturing process.

Keywords: PETG, PET, wind blades, wind energy, 3D printing.

B-2.1-18

A Comparative Analysis of Annual Wind Energy Production in Brazilian Equatorial Region Using Traditional Approach and LiDAR

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The wind has different features not captured by the standard models, and deviations in wind speed may cause a significant difference between expected and real energy production at some power plants. Given the Brazilian wind potential and the need to investigate and understand the impact of micrometeorological phenomena on wind turbine performance under local conditions and at heights above 100 m – given the evolution of technology in the sector that produces turbines with ever-higher heights – this paper presents a comparative analysis of available energy potential between power the curve of the wind turbine and modeling from measurement data of a LiDAR (Light Detection and Ranging technique) in the equatorial region of Maranhão. The results from traditional wind forecasting models will be compared to LIDAR data to show the energy forecast differences using each method.

Keywords: Available Energy Production, Equatorial Region, LIDAR, Wind Power.

B-2.1-20

Energy Dependence: Challenges, Dilemmas and Limitations of Energy Resources Exploitation

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Human intervention on environment has been associated with severe environmental devastation and accelerated loss of biodiversity. The human population grows rapidly, as well as its energy consumption and dependence, and even renewable sources have achievable limits for their exploitation. Much has been said about the great potential of renewable sources, however, little is portrayed in the literature about the natural and anthropocentric limits for their use. How much, then, can our energy consumption still grow? What is the really usable potential of renewable sources? Understanding such limits can help humanity plan its future in terms of its interactions with natural resources and, consequently, the future of the planet itself. In this work, we intend to carry out a bibliographic review of the literature that deals with the anthropocentric limits of exploitation of energy resources and bring a reflection on the model of humanity's relationship with energy, technology and its environment.

Keywords: Anthropocentric Limits, Renewable Energy, Sustentability, Theoretical Limits.

B-2.1-21

The generation of photovoltaic energy: a comparative analysis of Energy Operation Plans (PEN) from 2017 and 2018 with related environmental questions.

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The implementation of the use of photovoltaic energy in Brazil has had a significant increase, especially over the past five years, increasing 58% in 2020, according to Gimenes (2020). This article presents a comparison between Energy Operation Plans (PENs) in 2017 and 2018, besides changes that have happened in the Energy Grid during this period. In the international context, Energy Grid imbalance is called into question, caused by increase in photovoltaic generation without adequate implementation, unleashing problems such as the following: energy failure, rises in energy bills and lack of harmony between energy generation and consumption (TVERBERG, 2017). One sets out from the assumption that problematic situations found internationally could also occur in Brazil with the unbalanced transition undertaken for the energy grid, possibly having a negative impact in the short and long terms. Among the possible consequences, it is possible to cite the following: interruptions in energy supply, irregular pricing of certain energy sources and environmental impacts occasioned by the improper manufacturing and/or disposal of photovoltaic modules. The research methodology consisted of bibliographic review and examination of documents. Energy Operation Plans from 2017 and 2018, national articles such as those written by Mauro Sérgio Crestani for the Fotovolt journal, and international articles written by authors like Gail Tverberg (2017) and Dustin Mulvaney (2014) were analyzed. Tverberg and Mulvaney were responsible for contributing to positions taken in relation to methodology for evaluating the cost of inserting modules into the energy grid and queries about environmental impacts, respectively. The results indicate that, as long as it is carried out correctly, photovoltaic generation, alongside other clean energy sources, has the capacity to supply a significant portion of charge to the national energy grid and contribute to the country's abiding by international agreements.

Keywords: Electrical Engineering, Solar Energy, Energy Grid, Energy Operation Plan (PEN), Environmental questions.

B-2.1-22

Development of locational incentives for distributed electricity generation

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This work proposes, within the context of the Brazilian electricity sector, a locational signaling methodology within the Tariff for Distribution System Use (TUSD) that seeks to encourage the growth of micro and mini distributed generation (DG) towards the most technically favorable locations for DG along an electrical feeder.Technical indicator as voltage magnitude, technical losses, loading, overload, imbalance and occurrence of reverse flows, are evaluated to classify the best and worst regions of the distribution network for DG installation. A case study of the proposed methodology is evaluated in real Brazilian distribution networks. Based on a multiple step methodology – division of the distribution network into pre-defined regions; calculation of the different hosting capacities of the feeder according to the positional insertion of the DG; and construction of standardized technical indicators - it was possible to classify different regions of the electric feeder through power flow simulations. The classifications of the regions were segregated by grid voltage level (MV and LV) and performed for each level of DG insertion. This differentiation proved to be important, since the classifications obtained in the case study for

three real networks varied between the voltage levels of the network and between the DG penetration levels. The need for periodic review of the locational signal for each feeder was evidenced as the DG scenario evolves in the distribution network. In the Brazilian regulatory context, this review can take place at the time of the tariff review of energy utilities. From the classification results, it was possible to build the locational signal in the TUSD tariff, keeping the same revenue to the utility and varying the generators tariffs proportionally with the performance classifications of the technical indicators collected in the power flow simulations.

Keywords: Energy Distribution, Distributed Generation, Locational Tariff, Hosting Capacity, Distributed Energy Resources.

B-2.1-23

PCH and Photovoltaic Distributed Generation Analysis using ATPDraw software

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DG is a power generation that is characterized by using renewable sources and being located close to final consumers, so it does not need to use electricity transmission networks, as it is directly connected to the distribution networks. In this way, this type of generation reduces the consumption of fossil fuels and the emission of gases, helping to preserve the environment, and also reduces costs and energy losses with electric power transmission lines. However, the insertion of distributed generation in electrical distribution networks causes changes in relevant behavior at operational levels, altering voltage, current, harmonics and protection limits. Therefore, it is necessary to carry out studies on these changes in order to increasingly improve the availability of energy to various consumers. In this scenario, this work proposes the study of the behavior of the voltage level of an electrical system when a solar photovoltaic (PV) and a small hydroelectric plant (SHP) are connected to it, in the event of short circuits. For this, modeling of the feeder and of the Solar DGs and PCH were made in the ATPDraw software, where the simulation of the occurrence of single-phase, two-phase and three-phase short circuits in this electrical system was performed. With this, in this way, the results were obtained for MatLab so that a more detailed analysis could be carried out, thus, these results were obtained, making a comparison of the effects caused by these disturbances in the electrical network. As a result, it was found that connecting the DG to the distribution network impacts the transient improvement, as it reduces voltage sag; in addition to also verifying that the PCH, when compared to the PV, has a higher voltage level rise in the occurrence of short circuits in the network.

Keywords: ATPDraw, Short circuit, Distributed generation, Small Hydroelectric Power Station, solar photovoltaic.

B-2.1-24

Advances and developments of solar photovoltaic generation in Brazil: A case study applying different photovoltaic cells technologies for distributed generation

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This study performs the projection of a gridconnected photovoltaic solar generation microsystem, analyzing the technical-economic and environmental feasibility of implementing p-Si and CdTe cell technologies, both predominant among the applications of crystalline silicon and thin film cells, which encompass the first and second generation of photovoltaic cells, respectively. For the simulations, the PVsyst software was used to precisely define the calculated parameters and system requirements. The results of the project emphasize and demonstrate the consolidation of CdTe cells, of which they obtained excellent technical and economic performance indices, besides the good reduction of CO2 emission in the generation system, compared to p-Si cells. On the other hand, it becomes remarkable how impacting is the size of the system, besides the operation conditions submitted, influencing factors of losses, stability, and yield, with the crystalline silicon technologies still standing out over the other technologies.

Keywords: Cadmium telluride, Crystalline silicon, Photovoltaic cells, Polycrystalline silicon, Thin film.

B-2.1-25

Technical Impact of the Insertion of Distributed Mini and Microgeneration in Typical Distribution Networks

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The world has been going through a significant change in the energy matrix, with renewable energy sources gaining prominence, especially photovoltaic solar energy, due to its low environmental impact and energy and financial efficiency. The insertion of distributed generators among a distribution network cause impacts that can decrease the useful life and damage equipment, in addition to unbalancing voltage controllers and protection circuits, for example. This paper consists of the three-phase modeling of two distribution networks, one Rural and one Urban, representing typical networks of these two scenarios. The objective of the work is to analyze these impacts in the critical scenarios of each system. In all simulation cases, technical impacts such as voltage limit violations, ohmic losses in the feeders and possible reversal of power flow were investigated. For the two analyzed grids, it was possible to observe voltage limit

violations, power flow reversal, and depending on the generation allocation both increased and decreased losses on the feeders occurred.

Keywords: Distributed Generation, Distribution System, Voltage Profile, Ohmic Losses, Power Flow Reversal.

B-2.1-28

Potentiality of the Wind Source as a mitigator of the water crisis in Brazil

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In 2021, the Brazilian electricity sector went through a crisis aggravated mainly by the fluctuations of water sources that supply the reservoirs of large hydroelectric plants, which correspond to most of the country's electrical matrix. These impacts are increasingly visible in the national integrated system, which has required greater use of fossil fuel-derived sources, such as thermoelectric plants. That said, the methodology consisted of a comprehensive review of data present in the literature of several governmental studies, national and international bodies, from this information, the importance of the complementarity of wind and hydraulic resources in Brazil and aligned offshore wind potential were analyzed. With the development of the green hydrogen economy. So that in the dry season the winds are stronger, while in the winter season the level of the reservoirs increases, within this perspective of the energy transition, renewable sources are intermittent and do not supply the capacity of several sectors. The present study sought to highlight the importance of analyzing the wind potential, to mitigate the water crisis in the country, as a complementarity of hydroelectric plants with reach the stability of the energy transmission and distribution system.

Keywords: climate change, water crisis, wind energy.

B-2.1-30

An Accurate Evaluation of Load Profile in Optimal Allocation of Distributed Generation in Power Systems

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The placement of distributed generation (DG) units in power systems is an efficient way for energy loss reduction, especially when penetration of DG in modern systems is growing due to their impacts on environmental sustainability. On the other hand, load variations and method of electricity consumption affect energy losses amount. Therefore, power demand variations have an essential role in the determination of energy loss amount and optimal generation of DG. However, considering the variability of load level in the DG allocation problem increases the burden and computational time and neglecting it causes the energy losses is calculated

inaccurately. Therefore, this paper aims to evaluate effect of load pattern on renewable DG allocation plans in order to find out importance of considering load variations in energy losses minimization via DG placement. The analysis has been conducted on well-known distribution systems by a classic optimization tool named as AMPL.

Keywords: Accurate evaluation, consumption pattern, distributed generation, load profile, renewable power.

B-2.1-31

Analysis of hosting capacity and network support connecting electric vehicles using PSCAD

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Government policies have been developed in several countries with the objective of decarbonizing the generation of energy and the transport sector. Most Resources Distributed Energy Systems (REDs), including generation, batteries and charging Electric Vehicles (EVs), are connected to the electrical network through power electronics. Is this necessary to adapt the electrical characteristics of the generation (magnitude voltage, frequency and phase sequence) with the Point of Common Coupling (PAC) in the power grid. Faced with this In this context, this work is dedicated to the average modeling of EVs (with based on the Nissan Leaf model), in order to validate and deepen the their impacts on a distribution network. As a proposal of mitigation of possible problems, battery banks are inserted on the network for active management. The proposed management mitigated the occurrence of undervoltage caused by high penetration of EVs in the network and also overvoltage due to the high penetration of photovoltaic systems.

Keywords: Active Network Management, Impacts on a Network Distribution, Distributed Energy Resources, Systems Photovoltaics, Electric Vehicles.

B-2.1-39

A business model and technical economic evaluation of replacement of thermal plants using renewable energy microgrids for electrification in the Peruvian Amazonia

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In this paper, the implementation of renewable energy microgrids that replace the current thermal power plants in the Peruvian Amazonia was analyzed from technical economic and

business model approach. To study the technical and economic feasibility, communities with thermal plants were identified using georeferenced information. For each community the energy demand was obtained using measured real data or estimations based on typical demands. Then, the photovoltaic and battery capacity for each community was sized considered solar resource and other geographical characteristics. The CAPEX and OPEX for the microgrids were obtained based on costs of several real projects in Peru. Finally, the LCOE calculations of the microgrids were performed and compared with the LCOE of current thermal plants. The study findings show that the replacement is technically feasible and economically reliable, as in the average case the investment IRR of 19% is obtained while an average LCOE with microgrids would be 160 USD/MWh comparing with the 211 USD/MWh current LCOE, indicating a potential reduction of 25% when adopting the renewable generation solution.

Keywords: microgrids, renewable energy, electrification, Peruvian Amazonia.

B-2.1-41

Proposal for a decentralized unit for distributed generation of electricity and hydrogen operating with ethanol: aggregate system at a Fuel station

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The work presents a model of unit that generates electricity and hydrogen in order to be applied and allocated strategically at fuel-stations, considering the Brazilian conditions. In Brazil such fuel-stations already follows marketing and logistics premises that allows to being regularity provided with ethanol fuel as well are usually near to the consumers, configuring themselves as a strategic possibility of wide network in relevant locations such as urban centers and highways for hydrogen supplying. Considering a strategy of decentralization of the distributed generation of electricity, there is a valued possibility of diversification related to Brazilian primary energy source configuration, regarding that the fuel-stations could be able to supply the electric-energy demands considering the proximity of the consumers, also starting to be a green-hydrogen provider, using the ethanol as a biofuel already extremely widespread and applied over all Brazilian territory. Therefore, the proposal is the establishment of a unit in the fuel-station with a dimension similar of 10 feet (3.05 m) container, containing inside a SOFC and PEMFC fuel-cells, an ethanol reformer and others auxiliary components. The operational model proposed for this unit establishes an immediate supply of power distributed in the electrical grid provided from the PEMFC that has a rapid startup due to a hydrogen reservoir already operational at the unit itself, until the SOFC reaches the ideal temperature which varies about 700 °C and 900 °C, also providing electricity-power and being the cogenerating source of heat directed for the reform of ethanol (i.e. synthesis, shift gases) and water vapor obtaining, thus providing the production of hydrogen (H2). Preliminary theoretical results indicate the technical feasibility of the unit, especially the definition of energy parity between SOFC and reformer. Hence, the cogeneration of electricity and heat provided by the SOFC is used (depending of the configuration of the unit, because the thermal energy is in a first analysis the scope of this parity, however there is also the possibility of

using electrical energy) and the reform endothermic reaction, in order to obtain the modeled output of 1 kg of hydrogen (H2).

Keywords: Fuel-Cell SOFC, PEMFC, Cogeneration, Green Hydrogen, Ethanol Reform, Distributed Generation of Electricity, Thermodynamic, Modeling.

B-2.1-42

The need for new technologies Energy Storage Systems on the growth scenario of Variable Renewable Energy

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The growth of Variable Renewable Energy (VRE) in electricity, and the reduction of traditional sources, imply the source of variability in generation. Requiring new actions to maintain the tariff modality and reliability of the system, in which the new technologies of Energy Storage Systems (ESS) can play an important role. The objective of this work is to analyze the need to expand new ESS technologies in the electrical matrix. This study, its focus on the transmission level of Brazil, is evaluating the technological conditions of introduction, new technologies, and the integration system/transmission system in the National Interconnected System (SIN), more specifically in the integration between the submarkets and Northeast Center -west.

Keywords: wind, solar, regulation, energy market, energy storage systems (ESS).

B-2.1-43

Insertion of PV-BESS Hybrid Plant in a Wind Farm: Case Study of Casa Nova, Bahia

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Traditionally, photovoltaic (PV) and wind (WT) systems are installed separately to generate electricity. However, Hybrid Systems (HS) have been increasingly implemented to mitigate the intermittent nature of renewable resources. In addition, Battery Energy Storage System (BESS) has been associated with PV/WT systems to improve energy resource integration. The main objective of this paper is to evaluate the impacts of a PV-WT-BESS hybrid power plant, considering the hybridization of one wind park in Casa Nova, Bahia. The results showed that the insertion of the HS increased the reactive control capacity of the wind farm, and it did not cause violations in the voltage profile and power factor. Additionally, there was no increase in active power losses at the wind farm.

Keywords: BESS, Hybrid Plants, Photovoltaic, Wind Turbines.

B-2.1-44

Electric Catamaran and Energy Efficiency for sustainable development and tourism innovation in the Amazon.

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The high use of fossil fuels in the Amazon region, both by ships and by the use of generators for electricity generation, contributes to the emission of carbon dioxide (CO2) into the atmosphere. In the northern region of Brazil, in particular the municipality of Belém-Pará, there is a diversity of rivers, among them the Guajará Bay, which is formed by the meeting of the mouth of the Guamá and Acará rivers, in which are important waterways that serve mainly for the displacement of the population and the realization of tourist routes. These waterway tourism routes carried out by the Bay use combustion vessels that contribute to various environmental impacts. Thus, the municipality has geographic characteristics that can provide innovation in the waterway matrix to combustion by a renewable source powered by electricity. Based on the above, the present research aims to present the survey regarding the feasibility of replacing a diesel-powered tourist boat with a Hybrid Solar Electric Catamaran with capacity for 100 people as a way of promoting sustainable tourism in the Amazon.

Keywords: Clean energy; Electric boat; Energy Efficiency Photovoltaic Solar Energy.

B-2.1-45

Analysis of Sizing Internal Network of Wind Farm using Genetic Algorithm: A Case Study

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This paper presents an analysis of the sizing of the internal electrical network of a wind farm using a sizing methodology involving the application of genetic algorithms (GAs) for solution optimization. A real wind farm in Brazil is used in the analysis, with the internal electrical network configuration defined by the conventional method of electrical engineering for sizing networks with subterranean cables directly buried in the ground. In the formulation of the GA methodology, the required investment in building and current energy losses are defined as objective functions in the optimisation process, and the economic calculation of the cable is used. Simulations are performed for network optimisation, and the results are implemented with the project solution in the wind farm. The influence of short circuits on network sizing is also analysed. The results show the economics of an internal network with the implementation of the topology of the proposed optimisation method. In the studied case, the short-circuit sizing was not significantly affected by the diameter of the internal network cable.

Keywords: Wind farm, Internal network, Genetic Algorithm, Optimization.

B-2.1-49

Application of the DER_A Model of Distributed Energy Resources in Power System Stability Studies

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To assess the effects of Distributed Energy Resources (DERs) on the grid, robust models for frequency inverters are needed, with the ability to adequately represent the impacts and responses to control modes. In order to use less complex and updated models, as well as being representative in stability studies, a generic positive-sequence model was developed in CEPEL ANATEM program based on the EPRI model. The model was simulated under the same operating conditions as the EPRI tests. A system with a source emulating voltage and frequency curves (play-in voltage and play-in frequency) was considered. Results demonstrate the validation of the model, obtaining results similar to EPRI tests. The model presented is recommended to evaluate the impact of DERs connected in the bulk system, verifying the performance of protections and disconnections and the respective effect on the transmission system.

Keywords: Distributed energy resources, power system, RED, dynamic analysis, photovoltaic, Anatem, DER_A model.

B-2.1-50

Active Management of Distributed Energy Resources for voltage regulation of electrical network using Python/PSCAD Platform

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The inclusion of Distributed Energy Resources (DERs), driven by new technologies, increasingly financially viable, are examples of elements that make the operation and functioning of larger electrical grids an ever-increasing challenge. The intermittent conditions of generation, which generate problems in maintaining the operating conditions of the network, such as voltage and frequency, under the parameters of safety and reliability at the lowest possible consumption and evaluate the impacts and control techniques of active networks, in medium and low voltage. In this way, the main objective is to study, model, and propose a simulation environment capable of portraying realistic characteristics with high resistance of renewed electrical systems and the active management of DERs can help in mitigating the problems due to this same high penetration. With this, the EPRI-CKT5-Modified electrical system was implemented in the PSCAD software, an electrical network of 7,132 MW with 157 bus and a nominal voltage of 12.47 kV. As a

way to investigate the impacts generated by DERs in the electric networks, were model Photovoltaic Generation Systems (PV), Electric Vehicles (EVs) and Battery Energy Storage Systems (BESSs), and this models were connected to the study system under study levels of interest understood with the disturbances of interest. Different local control techniques were implemented. For the control of PV systems, On-Off control and Reactive Power control are implemented. These will have the objective of protecting the inverters against over the grid, above 1.05 p.u, and will help in the regulation of the connection bus, with which the controls will remain within the range of 0.95 to 1.05 p.u. EVs, on the other hand, run like loads, but with high consumption at certain times of the day. For the BESSs, a droop control is implemented, which contributes to the regulation of the system's coordination profile, in the face of load intermittence, EVs consumption characteristics, and PV generation. The electrical system simulation is developed in PSCAD software and the DERs controls are done in Python language. With this, a communication platform of the Python language with PSCAD was created, which allows, in addition to research, control proposals, with new optimizers to offer the best results, compared to controls implemented directly in the PSCAD software. Thus, a proposal for managing the DERs is due to the results obtained, concluding that it is possible to use DERs as tools for ancillary services, such as grid voltage regulation. Finally, in future work, new ways of managing DERs that can be created with the Python-PSCAD platform, due to the capacity that the Python language has for elaborating more complex controls, either for operation or for operation planning.

Keywords: Battery Energy Storage Systems, active management, distributed energy resources, Python/PSCAD Platform, photovoltaic systems, electrical vehicles.

B-2.1-53

Optimal Recloser Allocation Considering Quality of Service Indexes in Distribution Grids with Wind Power Systems

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This paper presents the methodology for the optimal allocation of reclosers using the genetic algorithm optimization technique in conventional distribution systems, considering the insertion of distributed resources, such as wind generation systems. The methodology includes the solution of the power flow using the OpenDSS open-source software, through the interface developed by the Electric Power Research Institute - EPRI. The values of voltages, currents, powers, and SAIFI/SAIDI indicators are transferred to the Matlab software. The optimization algorithm determines the most interesting positions to install reclosers. The results of the implementation of the methodology in the small distribution network system brought significant improvements in the indicators. Approximately 70% in SAIFI, SAIDI and fixed costs reclosers, and 33% in the number of users outside the service. It is important to note that the initial scenario considers all reclosers with coordination of their protections.

Keywords: reclosers, genetic algorithm, distributed energy resources, wind generation systems, OpenDSS, quality of service, SAIFI, SAIDI.

B-2.1-56

Open-architecture GA-based Optimization Tool for the Design of Hybrid Power Systems

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This work presents a GA-based optimization software developed to design Hybrid Power Systems (HPS) with renewable generation sources. The software was developed as an open-source tool within the MATLAB environment that allows great flexibility in the technologies included and the control strategies considered. The tool is composed of a simulation module and an optimization module, which continuously interact with the objective of finding the optimum HPS configuration with the lowest cost. The developed tool was tested against the widely known commercial software HOMER. The proposed software implements a Genetic Algorithm optimization method which allows reducing the simulation time in up to 90% to find the same optimal configuration as with HOMER. It is concluded that the development of the tool as an open-architecture software meets the expectations of a flexible tool for teaching and researching purposes as well.

Keywords: renewable energy, simulation-based optimization, research tool.

B-2.1-57a

Battery Energy Storage System Sizing for Residential Photovoltaic Plant

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This paper presents a methodology for sizing and selection of a battery energy storage system for a typical residential photovoltaic plant. The recent droughts that affected important basins in Brazil highlighted the vulnerability of the country energy generation system, which has 63% of all its installed capacity in hydropower plants. Increase the photovoltaic energy share in the energy matrix is a global tendency and a sustainable solution to reduce this hydropower dependency. However, the inherent intermittent nature of this type of energy is a key factor retarding its extensive application. Energy storage systems are a promising solution to normalize the renewables generation and overcome this intermittence issue. Although the high cost makes a residential battery storage system impractical, the concepts discussed in this work can be applied to storage systems of other types, in applications where it can be technical and economical advantageous.

Keywords: Battery, Energy Storage, Hydropower, Photovoltaic Energy, Solar Radiation.

B-2.1-57b

Structuring Concepts and Tools for Formatting a Decarbonization Market in the Brazilian Energy Sector

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Renewable growth and sustainable energy industry development are a reality for the future of an environmentally harmonious society. The International Energy Agency (EIA) estimates that 80% of the electricity demand in the US will be supplied by renewable energies [1]. Developed countries lead this transition through policies to encourage sustainability. Vanguard nations in the energy transition lead the process due to institutions and active civil society that pressure governments in the pursuit of decarbonization of the matrix. Even renewable energy sources being the cheapest sources of energy generation in much of the globe [1] the structuring of markets and pro-decarbonization tools can accelerate the energy transition process, bringing a greener matrix faster. Centrally organized policies can be capital in rapid change, establishing a more sustainable society during the shift to a clean world. This work aims to show methods for accelerating the decarbonization of the Brazilian energy matrix, conceptualizing some of the main incentive methods and major characteristics. Such as efficiency, simplicity and coverage. These methods will be described and analyzed with international examples of successful applications and possible challenges adapting to Brazilian reality. Subsequently, some sustainable policy initiatives already implemented in the country will be discussed and they will interact with those new policies, covering the challenges for the next steps for a pioneering and harmonious transition respecting the current policies.

Keywords: Carbon Pricingon Pricing, Decarbonization Strategies, Energy Trade Systems, Renewables Energy, Sustainability.

B-2.1-60

Design and economic feasibility analysis of a grid-connected photovoltaic power systems at the Federal Institute of Roraima – Campus of Amajari (IFRR-CAM)

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This work presents economic feasibility analyses of three grid-connected photovoltaic power systems (GCPPS) for the Federal Institute of Roraima - Campus Amajari (IFRR_CAM) situated in the

north of Brazil. Scenario 1 (in operation) produces about 20% of the energy consumed at the site. Scenarios 2 and 3, projected to supply 50% e 100% of the energy consumed at the site, are under study. First, this study investigated technical feasibility analysis for using solar energy in the region of the IFRR_CAM based on experimental data. Then it presented the economic feasibility analysis for the scenarios based on three economic indicators: payback period (PB), net present value (NPV), and internal rate of return (IRR). According to the PB analysis, the investment will be profitable for all scenarios in less than 10 years. The NPV becomes positive for all scenarios after about 9 and a half years. Regarding the Internal Rate of Return (IRR) for a Minimum Rate of Attractiveness (MRA) of 6% a.a., the IRR exceeds MRA before 10 years for all scenarios. Finally, one concluded that investments in GCPPS are pretty attractive.

Keywords: Renewable energy, Solar energy, Economic analyze.

B-2.1-61

Technical, economical and environmental analysis of electrolyser running of bioeletricity from vinasse biogas

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This paper consists in two parts, the first one is the bioelectricity generation system, which uses an internal combustion engine (ICE) associated to electric generator. It operates with biogas from vinasse, a by-product of sugarcane industry. In the second part is studied the process of electrolysis of water to obtain biohydrogen using the bioelectricity of treatment vinasse. Taking advantage of the heat of the exhaust gases of the ICE, the potential of generating useful thermal energy for the application of cogeneration is also studied, considering the cases of generation of cold water and hot water. Subsequently, energy, economic and environmental analyzes of the system are carried out considering the generation of bioelectricity and biohydrogen. From the energy analysis it was possible to determine the potential for electricity generation based on the availability of biogas, where from the generated data a SANKEY diagram of the bioelectricity generation plant is constructed. From the economic analysis, was obtained the cost of electricity production, the cost of biohydrogen production, with the cogeneration of hot and cold water in US$/kWh and the expected annual income, using the payback method. Finally, also environmental impact studies were carried out to determine the ecological efficiency of the biohydrogen production process. As conclusion are considerate the advantages of this process of green hydrogen production associated in the sugarcane industry as regards to Brazilian conditions.

Keywords: Biogas, Internal Combustion Engine, Vinasse, Biohydrogen, Electrolysis, Energy Analysis, Economic Analysis, Ecological Analysis.

B-2.2-1

The energy transition and the potential for Use of Micro and Mini-cogeneration in Urban Centers - Case Analysis

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This work, based on the energy transition and decarbonization processes, demonstrates the viability of different energy sources in relation to access requests and indicates the potential of other energy sources for urban centers. A comparison is made between the most viable renewable energy sources in urban centers. The work discusses natural gas cogeneration in places where the offer of roofs and areas for the implementation of solar systems are not possible or interesting, due to shading, positioning, area limitation, inadequate geometry, area costs or others. As part of the work, a case study and financial analysis are presented to demonstrate its feasibility. The future growth of this type of access must be considered for planning and operation of distribution networks, as it will have a considerable participation in the constitution of electrical systems in urban centers.

Keywords: Cogeneration, Energy Transition, Distributed Generation, Electrical Planning.

B-2.2-3

Modelling of an Equivalent Virtual Power Plant in Stability Simulations

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Due to increased high penetration of renewable energy resources in power systems, the concept of Virtual Power Plant (VPP) has been proposed to aggregate Distributed Generations to act like a single power plant. In this context, the purpose of this work is the development of a method to aggregate the DG units, which use the interface with the electrical network by converters, representing them by equivalent VPPs. In addition to this representation, it is necessary to estimate the parameters of the equivalent VPP model. The method used for this purpose is based on the Gray-box method and a Differential Evolutionary (DE) algorithm, which allows the use of measurement data that can be performed at the boundary between the distribution system and the system under study. The model is validated using the MATLAB/SIMULINK software to simulate a test network and obtain parameters of the equivalent model.

Keywords: Distributed generation, distribution network, Gray-box approach, stability of power systems , virtual power plant.

B-2.3-6

Analysis of Energy Generation Potential with Waste and Effluents in an Agroindustrial Unit

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The main objective of this work is to analyze the potential for energy generation from the direct burning and anaerobic decomposition of agro-industrial organic solid waste and liquid effluents in a large agro-industrial unit, consisting of poultry and swine slaughterhouses, a food and feed, as well as a hatchery. The main organic residues were surveyed, as well as the main quantitative and qualitative parameters of the liquid effluents generated in this industrial complex, and equivalences were used to determine the generation of methane and biogas based on the literature. As a result of the studies, an average monthly energy potential of 30,808 GJ was obtained in the unit and, if there is an adequate energy conversion, this could represent an average monthly production of 17,758 GJ of thermal energy and 4,112 MWh of equivalent electrical energy. Finally, the cost to implement the energy use system was raised, resulting in a discounted payback of 37 months, making it perfectly feasible to carry out the investments.

Keywords: Biogas, Slaughterhouse, Anaerobic Digestion, Co-digestion.

B-2.3-7

The Brazilian Potential for Waste-to-Energy Towards the 2030 Agenda

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The United Nations 2030 Agenda has been paving the way for the scientific community for guiding the necessary steps for sustainable development, which includes providing affordable and clean energy to the people. This research paper discusses the Brazilian scenario of distributed generation considering trending biochemical and thermochemical processes for the energy recovery of municipal and forest waste materials, especially the highly discussed ones such as anaerobic digestion, incineration, and gasification. Some technical, economic, and environmental aspects of waste-to-energy are presented, including the main challenges observed from some study cases and applications of these waste treatment alternatives. It is observed a great potential for cleaner power generation in the country and the Latin American region, going towards the goal of reducing fossil fuels dependency and their health and environmental issues related to high emissions of pollutants. Waste-to-energy must be considered for enhancing the

energy matrix whilst predicting new job creation, better quality energy, and lesser greenhouse gases emissions to the atmosphere.

Keywords: Energy generation, Gasification, Sustainable development, Waste-to-energy.

B-2.3-15

Utilization of MSW on the electricity generation for electric buses in a medium-sized Brazilian city

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In the city of Guaratinuguetá, located in the state of São Paulo, Brazil, 104.4 tons of MSW are produced daily. Of this total, 45.3% is composed of organic material, mainly materials such as food and vegetable residues in general. The remainder comprises recyclable material and tailings. Considering such quantity and composition, this study proposes the calculation of the potential for generating biogas through the anaerobic digestion of the Organic Fraction of Municipal Solid Waste (OFMSW) which, once segregated from recyclable waste and other waste, can be processed in a biodigester. With the equations provided as well as OFMSW conversion constants into biogas, a potential generation of 3,125 Nm3 of biogas per day, equivalent to 3,603 kg/day, was calculated. Taking into account the burning of this biogas Internal Combustion Engines (ICE) it was possible to estimate an electrical potential of 5.75 MWh/day, enough to provide a fleet of urban buses with a daily autonomy of 3,738 total km. The economic analysis, in turn, proposes calculating the cost of the generated electric energy, considering the acquisition and maintenance costs of the generating plant, with the costs of electric energy generation calculated between 32.81 and 37.08 USD/MWh depending on the rate of interest applied. The payback of investment in electricity generation was estimated between 4 and 6 years, for a local tariff of 43.98 USD/MWh.

Keywords: Municipal Solid Waste, Biogas, Distributed Generation, Gas turbines, Electric buses.

TOPIC 3 - Bioenergy and Hydrogen

B-3.1-2

Decentralized Station for Distributed Generation of Electricity and Hydrogen Operating on Biogas: a case study review

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Currently in Brazil and in other countries, practically all garbage and waste from large and small cities are wasted and poorly disposed of. With this in mind, the possibility of meeting and partially supplying the energy demands of our society has been analyzed, promoting good use of its burning and the transformation of its waste and residues, generating sustainable and ecologically correct electric energy, being able to obtain heat residual, still use biogas. This work presents a discussion on ways and methods for the combined use of SOFC (Solid Oxide Fuel Cell) fuel cell, together with biodigesters and biogas reformers, in order to obtain the greatest possible energy and electrical potential, through the production combination of hydrogen (H2). Thus, in order to evaluate this proposal, a bibliographic review was carried out on methodologies aimed at carrying out thermodynamic and economic analysis for the implementation of decentralized units of Distributed Generation of Electricity and Hydrogen in several sanitary landfills and ETEs (Effluent Treatment Station). It is noteworthy that the literature review carried out in this work will enable the development of a model system for generating electricity and thermal energy from biogas, making it possible to carry out a comparative analysis between the existing systems of landfill biogas use.

Keywords: Fuel Cell, Cogeneration, Biogas, Decentralized Electricity, Hydrogen Production, Thermodynamic Analysis.

B-3.2-3

Feasibility study of hydrogen production in Effluent Treatment Stations in the State of São Paulo

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The emission of gases responsible for the greenhouse effect is a growing concern due to the increasing temperature of the planet. This concern has led countries to seek alternatives for the decarbonization of the economy, that is, reduction of carbon emissions into the atmosphere, mainly carbon dioxide (CO2). The production of hydrogen from Effluent Treatment Stations (ETEs) in São Paulo, which is the most populous state in Brazil, can be an interesting option for mitigating the emission of greenhouse gases and for the use of waste from the process. For this, the main effluent treatment processes used were listed and statistics provided in 2017 by the Brazilian Institute of Geography and Statistics (IBGE) on the number of plants in the State of São Paulo and

their respective technology, a review of technologies for production of hydrogen gas and the pros and cons of implementing it in existing ETEs were analyzed. The cheapest methods were listed as pyrolysis of methane gas and biomass (in this case it would be the sludge generated in the process), followed by methane reform. It was verified that in compact stations, with reactors and activated sludge systems, they are the simplest installations to implement hydrogen generation because they have a larger infrastructure than in the lagoon, which is a simpler and cheaper treatment system. With the production of H2, the sanitary sewage system would have greater investments if there was a commercial value in its generated by-products.

Keywords: Greenhouse effect; Sewage; Effluent Treatment Stations; Hydrogen; Sao Paulo.

B-3.2-4

Technical and Economical Analysis of green hydrogen production in the Steel Industry

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The use of fossil fuels in world power generation resulted in a total of 3.31 billion tons of CO2 in the atmosphere in 2018. Among the sources of CO2 emissions, the steel industry represents 15% of all CO2 emitted into the atmosphere. The steel industry can be considered the largest consumer of coal today, as it does not use coal only to generate energy. The objective of the research is to develop the economic study of the process of producing green hydrogen using energy from a renewable source to feed the electrolysis process and its use in the steel industry. In this study, an industrial scale water electrolyzer with a flow rate of 80 m3/h of hydrogen with 99% purity was used. The power of the photovoltaic system sized to meet the demand for hydrogen from the electrolyzer was 448 kWp, considering specific photovoltaic power output is 1700 kWh/kWp. The costs for producing green hydrogen via solar source were 0.20 - 0.47 US$/kWh. considering an interest rate of 4% to 12% per year. The efficiency of the electrolyzer for this scenario was approximately 59%, with an electrolysis efficiency of 19%.

Keywords: Photovoltaic System; Clean Energies; Water Electrolysis; renewable energy; sustainability.

B-3.2-5

Comparative Analysis Between green solar and wind hydrogen production: Technical, Economic and Environmental Aspects

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Decentralized energy Generation has been expanded in Brazil, and in the near future, in the hydrogen era, the country can be classified in a favorable situation regarding the potential for green hydrogen production. This is both from expanding wind plants and photovoltaic plants in Brazil energy matrix, given the enormous potential for the Brazilian electricity production. In this work, a hybrid plant for the energy production and green hydrogen installed at the IPBEN – UNESP, Associated Guaratinguetá's Laboratory, is studied. Initially, the hybrid hydrogen production components system are characterized, based on data and in accordance with the universal project entitled "Renewable Hydrogen Production> Technical, Economic and Environmental Aspects", contemplated and installed by Energy Systems Optimization Group. At a later stage, system energy analyzes and of each unit are carried out individually, in order to determine efficiency levels in electric energy production and green hydrogen production. Then, economic engineering calculations are performed in order to allocate the system production costs, that is, to determine the production and green hydrogen costs in US$/kWh, depending on several factors. An environmental green hydrogen production analysis is also carried out, aiming to predict the environmental hybrid hydrogen production system impact. It concludes with energetic, economic and environmental performance of the decentralized hybrid system for electricity production and hydrogen production.

Keywords: Economic Aspects; Energetic Aspects; Green Hydrogen; Photovoltaic Energy; Wind Energy.

TOPIC 4 - Electric Power Transmission and Distribution

B-4.1-1

A Framework Development to the Application of a Bilevel Optimization in Demand Side Management

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Demand management focuses on flattening the demand profile, allowing the reduction of energy losses, grid investments and generation capacity. In this sense, a bilevel optimization appears, that is a recent approach to demand-side management and involves a supplier-user interaction. This optimization establishes a hierarchical relationship between several users and a supplier, and their objectives often present some antagonism. In the upper level the supplier needs to know its supply cost to determine its profit and propose a reasonable pricing scheme, however, interest in obtaining a real and scalable supply cost function has been scarce and the existents ones do not meet this requirement. A scalable function enables to apply this optimization in a real-life environment. In addition, the bilevel optimization needs two ways of communication and common rules to interchange messages. The framework development for this optimization involves a novel scalable quadratic supply cost function and the selection of a communication protocol with the extension of its functionalities. Then, the bilevel optimization is performed to compare the supply cost functions, using a genetic algorithm in both levels and optimization simulations show the non-scalability and infeasibility of the existent functions and the flexibility, good performance and scalability of the proposed supply cost. As conclusion, the proposed framework that includes the communication protocol and the novel scalable supply cost enable to apply this optimization in a real-life environment

Keywords: Supply Cost, Communication Protocol, Demand Side Management, Electricity Pricing, Day-Ahead Pricing, Bilevel Optimization.

B-4.1-2

Loss of Selectivity of Protective Devices in Underground Distribution Systems

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The case of unjustified simultaneous operation of protections associated with circuits that share a power bus in an underground medium voltage distribution system is analyzed. The operation of these devices alters the continuity of service of both the faulty circuit and adjacent circuits without failure. A characteristic underground distribution system is modeled at 23 kV, with transformers of grounded wye-grounded wye distribution and five-legged cores, characteristics of

the circuits that have presented this undesirable condition. A single-phase failure event is recreated that allows the analysis of the interaction of fault currents in adjacent circuits. From the analysis of the negative and zero sequence currents, improvements are proposed in the adjustments to the protection schemes, and they are compared with records of anomalies that have occurred in the period from 2019 to 2021.

Keywords: Five Legged, Core Transformer, Grounded Wye, Overcurrent Protection, Simultaneous Tripping, Underground Distribution.

B-4.1-5

DC microgrids power flow analysis

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One of the solutions proposed in the new context of the electrical system to mitigate losses and improve efficiency is the constitution of topological and operational arrangements known as microgrids. Microgrids are characterized as small independent electrical systems, composed of distributed generation sources and storage systems to meet local loads. It is noted that the classical methods for power systems analysis should be reviewed and adapted to the microgrids context to properly contemplate their different topological and operational arrangements. This paper intends to contribute to this area of research, presenting a methodology for power flow analysis of DC microgrids.

Keywords: DC Microgrids; Power flow analysis; Electrical power systems.

B-4.1-7

Decoupled methodology for power flow analysis in islanded microgrids

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The increase in energy demand and the presence of generation close to consumers tend to modify the structure of distribution networks, making them subject to bidirectional power flows. These networks start to behave as active agents of the power system. In this context, microgrids are advanced arrangements associated with distribution systems, which can operate in an islanded way or electrically connected to the bulk power system. In islanded mode, the individual units of distributed generation regulate, in addition to voltage, the electrical frequency of the microgrid through control structures. In distribution networks, the R/X ratio of microgrid conductors is typically high. Taking this into account, there is a need to develop methodologies that allow a more realistic analysis of microgrids in islanded operation. This article proposes a method for calculating the power flow in islanded microgrids, using the adapted fast decoupled approach.

Keywords: Microgris, Distributed Generation, Decoupled Power Flow, Droop Control.

B-4.1-8

Optimal Allocation of EV Charging Stations with PV units and Energy Storage Systems in Distribution Systems for a Low-carbon Development Strategy

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Representatives of governments, companies, and other organizations pledged at COP26 to accelerate the transition to zero-emission vehicles to achieve the goals of the Paris Agreement. Investment in electric vehicle (EV) charging stations is vital to achieving these goals. Thus, a mixed-integer second-order cone programming model is proposed in this paper for the allocation of EV charging stations equipped with photovoltaic units and energy storage systems in electric distribution systems. Such technologies are scaled using the proposed model, considering uncertainties related to EV demand and the output power of PV units. A zone constraint has been adopted to distribute EV charging stations over the system. Furthermore, environmental constraints are included in the model aiming at a low-carbon development strategy. Finally, results for the application of the optimization model in the IEEE 33-node system demonstrate the applicability of the proposed model.

Keywords: Electric vehicles, EV charging stations, photovoltaic units, energy storage systems, low-carbon development.

B-4.1-9

Analysis Of Blockchain Applications In Energy Transactions And Smart Networks

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The Brazilian energy market is going through many regulation changes focused especially at modernizing the electricity sector. One of the main changes is the development of a free energy market, where all the players are allowed to trade electric energy freely among themselves, creating new opportunities. From the optics of distributed energy resources, transactions and payment, financing and settlement systems, there is a need to implement technological mechanisms capable of assuring the reliability of transactions and the safe storage of data related to the energy market. There are different initiatives presented in the literature regarding innovative projects applied in countries with advanced energy markets, for instance blockchain and cryptocurrencies. Blockchain is a technology of distributed ledger, in which the information and transactions are performed through a network by a group of users using consensus protocols,

which are the basis for the security of this technology. It has been used for financing energy generation projects and in records of peer-to-peer energy transactions both in private residential networks projects and in the wholesale market. However, as an incipient technology, it raises questions about data privacy, relevance to the energy sector regulation, speed and optimization of process due to consensus protocols, and security and reliability in its use. As a consequence, this work aims to analyze the blockchain application in the electricity sector, based on a survey of companies and startups that are pioneers in its use. Finally, it is possible to notice that the technology is in an initial phase, despite its potential in a variety of areas. The decentralized protocols for transaction validations and data can bring reliability to the network, but, as with many new technologies, it may need some cultural changes to break some beliefs and paradigms for different settings and processes.

Keywords: Blockchain, Peer-to-peer transactions, Distributed energy resources, Smart grids, Smart contracts.

B-4.1-11

BI Interface for Power Transmission Insulators Health Monitoring

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Asset management has been a keynote in transmission systems in recent times, especially when the health of the devices must be used on decision making. In other hand, to efficiently monitoring a specific asset, several types of data including laboratory tests, climatic variables, mechanical and electrical signals have been taking account. The scenario with heterogeneous databases presents several challenges of integration and to achieve it this work proposes a combination of Data Science, Data Base Management System and a Business Intelligence Interface for Insulators health monitoring in Transmission Systems. Insulators can decrease their functioning in environments with a high level of environmental pollution, such as saline pollution and dust deposition. Therefore, wind and electrical discharges conditions, humidity and others climatic variables can improve the pollution degradation of the insulators, making these variables of huge interest. The stratification of these data can be performed in different ways and these approach uses georeferencing and time stamps to uniformize the information. In the next step, all processed data is stored in the MariaDB data base, which is accessed using Tableau BI Software. The information about insulators is used then in a GUI way, presenting reports, relations between variables and health information of this asset all integrated and processed, so the user can perform a Decision-Making Analysis very quickly and assertive about maintenance. Results will be presented with real data of variables associated with the integrity of insulators installed in a power transmission company and shown that the approach can be used to monitoring the health of other types of assets with great efficiency.

Keywords: Business Intelligence, Data Science, Insulators Monitoring, Power Transmission.

B-4.1-14

Market clearing procedure in transactive energy markets for distribution systems operators

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Distribution system operators (DSOs) are traditionally responsible for the reliable operation of energy distribution systems for consumption. However, the development and expansion of distributed energy resources (DREs) and microgrids in distribution networks has required a new platform for these operators. New variables are added to this platform, such as the management of small generators, energy storage units and consumers with flexible loads (consumers who are willing to shift part of their demand to other market periods in search of better prices). Changes also occur in the role that the system operators play in the energy markets, now they coordinate and balance the transactive dispatch of supply and demand at the distribution level and make the connection between the wholesale energy markets, represented by generation and transmission, and the retail energy market. Therefore, the operator must take into account the parameters of its network, such as the operating costs of distributed energy resources, charge and discharge restrictions of the storage units, the power flow restrictions of its network, and the flexibility of consumers, in addition to an external parameter, given by the energy price practiced in the wholesale market, in order to propose a reliable and efficient dispatch that minimize a cost function. The objective of this work is to develop a distribution market model, that is able to calculating the efficient dispatch of distributed generators, minimizing the impact of demand peaks in specific periods of the market horizon, by taking advantage of consumers' flexibility and establishing an equilibrium price for the retailer market, based on the costs of its network generators and an external energy price, calculated in the generation and transmission market.

Keywords: Transactive dispatch, electricity market, DSO.

B-4.1-16

Service Restoration in Distribution Systems adressing Different Voltage Levels

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There are several techniques and methodologies to deal with the problem of service restoration in distribution systems. The most advanced approaches present good solutions to the problem and consider several practical characteristics of the system. However, few methodologies approach the problem considering distribution networks with different voltage levels. This paper presents a study based on a real Brazilian distribution system whose primary networks operate at 34.5 kV and 13.8 kV. To consider the unbalanced and asymmetric nature of the distribution system, the study was developed through a three-phase backward/forward sweep load flow that

considers unbalanced loads and real elements of the distribution system. The results obtained indicate the relevance of simultaneously addressing the 13.8 kV and 34.5 kV networks in the problem of service restoration in distribution systems.

Keywords: Distribution Systems, Service Restoration, Network Reconfiguration, Three-phase Load Flow, Voltage Levels.

B-4.1-20

Data Pre-Treatment And Prediction Of Electrical Quantities Using Lstm Neural Network Models

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The growing demand for electric energy, allied to the needs presented by supervisory bodies and consumers, has led the conventional electric energy distribution system to evolve into the Smart Grid context. Data acquisition and analysis are central to evolution. Machine learning technologies are gaining the spotlight in the literature, but related studies do not cover all data preparation and analysis of different models. Thus, this study presents the development of a framework for pre-treatment data of electrical quantities with the application in artificial neural networks. This paper presents models with a mean absolute percentage error (MAPE) of 0.17 that use real data. We also suggest models with MAPE below 0.19 and training time of fewer than two minutes, making them accurate and easy to use in real-time. Comparisons between models using the pre-treated and raw data are discussed, showing an almost one hundredfold improvement with the clustering technique created to correct imperfect data.

Keywords: Artificial Neural Networks, Clusters, Data Pre-Treatment, Electrical Quantities, Machine Learning, Smart Grid.

B-4.1-21

The Pathway To Electromobility In Brazil: Challenges And Initiatives From Electrical Sector

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This paper presents a bibliographic survey on the main technological and economic impacts concerning to the insertion and dissemination of electric vehicles in the Brazilian electrical power sector, as well as the main incentive adopted by the stakeholders of the Brazilian power sector, in particular the electrical power utilities, given the great difference between the introduction of

electric vehicle in the world market and in Brazil. This paper has an exploratory character since it provides the impacts and its main incentives for the dissemination of electromobility in Brazil.

Keywords: electrical vehicles, eletromobility.

B-4.1-22

Assessment of Energy Storage in Improving the Performance of Smart Grids

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The objective of this work is to analyze the power system architecture assuming the energy storage as a fundamental factor in the availability of smart grids. This study highlights the main role that energy storage will play in the regulation of supply energy systems and it will make smart grids more robust, reliable and available. Due to the high cost and technological limitations, it is difficult to develop a model in scale where energy storage plays a relevant role of energy manager. Today, basically hydroelectric dams and oil and gas reserves are strategic energy stocks, these centralized, locked and old systems are being replaced by decentralized, distributed, self-regulating and intelligent systems, mainly due to the rapid growth of renewable energies (Solar and Wind) which have fluctuating characteristics and dispersion over large areas, consequently energy storage systems are essential partners to keep power system reliable, robust, stable and available. Energy crises will increase because all sources have their seasonality factor or supply risk, whether due to lack of rain, intense climate changes, conflicts and crises in regions with energy resources, changes in wind seasons, daily alternation of solar incidence, etc. New technologies distributed together with traditional ones will be important to generate energy as well as long-term energy storage sources and distributed storage will also be important for an available, reliable, self-regulated and intelligent energy system. Just as the producers of any commodity have regulatory stocks (silos, warehouses, tanks, etc.) to financially and economically optimize their product, waiting for the best time to sell or buy, energy trading in the future, all entities participating in the energy system will be somehow at the same time consumers, producers and energy stores with strategies for buying, selling and effectively consuming energy throughout the year to make their business viable. The article shows in general how energy storage, which today has a passive role, in most cases today is an simple emergency backup of energy in case of a utility failure (such as nobreaks, battery room, diesel tanks and gas stock) should be an important smart energy manager, fundamental for the development of smart grids in the near future.

Keywords: Energy storage , smart grid , energy planning, renewable energy, hybrid energy storage system.

B-4.1-23

Blockchain Applied to the Energy Market

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The future of energy and its ramifications between generation, transmission, commercialization and consumption, are still uncertain. With floating renewable resources in systems each increasingly distributed, price volatility suggests that themarket still needs to evolve in several aspects to make it reliable and scalable. Blockchain is a timely innovation whose potential for facilitating this future will be detailed here. In an approach more functional than technical, we will point out the challenges and also the potential of the systemic solutions already addressed in the energy systems that can or already use the technology blockchain. The system is complex and some of the problems in this sector are hard to get over. At the center of discussions that seek solution to these problems is blockchain technology, with a point-to-point transmission and a consensus with encryption algorithms and contracts intelligent, capable of adding value through transparency, interoperability and immutability of data.

Keywords: Blockchain, microgrid, peer-to-peer, renewable energy, institutions, sustainable energy.

B-4.1-24

Analysis of the Impact of High Penetration Solar Photovoltaic Systems in a University Distribution Grid

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The integration of generation systems provided by renewable sources, called distributed generation systems, at the distribution systems have been growing a lot in recent years. Most of these systems of distributed generation come from solar photovoltaic systems. Currently, several photovoltaic systems have been and are being installed in the principal Campus of Federal University of Pará, in Belém, and various studies are being made in this distribution grid considering the presence of distributed generation on the grid energetic balance. In this work a study is done through the OpenDSS software from an existent modelling of the Campus distribution grid. The main objective is to evaluate the impacts of high penetration levels of distributed generation in one of the medium voltage feeders of the Campus. The simulations seek to evaluate the voltage variation and the feeder energetic balance from many solar photovoltaic sources in the system low voltage buses. The simulations interfacing is made through Python language from the Component Object Model available in the OpenDSS library, that allows a better data analysis. The photovoltaic systems are built from Belém weather data and from datasheets of some existing photovoltaic systems of the Campus, looking for the best daily simulations of the distribution system. Additionally, in this work the number of photovoltaic systems was extrapolated, because currently the Campus is not in a high penetration scenario of distributed

generation. From the results of the proposed analysis, it was observed that the voltage levels in the feeder have varied in almost negligible values, specially because the feeder, operating at 13,8 kV, is more robust and less susceptible to voltage variations caused by the photovoltaic systems connected at low voltage. Furthermore, there were large variations in the behaviour in the feeder power flow, in this case the reactive power supply remained constant and active power supply was reduced, because the distributed generation operates with a unitary power factor. Due to this large variation in the behaviour of the active power supplied, the feeder daily power factor curve was depreciated. To correct this problem, a non-unitary operation was proposed to the photovoltaic systems. In this sense, the distributed generation also supplies reactive power to the grid in such a way that the feeder power factor is improved. The power factor adjustment is done empirically through load flow, and the work shows that the distributed generation do not improve the feeder power factor out of its operation zone.

Keywords: Power Flow, Photovoltaic generation, Distributed generation, Renewable energies, OpenDSS.

B-4.1-25

Regulatory Aspects of the Insertion of a Sustainable Alternative of Third Energy Source for Transmission Substations.

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Photovoltaic systems have shown high growth rates around the world, making the way to generate safe, clean, reliable and renewable energy. Auxiliary service is the name given to the function of supplying the energy demand for the operation of the substation itself. The auxiliary services in alternating current can be supplied by the appropriate concessionaire, by the generator engine group or by the auxiliary service transformer, the latter being the most used. Direct current auxiliary services are powered by the rectifier and the battery bank. The proposal in this article is to present the regulatory impact for the insertion of photovoltaic systems as a new option for power supply of auxiliary services in substations, making the system safer and more sustainable without emission of pollutants and with the use of an inexhaustible source of energy.

Keywords: Regulatory Aspect, Battery, Auxiliary Service, Photovoltaic System, Substation.

B-4.2-1

Conceptual Design of an Inspection Robot for Distribution Power Lines that Moves on the Cables

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Components of distribution power lines that are degraded by time, poorly installed or broken can damage and even interrupt the electrical energy supply. Therefore, distribution power lines are inspected periodically. The use of robots is a means to make the inspection more efficient. There are several projects and commercial products for monitoring transmission power lines, but systems for distribution power lines are rare. The main reason is the requirement for the robot to travel over the cables, so that is closer to the monitored region. However, the immense variability of elements present in the distribution power lines impairs the robot's displacement, making the project complex. Considering these difficulties, this work presents five robot concepts to inspect distribution power lines, focusing on overcoming obstacles. The operation of these concepts is not limited to distribution power lines: they can operate in any environment involving suspended cables, including transmission power lines. The concepts were created and evaluated following the PRODIP design methodology, which is divided into three major phases: planning, design and implementation. The technical engineering development is directly applied during the design phase, also divided into some stages. One of the main stages of the design phase is the conceptual design, which is characterized by the ideation of several alternative solutions to the same problem. At the end, a solution is selected to become a functional prototype through the Pugh matrix, where a concept is taken as reference and a grade is assigned to each concept according to the fulfillment of a certain comparison criterion in relation to the reference concept. The concept that obtains the highest grade is chosen to continue the project.

Keywords: Inspection robot, Conceptual design, Inspection, Monitoring, Overcoming obstacles on power lines.

B-4.2-2

Development of a System for Installing Robots on Electric Power Distribution Networks

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The quality of electricity delivered to consumers is affected by the interruption in its supply. In this scope, devices for inspection of the distribution network can contribute to reducing interruptions and modernizing the networks. This work presents an installation system prototype designed to lift, position, and connect an inspection robot to the power cables of the Santa Catarina state power distribution company. The installation system had as requirements the ergonomics of the operator and the safety of the robot. Based on these requirements, an adjustable tubular structure was developed, capable of attaching to different models of basket trucks. Different concepts are listed and the most promising one is selected and developed in detail. Two field tests were carried out with the prototype, which indicated that the system is well suited to its primary function and that it is possible to adapt it to install different equipment on the distribution lines.

Keywords: Inspection, Maintenance, Power distribution networks, Power quality, Power system faults, Power system reliability, Product development.

B-4.2-3

Optimal Charging/Discharging Management of Electric Vehicles to Boost Internal Consumption of Local Energy Communities

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Local energy communities (LEC) are within the concept of local markets, gathering several consumers/producers who carry out negotiations among them, while seeking to make the best use of their internal energy. However, LEC continue to face obstacles to achieve energy self-sufficiency, such as the inability to meet all community demands or surplus generation leading to undesired curtailment. In this context, the coordination of flexible loads such as electric vehicles (EVs) could be leveraged to overcome these limitations. This paper proposes a mixed-integer linear programming mathematical model to optimize a local market based of LECs, where an aggregator (responsible for managing the commercial interactions of LECs) aims to maximize local consumption through the control EV charge/discharge. The impact of economic interaction between communities as well as EV charging/discharging control on consumption within LECs was analyzed in the IEEE 33-bus distribution system under different test conditions. Results indicate that enabling energy exchange between the LECs results in an increase of the social benefit in terms of economic cost, local consumption, and environmental impact.

Keywords: Electric Vehicles, Energy Communities, Local Markets.

B-4.2-4

Development of a User Interface for Operation of an Overhead Power Distribution Network Inspection Robot

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Energy utility companies need to ensure constant maintenance of their overhead power networks in order to reduce the impacts of weather, pollution, aging degradation and technician actions on the reliability and efficiency of energy distribution. However, carrying out regular inspections is often expensive and time consuming as the technicians usually perform the inspections via land patrols, by capturing thermal images of conductors and structures for further analysis. Additionally, due to the Brazilian distribution networks extension, inspecting the whole distribution grid is also unfeasible, making it difficult for proper predictive maintenance actions before electrical failures evolve to energy distribution inefficiency or even interruption. One approach to solve the aforementioned problems is to automate the distribution network inspections using robotic systems. One of the challenges in the development of robots when

human-machine interaction is needed is the design of user-friendly and intuitive operation interfaces that allow users to perform the same tasks they already perform, but with greater efficiency and comfort. This work describes the development of a graphical user interface for an overhead distribution network inspection robot through a task-centered system design methodology, documenting the developed interface and the procedures used. Through the developed interface, the user can control a robot that is capable of moving forward and backward along the conductors of the distribution networks, capturing visual and thermal images of the distribution grid and transposing insulators, connectors and other elements that may act as obstacles for robot operation. The procedures documented in this paper can also be followed to ensure the usability of human-machine interfaces in other applications.

Keywords: design methodology, power distribution lines, inspection, user interfaces.

B-4.2-5

Computing power systems voltage stability margins via a second-order power flow with step size optimization and a linear index

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The voltage stability margin of power systems is crucial information for guaranteeing their secure operation. The existing voltage stability methods are either accurate and time consuming, or less accurate and fast. The main idea of this paper is to fill the gap between these two requirements, which are especially important in real-time operation environments. A new method for computing the voltage stability margin is proposed, where this margin is obtained using a powerful, non-divergent, second-order power flow with step size optimization. An educated initialization of such a procedure is obtained through a linear voltage stability index. This combination resulted in a fast and robust method, allowing it to be used in real-time operation environments. The proposed method was tested using small benchmark to large realistic power systems. The simulation results showed that the proposed method meets the requirements for real-time use, namely, accuracy and computational efficiency.

Keywords: Power systems, Operation, Load flow, Power system stability, Index.

B-4.2-7

Reliability Optimization Technique for Distribution Networks with Microgrids: A Bi-level Multi-Criteria and Multi-objective Approach

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This work presents an optimization approach for allocating protection and control devices in distribution networks with distributed generation, battery energy storage, and electric vehicle charging stations. Conventional demand, electric vehicles demand, and renewable generation

uncertainties are taken into account. The non-dominated sorting genetic algorithm II is applied to solve the allocation problem as the upper-level task considering two conflicting objectives, and a genetic algorithm ensures the protection system coordination as the lower-level task. Protection devices includes reclosers, fuses, and directional relays, while control devices comprise remoted-controlled switches, enabling reliability enhancement by load restoration. The protection coordination scheme also considers local protections at the point of coupling, such as voltage-restrained overcurrent relays and frequency relays. The compromise programming technique is performed to identify the best solution from the Pareto front. The results show the most suitable setups for the protection system and viability of islanding operation depending on the decision-maker criteria.

Keywords: Microgrids, multi-objective programming, power distribution planning, power system protection, power system relaying, protective relaying, reliability.

B-4.2-8

Integrated Analysis of T&D Networks using Single-line/Three-phase Modelling

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The studies and analysis of electrical power systems have been taking on new challenges owning to the increasingly consistent presence of Distributed Generation over the last decades. This new scenario, already a reality and whose projections point to even more substantial growth in the coming years, brings greater complexity to the planning and operation of electrical systems. It also introduces deeper dynamics and interactions between transmission and distribution networks (T\&D). As a consequence, the need to develop methodologies for integrated analysis of T\&D systems, and no longer study them separately, as usual in traditional approaches, is highly relevant. Therefore, this paper proposes the formulation of an integrated analysis methodology for electric power transmission and distribution systems, applied to the power flow calculation based on the computational efficiency of the well-known Fast Decoupled Method. The proposed approach considers the complex per unit normalization (c.p.u.) technique to enable the simultaneous calculation of the power flow in both transmission and distribution networks. Also, in this proposal, the transmission system, being a reasonably balanced system, is represented as a single-phase network. In turn, the distribution system is represented by a correspondent multi-phase modelling, preserving the observation of phase unbalances due to load concerns, two and/or single-line branches and the growing presence of distributed mini and microgeneration units. The proposed methodology proves to be extremely attractive in dealing with the large dimensions of modern electric power systems, combining high computational efficiency and precision in determining the interactions between transmission grids and emerging active distribution systems. This article presents the performance of the proposed methodology, which demonstrates, from the promising results, its relevance for modern power system analysis.

Keywords: Transmission and Distribution Systems, Fast Decoupled Power Flow Method, Complex Per Unit Normalization.

B-4.2-10

Battery Management and Allocation Analysis Considering Cost and Depth of Discharge

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With the growing demand for electricity and increase of renewable sources, new technologies are needed to maintain quality indicators. In this scenario, batteries stand out because their use can bring several advantages for the electrical systems, including voltage regulation and losses reduction, which shall be done in this work. The objective of the proposed method, besides battery allocation, is to define the impact which several batteries can bring into a system and what benefits can be obtained with their use. Besides that, a factor that couldn't be neglected is the depth of discharge because its consideration may affect some solutions making them unfeasible. To do this, this article proposes a method based on Genetic Algorithm considering costs.

Keywords: Batteries, Lifespan, Distribution Systems, Optimization, Power Flow, Losses.

B-4.2-11

Energy Commercialization Evaluation into a Peer-to-Peer (P2P) framework in Microgrids looking for Energy Communities

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The objective of this work is to analyze the energy commercialization into a Peer-to-Peer (P2P) framework in micro/mini-networks of energy communities using as a pilot project conducted in some zones from the the Brazilian Legal Amazon. The energy market is now evolving from a centralized system to a decentralized energy system. Recently, a new proposal has emerged for the energy commercialization into a Peer-to-Peer (P2P) context that allows energy professionals to directly share their electrical energy and their investments, with other interested users. These P2P markets have a bottom-up, consumer-centric perspective, giving to the consumers the opportunity to choose themselves how they would like to purchase their electricity. So, the main objective of this pilot project is to provide some mechanisms or tools that can be used to promote universal access to affordable, reliable, sustainable, and modern energy services at the Brazilian legal Amazon.

Keywords: Consumer-Centric Electricity Market; Decentralized And Distributed Optimization; Energy Community; Peer-To-Peer Energy Trading; Prosumers.

B-4.2-12

Development of a Battery Induction Charging Model for Drones

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The advancement of technology associated with the growing needs of society, led the unmanned aerial vehicle (UAV), which was initially designed for a function more related to entertainment, to have applications that facilitate or carry out activities that man often would not have access to. Depending on the operation to be performed, having a means of charging the batteries autonomously and close to the place of operation is essential. The present work aims to develop an induction charging system for application in UAV operations. Research was based on the improvement of known auto-oscillator circuits, in order to reach a satisfactory model that meets the previously defined design requirements. Characteristics of the UAV imposed restrictive conditions for development such as weight limitation and flight time. Results achieved satisfies the UAV's battery charging needs.

Keywords: Wireless Power Transmission, Auto-oscillator, Drone Wireless Battery Charging.

B-4.2-14

Second life of lithium ion batteries: hardware development and experimental analysis of cyclic aging

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The reuse of lithium-ion batteries at the end of their useful life in electric vehicles (EVs) consists of a business model based on extracting the final value of these units, representing, therefore, an opportunity to extend their useful life - this concept is called second life. In this context, the pioneering Research and Development (R&D) project “CPFL Second-Life” of the Electricity Utility Company CPFL Energia is under development in Brazil, in cooperation with CPQD (Telecommunications Research and Development Center). The aim of the project is to develop energy storage solutions using second-life batteries already degraded during use in EVs. This article seeks to compile the main results of the project, which comprises the elaboration of a process of selection and classification of cells and components, development of BMSs, and specific algorithms of state of charge (SoC) and state of health (SoH) for several second-life applications, mechanical packaging, among others.

Keywords: Algorithm design and analysis, Battery management system, Data analysis, Electric Vehicles, Energy Storage, Hardware, Lithium-ion batteries, Second life.

B-4.2-15

Proposal for less sensitive protection of the number of starts per hour of three-phase induction motors considering the experience in a mining company

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In the mining industry, sometimes the production process requires that engines, especially those that drive conveyor belts, perform several starts in a short period of time, exceeding the maximum allowed by standards and manufacturers manuals. In these cases, it is necessary to increase the adjustment so that there are no productive losses. However, it is also necessary to ensure the protection of these engines. This work proposes a desensitization of the ANSI 66 function – Supervision of number of starts, giving greater operational flexibility without loss of protection to induction motors. For this, a theoretical conceptualization about induction motors is made, as well as about protection configuration recommendations. Subsequently, practical tests were carried out with the objective of measuring the temperature in the rotor and stator using a camera with infrared technology, during load starting. Finally, there are the results achieved in the essays, a discussion proposal and a conclusion bringing together the main points identified during the work.

Keywords: Induction motor, ANSI 66, Starts per hour protection, Start Supervision.

B-4.2-16

Method for Static Contingency Analysis in Electrical Power Systems Using Fast Decoupled Continuation Power Flow

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This work presents a method for the static analysis of contingencies in electric power systems using the fast decoupled continuation power flow. The proposed method obtains the post-contingency loading margins starting from the maximum loading and using a bus voltage magnitude as a parameter. The branch selected for the contingency evaluation is parameterised using a scaling factor, which allows its gradual removal and assures the continuation power flow convergence for the cases where the method would diverge for the complete transmission line or transformer removal. The effectiveness of the proposed methodology has been investigated on IEEE systems (57 and 118 buses) and compared with the continuation power flow. The proposed methodology can be used as an alternative technique to verify and obtain the list of critical contingencies supplied by the electric power systems security analysis function. Thus, a significant reduction in the global number of iterations is achieved.

Keywords: Contingency Analysis, Continuation Methods, Load Flow, Maximum Loading Point, Voltage Collapse, Voltage Stability Margin.

B-4.2-17

Commissioning the Protection of a 230 kV Transmission Line: A Case Study in Northeast Brazil

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During the study and commissioning stages of TLs that make up the Brazilian electrical system, it was faced with the need to verify the protection system of a TL located in the Northeast region of Brazil. This motivated the realization of a short-circuit study to propose adjustments of the protection functions of this TL and analysis of its response in the face of fault scenarios. In this sense, this work presents a case study of a protection commissioning of a 230 kV transmission line located in the northeast region of Brazil. For this, the ANAFAS software was used as a computational tool to simulate short circuits and later calculate the adjustments of the main protections of a TL, being the distance protection, timed neutral directional overcurrent, and emergency overcurrent. Another topic addressed is the teleprotection scheme used in this TL and its improvements for the system studied. A system was implemented in the laboratory to simulate the equipment of a substation: circuit breaker and disconnector and, through a test case equipment, protection tests were carried out on a numerical relay. The main results of the relay behavior for the study carried out are presented and discussed in this work.

Keywords: Transmission Line, short circuit, selective, distance protection, timed neutral directional overcurrent, timed emergency overcurrent, teleprotection.

B-4.2-18

Supercap Applied on Energy and Electric Mobility: A Survey

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The development of Industry 4.0 technologies has brought challenges and new opportunities for all sectors of the economy. The world demands increasingly portable solutions, with connectivity and based on cleaner technologies. The introduction of the Internet of Things, combined with concepts such as energy harvesting and electric mobility has demanded the evolution of equipment, which inevitably goes through the evolution of the components that compose it. The sensing of an infinity of equipment, be it of a power grid, a fleet of vehicles, products in a supermarket or a pharmacy, depends on the ability to provide communication, power support, as well as reduced weight and dimensions so that there is scale use of the technologies. Energy storage is a very relevant topic when it comes to decarbonization of the energy matrix and electric mobility. Renewable sources such as solar and wind are not dispatchable and require storage

systems so that their use can contribute in a safe way to the electrical system. In electric mobility, energy storage is a fundamental factor. Old electronic components, such as valves, were fundamental for the development of electrical and electronic equipment in the past, but have been replaced by others, more modern and efficient. Like the valves, capacitors have also evolved to have the capacity to accumulate more charge, while maintaining the dimensions of traditional capacitors. In this context, this paper aims to explore the supercapacitor, focusing on the chronology of its development, materials used, applications to support the electrical sector and electric mobility, and future trends for this component increasingly present in various equipment that the world uses.

Keywords: electric mobility, energy, energy storage, supercapacitor.

B-4.2-21

Behavior analysis of high impedance fault detection methods under different fault models and conductor breakage cases

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High impedance faults (HIF) are events that occur with greater intensity in distribution systems, which can cause fire and expose humans and animals to the risk of electric shock. Usually, these events occur due to the rupture of an overhead conductor or contact of trees or objects with the electrical network. To detect these events, several HIF detection methods are proposed in the literature. Thus, this work aims to present a comparative analysis between four HIF detection methods, in order to evaluate the characteristics and efficiency of the methods in different types of simulation. For data analysis, hardware-in-the-loop tests were performed on the OPAL-RT platform. The results showed that the methods discussed in this work present difficulties in detecting and distinguishing HIF from other events, and mainly showed divergence in the results against different models of HIF.

Keywords: High impedance fault models, HIF detection methods, Comparative analysis.

B-4.2-22

Study of Power Transmission Systems in offshore Units

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The purpose of this article is to present an alternative case study for the use of energy transmission for operational and exploration and production units in the Santos Basin, which today represents the largest maritime sedimentary basin in Brazil. The supply of electricity to offshore oil and gas platforms in the Santos Basin aims to contextualize and confront technical

solutions that can create future decarbonization scenarios. In the elaboration of the study that gave rise to this work, an analysis was made of a scenario where we have a Gas Treatment Unit, which is closer to the gas pipeline network in Southeast Brazil. Therefore, the objective is to analyze the main solutions applied in the world for the supply of energy to the platforms. Understand the current generations of energy and present the advantages and disadvantages between the different types of proposed solutions.

Keywords: Platforms, oil and gas, electricity, alternating current, direct current and power transmission.

B-4.2-23

Photovoltaic Insertion Impacton the Distribution Transformer Losslife

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The insertion of distributed generation, driven by the growing demand for electricity, combined with environmental risks, presents significant challenges. Photovoltaic and wind systems have been highlighted as renewable and clean energy resources. However, there are some disadvantages such as: the intermittency that the solar source can cause, in this case, energy storage systems that have been studied; connection to the power system using DC-AC converters, which offers the possibility of faults such as: overload, reverse flow, insularity, harmonic distortions and harmonic resonances. Regarding the harmonic distortions that can be caused by photovoltaic systems, this can cause an increase in power losses in different elements connected to the power system. Thus, this research aims to evaluate the impacts on the distribution transformer caused by photovoltaic systems using OpenDss and Python tools. The results show that the current harmonic distortions affect the life of the transformer, as this causes an increase in losses and in temperature and therefore causes damage.

Keywords: Photovoltaic Distributed Generation; Current Harmonic Distortions; Distribution Transformer; Transformer Losslife; Net Present Value (NPV).

B-4.2-24

A Study on the Inspection of Inside Defects in 15 kV Polymeric Pin-type Insulator by Numerically Simulation and Experimental Using the Computerized Radiography

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The pin type polymeric insulators of 15 kV are made of high density polyethylene (HDPE) material due to its excellent electrical and mechanical properties, low cost, fast manufacture and they are rapidly replacing the traditional electric insulators made of glass and ceramic in 13.8 kV distribution networks. However, it is known during manufacturing process can generate voids inside of the polymeric insulator, which are not detected by the visual inspection. Furthermore, the presence of voids inside will damage the mechanical properties and from an electrical point of view, depending on the location of the voids and the presence of an electric field, partial discharge (PD) will occur, as a consequence, damaging the electrical isolation along time and leading to the occurrence of internal disruption causing the definitive outage of the electric energy transmission. Therefore, it is of fundamental importance to detect such manufacturing defects in the polymeric insulators and discarding them before their installation in the distribution network, thus increasing the reliability of the electrical system. Among the inspection techniques of non-destructive testing, radiographic inspection is the most interesting, in particular, the use of digital computerized radiography (CR) due to its excellent spatial resolution, high sensitivity and digital image processing of region of interest (ROI). In the present study on inspection of manufacturing defects, first, the detection of voids by radiographic images in the 15 kV polymeric pin-type insulators was evaluated by numerical simulation using a commercial CIVA-RT software. After that, the validation of the radiographic parameters obtained in the numerical simulation, the radiographic images of the defective insulators were obtained experimentally in the laboratory at UFPE. As a result,high quality and high resolution digital radiographic images were obtained by the CR system. Detailed of inside defects could be observed better by the digital image processing. Furthermore, after the pixel size calibration, dimensional analysis of defects inside could also be conducted.

Keywords: Hidden manufacturing defects in 15 kV polymeric pin-type insulators, partial discharges - PD, digital radiography, numerical simulation of radiographic image, experimental validation at laboratory, digital image processing and dimensional analysis.

B-4.3-1

Demonstration of Availability and Reliability Indexes in Electric Power Substations with Emphasis on Impacts on Power Supply of Subway Rail Systems

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This article aims to present an analysis and demonstration of the standards, concepts and methodologies of availability and reliability used in projects of high voltage substations that supply the metro-railway systems. This assessment considers the high levels of reliability and availability of electricity supply substations, required by companies in the metro-railway sector, in addition to the impact of interruption of operation due to lack of electricity. Reliability standards and concepts that are considered in the studies and projects of substations that need this high availability of service are presented. This study allows comparisons between several concepts of

these indicators applied in two different sectors and that need convergence, demonstrating the analysis of reliability and availability of the primary substation, in addition to an analysis of the expectations of the metro-railway market in relation to the electric power system. A proposal is still open, to further analyze the transmission lines, making it possible in the future to identify bottlenecks in power substations projects and support decision making on investments in new substations. Furthermore, the article later intends to identify whether the reliability levels are adequate for installations of metro-railway systems, based on the costs and losses incurred due to interruptions in the supply of electricity.

Keywords: reliability, availability, maintainability, indicators, substations, metro-railway, electricity, interruptions, loss.

B-4.3-2

Graphical Interface for Saturation Analysis in Current Transformers - TPY

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This paper presents a study of saturation of current transformers (CTs) applied in electrical power systems through the development of a graphical interface via Visual Studio in C#. The proposal is based on the development of a graphical interface that allows the analysis of the saturation of the CTs core, through simulations with real data for different conditions of three-phase and single-phase short-circuit levels, load variation according to the CT data, as well as the impedances connected to the secondary. In this way, the magnitude of the secondary voltage can be observed and compared with the levels described in norms, thus being able to conclude about the saturation of the TPY class current transformer core. This tool is later intended to help utilities in a practical and agile way to prevent saturation of current transformers so that the supply of electricity is not interrupted, resulting in financial benefits, as well as improvements in the process and customer service.

Keywords: Current Transformer (CT), Graphical Interface, Protection Application, Saturation Curve, Short-Circuit.

B-4.3-3

Overhead Line Insulators Performance Degradation Analysis Due to Environmental Pollution

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Overhead line insulators are one of the main equipment responsible for transmission lines safe and proper operation. Adverse environmental conditions, mainly the presence of pollution, are

the main cause of overhead line insulators early failure. The deposition of pollutants on the surface of the insulator, combined with moisture in the air, can lead to the occurrence of leakage currents on its surface, causing degradation of its operation and eventually leading to the occurrence of flashovers. In this paper, experimental tests were conducted in a high voltage laboratory with overhead line insulators towards verifying the electrical performance of such equipment after being naturally polluted during one year of operation in a high voltage transmission line. The insulators were tested in four different conditions: with dry and polluted surface; wet and with polluted surface; dry and clean surface; wet and clean surface. The results indicate a permanent degradation in the electrical performance of the insulators, characterized by a change in their surface's electrical characteristics. This permanent change might be due to surface erosion caused by the contaminant's deposition process and by the constant occurrence of partial discharges on the surface of the insulators. Furthermore, based on the results it can be observed that degradation: incurs in a higher leakage current, which increases the surface temperature; increases the number of partial discharges, which promote surface erosion; and leads to a change in the distribution of potentials along the chain. These conclusions demonstrate the necessity of assessing pollution severity prior to new developments due to the negative effects that the pollution layer has over insulator's long-term operation.

Keywords: Overhead line insulators, laboratory tests, partial discharges, pollution layer, flashover.

B-4.3-4

Modeling and Implementation of a Supervisory System for Control of a 230 kV Transmission Line Bay based on the IEC 61850 Standard

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The technological advances present in the electrical power system gave rise to the IED's (Intelligent Electronic Devices), which contributed to the enhancement of the SAS (Substation Automation Systems). In the context of SAS, the IEC 61850 is an international standard defining communication protocols for IED's at electrical substations. This work approaches the use of the standards described at IEC 61850 for the implementation of a supervision and control system of a bay with a double bus bar with a breaker and four switches, exploring aspects related to MMS (Manufacturing Message Specification) and the hierarchical data model described in the standard.

Keywords: Control, IEC 61850, IED, MMS Message, Supervision, SAS.

B-4.3-5

Thermal Monitoring Of Zinc Oxide (Zno) Surge Arrester Using CFD Analysis

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The surge arresters are electrical equipment extremely important to the electrical power systems. They are largely used in high voltage systems given its role of protection, assuring the reliability and continuity of supply of the system. Throughout their regulatory useful life, these equipment are exposed to degradation. The preventive method most used in the Brazilian power system is technique of inspection through infrared thermography. This technique is influenced by environmental factors and the thermographer's experience. In this context, the present study analyzes the use of computer simulation as a complementary tool to the thermographic inspection in order to provide greater security on the evaluation criteria, and on the expert's decision making process. The thermal behavior of a porcelain-housed ZnO surge arrester was evalueted based on computational simulations performed with the aid of CFD tool, aiming with this analyzes a far-reaching prospection of these equipment degradation level and prevention of terminal failures when associated to thermographic inspection results. The case study was performed using a porcelain-housed ZnO surge arrester of a 69 kV transmission line of the Chesf, being maneged for this equipment, parametrics studies of failure simulation and associating to these failures numerical results from the profile of surface temperature of the arrester, as well as its internal temperature field. In this way, with the simulations, it was possible to identify intense temperature fields in critical regions of the equipment above those recommended on the internal standard of the Chesf, showing then that the thermographic inspection may be aided on future interventions on the arresters before its failure in a safer way.

Keywords: Surge arrester, infrared thermography, thermal monitoring, CFD analysis.

B-4.3-6

Challenges and obstacles for the replacement of power transformers in buildings of collective use

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The informational design phase is intended to define the product's design specifications. First, user needs are divided into user requirements and then product design requirements are defined for different attributes, such as: functional, ergonomic, safety, reliability, modularity, aesthetics and legal. Considering the problem of replacing transformers in difficult-to-access building areas, the objective of this work is to present the collected information associated with obstacles included in the path between the entrance of a certain building and the place where the transformers are installed. The survey was carried out during the informational phase of a product design, based on technical visits to a set of buildings. Thus, all features are treated as an obstacle that the system to be designed must carry, such as through corridors, doors, ramps and gates. The identified obstacles are classified as: ground levels; steps; floor types; drains and grates; walls and narrow corridors; ramps; curves; obstacles in the substation After mapping the obstacles, the relevant Regulatory Norms for each type of obstacle are listed, so that the frequency and difficulty of overcoming obstacles can be discussed and confronted with the

current norms. Finally, all information is used to define the project requirements and specifications.

Keywords: Informational project, project methodology, substations reports, transformer locomotion, user requirements.

B-4.4-1

Bidirectional Hybrid Multilevel Inverter with 15 Levels Internet Connected to the Electrical Network

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This article proposes the presentation of a bidirectional multilevel inverter, with 15 output voltage levels, connected to the electrical grid (on-grid). Interconnection to the grid treats the inverter as a voltage source working as a current source. For the bidirectional power flow control, a closed loop current control was used using a proportional controller and a feedforward used in the reference and in the electrical network. Simulations were made for the control method and the prototype was physically implemented with the proportional control with the feedforward in the reference and in the electrical network, proving to be a very robust and efficient control that met the objective of the application. The controller was developed on a 1 kW prototype and a good performance was achieved in the bidirectional operation of the inverter energy flow when interconnected to the grid.

Keywords: Bidirectional Connection, Controller Feedforward, Closed Loop Control, Grid Interconnection, Multilevel Inverter.

ormational project, project methodology, substations report, transformers locomotion, user requirements.

B-4.4-2a

Optimal Power Flow Model Multiperiod for Hydrothermal System

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This paper propose a model for the Optimal Power Flow (OPF) problem related to hydrothermal systems. In the literature, the OPF models to hydrothermal systems, present simplified hydraulic constraints. The objective of this paper is to propose an OPF model that minimizes the fuel costs of thermoelectric, across an active/reactive dispatch, focusing on the representation of hydraulic constraints. The OPF Hydrotheral (OPFH) it's a problem nonlinear and dynamic, in which all constraints are considered for each hour of a daily operation, representing the dynamics of

hydroelectric power plant reservoirs and electricity consumption. The computational tests were performed using the IEEE 24-bus test system, which were adapted for hydrothermal systems with greater participation of hydroelectric. The results show the importance of hydraulic constraints to be represented in detail, showing the importance of water planning and to being particularly important for systems similar to the Brazilian.

Keywords: Optimal Power Flow, Hydrothermal Systems, Nonlinear Optimization.

B-4.4-2b

Multiperiod Optimal Power Flow Model for Hydrothermal Systems

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This paper propose a model for the Optimal Power Flow (OPF) problem related to hydrothermal systems. In the literature, the OPF models to hydrothermal systems, present simplified hydraulic constraints. The objective of this paper is to propose an OPF model that minimizes the fuel costs of thermoelectric, across an active/reactive dispatch, focusing on the representation of hydraulic constraints. The OPF Hydrotheral (OPFH) it's a problem nonlinear and dynamic, in which all constraints are considered for each hour of a daily operation, representing the dynamics of hydroelectric power plant reservoirs and electricity consumption. The computational tests were performed using the IEEE 24-bus test system, which were adapted for hydrothermal systems with greater participation of hydroelectric. The results show the importance of hydraulic constraints to be represented in detail, showing the importance of water planning and to being particularly important for systems similar to the Brazilian.

Keywords: Optimal Power Flow, Hydrothermal Systems, Nonlinear Optimization.

B-4-4-3

Analysis Of The Impacts Of New Regulations For The Energy Transition In Brazil: Barriers And Incentives For Small Consumers

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Talking about energy transition in Brazil is difficult, because unlike most countries, Brazil has always had a very large potential for power generation from renewable sources, mainly due to its geographical features, which allow it an abundance of different resources. However, as one of the greatest abundances is in the quantity and flow of the rivers, for many years the electric matrix was dominated by hydroelectric plants, which depended heavily on the rainfall regime and water storage in their reservoirs. As the country's load increased, this dependence became more and more critical, until the blackout crisis occurred in 2001 and 2002. After this event, there was a significant advance in the race towards a possible energy transition, with the increase of the

national generating park from other renewable sources, and one of the first regulatory milestones is in the Proinfa (Incentive Program for Alternative Sources of Electric Energy). Over the following years, other needs and regulations were evolving, until in 2012 the normative resolution 482 was enacted, which gave a general overview for the regulation of distributed generation in the country, establishing the general conditions for the access of distributed microgeneration and minigeneration to the electricity distribution systems, in addition to the electricity compensation systems. However, there were still points that needed to be improved, and for this reason, ten years later, this resolution evolved into law 14.300/2022, which became known as the Legal Framework of DG, and brought new guidelines for the entire issue of distributed generation in the country, bringing some regulations that were already lagging behind to the present day, and generating several impacts on the national electricity sector as a whole, both in the short and long term. The expected result that this article intends to bring is to question the main impacts that these regulatory changes, which aim to increase the scope and insertion of other renewable sources besides hydro, may generate in the country as a whole, with the focus being on small consumers, such as residential or small businesses, which are currently dependent on their local distributor, with little or no room for margin in the installation of distributed generation in their locations, in addition to highlighting whether these impacts can bring more barriers or incentives in the long term.

Keywords: Energy Transition; Regulation; Distributed Generation.

B-4.4-4

Analysis of Voltage Regulation Strategies in Systems with High Insertion of Photovoltaic Generation

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This paper aims to analyze alternatives for the mitigation of the voltage transgression in a circuit of a real feeder in the city of Taquari, Rio Grande do Sul. The analyzed consumer installation has a photovoltaic plants of 122.82 kWp. The feeder was modeled in OPENDSS software, where simulations were performed for a period of 24 hours. The alternatives studied were: reconductoring the low voltage circuit, and the Volt-var control curve characteristic that is based on Europe standart. It was considered the reactive power priority mode, and active power priority, and inverter oversizing. It was seen that the Volt-var control by the photovoltaic smart inverters and the reconductoring are able to mitigate voltage problems, maintaining the appropriate values.

Keywords: Distribution System, Overvoltage, Photovoltaic Distributed Generation, Power Quality, Reconductoring, Volt-var Control.

B-4.6-1

Study of Electromagnetic Interference from Transmission Lines in the Radio Frequency Spectrum

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Transporting energy from centralized generating units to consumer units has been a challenge as energy demand grows and the availability of physical space for the implementation of new overhead transmission lines decreases. In Brazil, the minimum performance requirements that a power transmission line must obey are established by Operador Nacional do Sistema Elétrico. One of the narrowest criteria in terms of design concerns the limits of electromagnetic emission in the form of radio interference, which can directly impact the reception of signals, especially AM radio signals, in the surroundings of the route line. This criterion also may be decisive in choosing the line's corridor width, and consequently, in the final cost of a transmission line project. This work performs a series of radio interference levels' predictions in different lines using the Bonneville Power Administration empirical method and discusses the socio-environmental impacts of this phenomenon.

Keywords: Electromagnetic interference, Radio interference, Corridor width, Socio-environmental impacts, Transmission lines.

B-4.6-4

Transient Analysis of Distinct Approaches for Modeling Transmission Lines Including Ground-Return Parameters

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Accurate electromagnetic analysis requires rigorous modeling of the ground-return parameters (impedance and admittance) and soil. In this paper, three different approaches to compute ground-return parameters proposed by Nagakawa (N), Sunde (S), and Petterssson (P), which takes into account the impact of earth conduction effects on both impedance and shunt admittance and the frequency effect on the soil parameters are investigated. Comparisons using Carson's approach which neglects the influence of imperfect earth on shunt admittances and assumes frequency-constant parameters of soil are carried out. Finally, several simulations for a 440-kV overhead transmission line on a frequency-dependent soil, under energization and lightning strike, are performed to evaluate the impact of these different approaches on the transient responses.

Keywords: electromagnetic transients, energization, ground-return parameters, lightning, transmission lines.

B-4.6-5

Assessing the influence of statistical distributions of tower-foot grounding resistance on lightning performance of overhead transmission lines

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This work analyzes two different procedures to contemplate the statistical distribution of tower foot resistance (Rt) in the lightning performance of transmission lines, particularly the division of the transmission line into sections of representative resistance values and the application of a Monte Carlo approach regarding the distribution of R_T characterized by a log-normal function. Conforming to the results, the two approaches generate similar estimation of the outage rates. It is also demonstrated that increasing the number of sections into which the line is divided does not necessarily causes refined results. Additionally, it is exposed that lines that have resistance distributions with approximate median values have approximately the same outage rates, even if the mean values of the distributions are moderately different.

Keywords: tower-foot resistance distribution, lightning performance of transmission lines, statistical analysis, Monte Carlo Approach.

B-4.6-9

A Study on the Use of Brackets for the Overhead Ground Wire in Reinforced Concrete Transmission Lines of 132 kV in Patagonia

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Most of the 132 kV transmission lines in northern Patagonia in Argentina are built with reinforced concrete poles with a small bracket for the overhead ground wire. The purpose of this bracket is to force a lightning shielding angle of 30° for the upper conductors and to allow the use of lower height columns for minimizing costs. It has the drawback of producing dangerous torsional loads in the event of ice accumulation imbalances and increasing the risk of initiating cascading mechanical failure events. This prompted a graduation project of Electrical Engineering at Comahue National University that aimed to carry out a study by applying the FLASH program of the IEEE to estimate the effect of not using the small bracket. The study showed that the elimination of the bracket in future projects would only produce a non-significant increase in the flashovers due to shielding failures, not being necessary a strict shielding angle of 30°, lowers investment costs and minimizes the risk of dangerous torsional loading and cascading mechanical failure.

Keywords: Transmission line, shield wire, shielding failure, lightning outage, flashover, bracket, IEEE Flash.

B-4.6-10

The Impact of Transmission Line considering Equivalent Resistivity of Multi-layer Soils on Lightning Overvoltages

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Transmission line (TL) modelling in electromagnetic transient simulations requires the detailed representation of the influence of the finite earth conductivity on the TL parameters, which are described by earth-return impedance and admittance terms. In most studies involving TLs, it has been considered a homogeneous soil for the earth-return impedance and admittance calculation. In addition, it is usually considered the ground conduction current to be much higher than the displacement current. These considerations can lead to errors in the case of multilayer soils and applications involving high frequencies, such as transients arising from the incidence of lightning in TLs. Considering earth-return parameters is to include the effects the intrinsic propagation constant of air, earth permittivity and earth-return admittance, therefore, the displacement current of earth and the phenomenon of high frequency are included in the wave propagation and transient simulations. It is worth mentioning that these considerations are neglected in the EMTPtype simulation tools. Moreover, in these tools multilayer soils are not taken into account. Therefore, in this paper investigates the influence of considering the earth-return impedance and admittance terms of multilayer soil in the transient overvoltage simulation in overhead TLs. The earth-return impedance and admittance terms are calculated considering the Wise equation and the equivalent resistivity of multilayer soils. The simulations are performed in the time domain and are obtained via a modified JMarti model. The results presented in this paper show, for the test case, that the use homogeneous soils generate very distant results, calculation of line parameters and calculation of overvoltages, when considering multilayer soils.

Keywords: Multi-layer soil, overhead transmission line, series impedance, shunt admittance, time-domain simulations.

B-4.6-12

Feasibility Analysis of the Implementation of Composite Insulator Cross-arm for Overhead Transmission Line Projects in Brazil

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This study has the objective of the presents a feasibility analysis of the composite insulator cross-arm for overhead transmission line projects in Brazil, as well as the economic and technical benefits that this technology has to offer to the enterprise. Usually, the transmission lines use insulators attached to the metallic cross-arm of the latticed towers. In the implementation of this technology, the metallic cross-arm is replaced by composite insulator cross-arm, dispensing the use of traditional insulators, while maintaining the two basic characteristics: electrical insulation and structural support. This brings several benefits to the project, such as: compacted right of way, enabling the optimization of the route line in urban stretches and/or those with environmental restrictions, reduced tower heights, smaller foundations, better performance against atmospheric discharges, reduced landfill cost, material savings, and optimized construction time. In order to prove the feasibility of implementing composite insulator cross-arm, a case study was realized on a 230 kV transmission line, single circuit. In this study, the results of the traditional solution of towers with insulators and the proposed solution of towers with composite insulator cross-arm is presented.

Keywords: Transmission line, Composite insulator cross-arm, Right of way, Compact overhead lines.

B-4.6-13

Insulated cross-arm on overhead transmission lines: a techno-economic review

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The necessity for expansion of the electric power transmission system, coupled with the ever-decreasing availability of physical space and the need to reduce environmental impact, create a requirement for better use of the transmission lines (TL) right of way (ROW) or even the development of compact transmission lines. In this context, this paper presents what is insulated cross-arm and how its application in overhead transmission lines (OHTL) is able to improve the performance of the transmission system, reducing the space occupied by the towers, or even expanding the delivery capacity of existing lines, optimizing the transmission capacity. Thus, a description of insulated cross-arm, a review on the development and application of this technology around the world under the technical, economic and environmental aspects will be made, followed by a case study comparing the use of insulated cross-arm and conventional towers that use suspended insulators.

Keywords: Insulated Cross-arm, Overhead Transmission Lines, Right of Way, Uprating, Transmission Capacity.

B-4.6-14

Analysis of the impacts of systemic variations in the secondary arc current using Python and ATP

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Statistics show that phase-to-ground faults represent about 80% of occurrences in electrical power systems. Thus, the single-pole reclosing is a practice adopted, whenever possible, due to its systemic benefits when compared to three-pole reclosing. The success of the single-pole reclosing is directly associated with the extinction of the secondary arc current. Therefore, the design stage of new transmission systems should aim at alternatives that minimize the secondary arc current and its direct increase in the probability of success of the maneuver. The evaluation of such alternatives is commonly carried out with the aid of electromagnetic transients programs, such as ATP, PSCAD, EMTP-RV among others. Although ATP has a few features for computing different scenarios, with different configurations, in a systematic manner, analyzing the impacts of such applied variations in the resulting transients is usually a daunting task. In this context, the main objective of the present work is to show how ATP simulations can be leveraged by means of master algorithms, implemented in Python, that can call ATP executable for running specific simulations with specified parameters. With this strategy, it is possible to simulate and analyze the secondary arc current and the transient over-voltages induced in the system as a function of several parameters, such as neutral reactor capacity, line length, compensation level, etc.

Keywords: ATP, Python, secondary arc current, singlepole reclosing.

TOPIC 5 - Energy Planning and Management

B-5.1-1

The Role of Energy Storage Systems in the Integration of Renewable Generation Sources and Power Quality

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Increased energy demand and environmental concern have motivated the growing search for renewable energy sources. However, these sources present temporal variability, making it difficult to insert them on a large scale in existing electrical systems. Given this scenario, Energy Storage Systems (ESS) represent a promising alternative in the integration of variable renewable sources and provision of grid support services. This article analyzes the role of ESS in the integration of renewable sources and in the quality of energy supplied by the grid, reviewing existing technologies as well as their main applications or services provided. The review indicates that there are several ESS capable of integrating renewable generation sources into existing electricity grids. Among the benefits of the ESS adoption are improvements in power quality, energy management, reduction of emissions and economic benefits by reducing fuel consumption and postponing investments in the electricity system.

Keywords: Batteries, Energy storage systems, Power Quality, Power System Planning, Renewable Energy Sources.

B-5.1-2

Spatial and Temporal Analysis Applied to the Optimal Battery Allocation in Electrical Distribution Systems

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The interest in integrating distributed energy resources (DERs) in the electric distribution system (EDS) is growing up due to the economic benefits that DERs can provide to the system operator and the operational benefits to the EDS. Specifically, batteries can be used for peak shaving, voltage regulation, and distributed generation hosting capacity improvement. Nevertheless, their allocation and sizing must be carefully planned, considering their costs, network constraints, and future scenarios for integrating photovoltaic generation. Based on a Markov chains, spatial analysis is developed to estimate future scenarios of photovoltaic penetration in the EDS based on the consumer's economics and geographical data. Then, a stochastic programming model is formulated for the optimal placement, sizing, and operation of batteries in the EDS, considering future stochastic scenarios of photovoltaic penetration. The proposed mixed-integer conic linear programming mathematical model was implemented in AMPL and solved with the commercial

solver CPLEX. Results obtained using the IEEE 33-bus test system showed that the optimal battery allocation leads to peak shaving and energy cost reduction (57% and 4.7%) while reducing voltage deviations. Furthermore, it was verified that improved spatial and temporal information leads to a more realistic estimation of the future EDS state, which impacts the battery allocation decision.

Keywords: Battery planning, distribution system, spatial analysis.

B-5.2-4

Calculation of Spinning Reserve and Reinforcements in Transmission for Systems with High Penetration of Wind Generation

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The high insertion of wind generation in power systems results in increased uncertainties related to the continuity of energy supply due to intermittence in the generation process. Therefore, it is essential to quantify the flexibility of non-wind generation necessary to maintain the reliability of the system. This work presents an approach to determine the amount of generation of non-wind units destined to the reserve, and the reinforcements in the transmission lines considering a budget available for investment. The k-means clustering algorithm is used to create wind generation scenarios based on historical data. To determine the amount of Spinning Reserve, an approach based on the Optimal Power Flow is presented, and the reinforcements in the transmission lines are identified through the Lagrange Coefficients. Additionally, non-wind generation contingency will be considered. The IEEE 118-bus test system is used to demonstrate the main concepts discussed in this work.

Keywords: Lagrange Coefficients; Generation Flexibility; Transmission Line Reinforcement; Wind Generation.

B-2.2-5

Systemic analysis of the technical-economic dimensions of natural gas between the Pre-Salt and Vaca Muerta

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This work analyzes the energy resources of natural gas for its technical-economic scope to point out energy integration. Also, for offshore production, consolidated in the Argentine and Brazilian market. The study regions are: Campo de Lula and Sapinhoá in Bahia de Santos and Campos, and also Vaca Muerta in Neuquén, Argentina. The possibilities of cross-border implementation of gas

pipelines, use and their interference will still be evaluated, such as the GASBOL line in relation to the Pre-Salt and Vaca Muerta and the application, in the established regions. This analysis verifies that public or private investments are necessary to make this energy resource viable in common agreement. That is why the necessary resources and tools can be explored, as both countries have investments in this sector. In this way, the technical-economic interest in the analysis of electricity production and expansion of gas pipelines can consolidate market influences and political relations.

Keywords: Energy resources, Energy integration, Natural gas, Pipelines, Technical-economic dimensions.

B-5.2-6

Probabilistic Optimal Power Flow Considering Load Uncertainties and Capacitor Allocation

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This paper proposes the use of Genetic Algorithm (GA) to perform a Probabilistic Optimal Power Flow to reduce the expected value of active losses in Transmission Systems. The load uncertainties are modelled with an approximation probabilistic method called 2m Point Estimate Method (PEM). The optimization problem aims to determine the optimal active generation, generation voltages and transformer taps. In addition, capacitors sites and sizes are also sought to improve the system performance. Simulations were carried out in two transmission systems: IEEE 14 Bus and IEEE 30 Bus. Losses were reduced and the voltage profile was improved in all cases. To validate the results, the procedure was compared to deterministic formulations and to MCS, where the technique precision and efficiency can be highlighted.

Keywords: Probabilistic Power Flow, Approximation Methods, Capacitor Allocation, Losses Minimization, Transmission Systems.

B-5.2-11

Calculating protection devices parameters by using open-source PandaPower software

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The electrical system planning aims to provide the electrical energy with quality. However, the system may be exposed to topological contingencies, discharges and equipment failures, such as generators, motors, and transformers. The search for better results regarding the power system

protection is important and many investigations have been developed to fulfill this objective. In addition, there are few freeware works dedicated to calculating parameters of relays, becoming easy and interactive for the users, normally technicians and electrical engineers. In this sense, a computational tool was developed to determine the settings of the overcurrent relays, aiming to guarantee a more reliable power electrical system. The work was developed in the Python language, which is easy to understand and has a relatively simple syntax. It has been used in numerous scientific researches, once there are a lot of libraries used for processing, and mathematical and data analysis. Another advantage is to become the code free to any person, allowing its utilization for academic purposes. The main library for the study was the Pandapower, developed by German researchers at the University of Kassel, to calculate power flow and short circuit with a high degree of automation. In this sense, we adjusted the tool to be employed in power system protection studies. For this work, the relay coordination problem has been treated as an optimization problem, so the Pyomo library was used to determine the optimal solution. Pyomo allows use several well-known solvers, such as, GLPK, CBC and Gurobi. Concluding, the pickup current, dial time and, operation time of all protective devices are automatically calculated via the proposed method.

Keywords: Protection, power flow, coordination, pandapower, Pyomo, relays.

B-5.2-12

Investigating multiple local minima for the economic dispatch problem with valve-point loading effect using a dynamic system approach

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The economic dispatch problem with representation of the valve-point effect (PDE-PV) is a challenging problem in the operation of electrical power and energy systems. This problem seeks to minimize the fuel costs of thermal power plants, subject to power balance constraints and physical and operational limits of generation. The PDE-PV is formulated as a non-linear, non-convex, non-differentiable and multimodal optimization problem. Its multimodality characteristics hinders the search for local and global solutions through exact or heuristic optimization methods. Several metaheuristic and deterministic approaches have been proposed in the literature to solve the PDE-PV problem. However, these solution approaches typically compute only a single local optimal or suboptimal point. In this papper, a new solution approach capable of finding multiple local optima and, possibly, the global optimal solution of the problem is proposed. This approach is an extension of a method described in the literature for unconstrained optimization problems, later extended to problems with equality constraints. Thus, it is proposed to generalize this approach in order to introduce the treatment of equality and inequality constraints in order to solve the PDE-PV. In the proposed solution approach, the original PDE-PV problem is replaced by an auxiliary dynamic system, which is obtained in such a way that its equilibrium points correspond to the local optimal solutions of the original optimization problem. The method searches all equilibrium points that correspond to the local and possibly global optimum of the original PDE-PV problem. The proposed solution approach is applied to find multiple local

optimum of the PDE-PV problem for a 3-generator system in order to allow the visualization of the geometric behavior of the method. The results obtained are compared to those determined by metaheuristic and deterministic methods previously proposed in the literature.

Keywords: Economic dispatch with valve-point load effects, global optimal solutions, non-linear optimization, optimization dynamic system, power systems operation, quasi-gradient, reflected gradient systems.

B-5.3-1

Analysis of Electric Energy Consumption in the Brazilian Industrial Sector

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In this article, an analysis of electricity consumption data in Brazil was performed, from 2016 to 2021, in order to understand the different demands for electricity in the prepandemic scenario, pandemic scenario and also consumption forecasts for the coming years. The study was carried out based on data released by Empresa de Pesquisa Energética (EPE), a service provider for the Ministério de Minas e Energia (MME). These analyzed data refer to the total consumption of electricity in Brazil and the total consumption of electricity by the Brazilian industrial sector, divided by geographic regions and electrical subsystems, in addition to consumption by Federative Unit. Based on the determination of the rate of electricity consumption evolution, forecasts were made for the coming years (until 2030) and compared with the results of the prospects for expanding production capacity, release by EPE in the “Plano Decenal de Expansão de Energia 2030”.

Keywords: Consumption, Data analysis, Electricity, Industrial Sector.

B-5.3-2

Study of Substation Grouping for Electric Energy Demand Forecast

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Forecasting electrical loads is a very promising field for companies in the energy sector, with it obtaining relevant information about the system, making it possible to plan strategies, and thus maintain the system with quality, reliability and safety so that there are no interruptions in supply, strengthening the electricity sector. These forecasts are related to the global load demand, that is, the total sum of electrical loads, and also to the information on their buses (multinodal forecast), making the forecast complex, but very important. In this work, the prediction of multinodal electrical loads was carried out. The method uses an ARTMAP Fuzzy neural network to perform the prediction in the substations and aims to identify the best

grouping (aggregation) of the substations, in order to obtain a better quality in the predictions of multinodal loads. For data validation, information from a New Zealand electric power system is used, using data from nine substations.

Keywords: Multinodal Electric Load Forecast, Participation Factor, Artificial Neural Networks, Aggregate Electric Load.

B-5.3-3

Strategic Offering Problem of a Price-Maker Company: Evaluating the Influence of Bid Forecasting from Other Agents

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In a Strategic Offering Problem (SOP), a price-maker generating company aims at maximizing its profits through strategic offers in the day-ahead market, which is generally solved by electric power auctions. In this environment, generating companies make offers to sell power blocks (MW) and consumers and retailers bid to buy power blocks (MW) at specified prices ($/MW) for purchase and sale. For such a purpose, this company must forecast the bids (price and amount) from the remaining companies and consumers. This paper uses a data base containing the offers/bids of quantity and price presented by the other agents to the market of the previous day to forecast the offer of these agents. The following forecasting techniques were considered: rolling averages and triple Holt-Winters smoothing. The first technique is widely used due to its ease of implementation and the need for little historical data for its application. The second technique is used in situations in which the time series presents a pattern with linear trend and seasonality, besides providing data prediction in a fast and reliable way and for a wide range of time series. For comparison purposes, the following three benchmark methods have also been considered: naive, average and harmonic mean methods. The tests were analyzed for a system with 12 generating units, 7 of which belong to the company that used the SOP and 17 consumer units in a period of 24 hours. After evaluating these five methods, those that presented the best accuracy in data forecasting were the average and the harmonic mean method. This is because the database used presents a specific situation of energy consumption, where there no trend in consumption is verified, either with an increase or decrease in demand. Although the averaging methods have shown the best results predicting quantity/price of competitors, the other investigated methods have also presented good results, since there has been no great disparity among the profits obtained, and the calculated errors are small (0.5% for the Holt-Winters method, for example).

Keywords: Strategic Offering Problem, Forecasting Methods, Time Series.

B-5.3-4

Statistical model for treatment of missing and outliers in time series for wind power forecast

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With the increase in the installed capacity of wind power in Brazil's electrical energy matrix, it has become essential to invest in the quality of data from these energy sources to support models of electrical energy operation and planning. In this sense, the present work deals with the development of a probabilistic filter methodology for correction of wind speed and generation series used by the current wind power forecast model of the National Electrical System Operator (ONS). The data from all wind farms connected to the basic grid (transmission system), which are necessary for the forecast models, are acquired by the Operator through the Supervisory Control and Data Acquisition (SCADA). However, the number of missing data in these histories is very expressive, thus requiring tools capable of processing these data before being used in the forecast models. The tool developed in this work integrates: (i) a real database, used by the ONS, that includes verified generation information obtained from the real-time historical base of ONS' supervision system and the Measurement and Billing System of the Electric Energy Commercialization Chamber (CCEE); and, for observed wind data, the use of the ONS supervision system and the Monitoring System of Anemometric Measurements of the Energy Research Company (EPE); (ii) a pre-treatment model with the identification of aberrant data and outliers through pre-defined rules and selection of redundant information from several databases; (iii) a state-space formulation with a Bayesian approach and direct application of the Kalman filter, with predictions derived from probability distributions obtained through data clusters, using a clustering methodology. Additionally, the results in this work might provide better inputs for the forecast models, as well as for the generation estimation models, which are used in the real-time operation models and in the constrained-off calculation processes.

Keywords: Wind Power, Missing and Outliers, Kalman Filter, Clustering.

B-5.3-5

Analysis of distributed generation in the Brazili-an electricity supply, post Law No. 14.300/2022: a study based on Autoregressive Integrated Moving Average (ARIMA) models

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Distributed electricity generation, associated with investments in energy efficiency, can reduce the need for expansion of centralized generation in Brazil. Furthermore, it has the potential to help meet the Brazilian electricity demand during peak hours, as well as reduce national electricity losses. This decentralized generation modality was boosted by the Brazilian

government, in 2012, through the approval of Normative Resolution No. 482/2012 which allowed the participation of minigeneration and microgeneration in the Brazilian electrical system, with the creation of the Electric Energy Compensation System. Ten years after the approval of the aforementioned resolution, Law No. 14.300/2022 brought profound changes to this sector, including the imposition of the payment of fees for the use of the electrical system, by those responsible for distributed generation connection points, and the alteration of the power range for non-dispatchable sources. Given this context, the work aims to analyze the possible impacts on the evolution of the participation of distributed generation in the Brazilian electricity supply, resulting from the approval of the law in question. To this end, the total installed capacity of Brazilian distributed generation was forecasted for the period after the approval of Law No. 14.300/2022, in order to compare it with the actual data observed in the same period. This forecast was obtained by applying the Autoregressive Integrated Moving Average (ARIMA) model, based on the historical monthly data of total installed power of distributed generation, up to the month immediately before the approval of the law. The comparison between predicted and observed data was also based on the individual impacts on distributed microgeneration and minigeneration, in order to understand how these types of generation interfere with the system as a whole.

Keywords: Distributed generation, Forecasting, Time series analysis, Auto-regressive moving average models.

B-5.3-7

Ant Colony Optimization Method with Directed Singularity Search for Solving the Economic Dispatch Problem

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The Economic Dispatch Problem (EDP) is an important problem involving Electric Power Systems, whose model belongs to nonlinear programming. Its resolution consists of determining the powers to be produced in each generating unit, in order to minimize the costs, satisfying constraints related to demand fulfillment and limits of the generation capacity of each generator. When we consider the effects of valve point loading, the model starts to better portray reality, but it becomes non-convex, multimodal and non-differentiable, since the objective function has a modular term. Several methods have been used to solve the EDP, but many of them have a very large search space, causing slowdowns, or end up stuck in local minima. More recently, good results have been obtained with the use of metaheuristics, especially swarm ones. Seeking to reduce the computational cost and avoid early convergence, as research shows that the vast majority of local minima are found in singularities, this paper proposes a search method directed to singular points, using the metaheuristic Ant System (AS). The AS is part of the ACO (Ant Colony Optimization), a set of metaheuristics inspired by the behavior of the ant colony, in the search for food. These methods are based on the fact that ants have the ability to minimize the path between the food and the nest, and this is possible through the deposition of a substance called pheromone. The method simulates this behavior, making artificial ants walk through the graph

that represents the problem and build feasible solutions. This construction is random and based on a probability of choice, where the best paths are more attractive than the others, due to the pheromone. The solution method was implemented in Python and numerical tests were performed with the EDP involving systems with 3 and 13 generating units. It proved to be quite efficient in comparison with other metaheuristics found in the literature.

Keywords: Economic dispatch, metaheuristics, optimization, singularities.

B-5.3-8

Harmonic Classifier for Efficiency Induction Motors using ANN

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Modern electrical systems have a significant presence of electronic loads, which in turn produce negative impacts on distribution systems and loads, this has motivated their study to be increasingly prioritized, aiming to reduce their impacts from corrective actions. Harmonics are classified as positive, negative, and zero sequence, and their impacts on loads can vary according to the harmonic present. In the case of electric motors, negative sequence harmonics result in the greatest impacts. This work presents a classifier of existing harmonics in the input waveform of electric motors classes IE2, IE3 and IE4 using artificial neural networks (ANN), for that purpose, negative (2nd), positive (7th) and zero sequence harmonics (3rd) were applied separately and combined in the electric motors, the data was exported for a classification algorithm to identify existing harmonics. The results show how the algorithm presents good approximations of the present harmonics, mainly with those of positive and negative sequence.

Keywords: Harmonics, Electric Motors, Artificial Neural Networks, Harmonics Forecasting, Harmonic analysis, Energy efficiency, Electric motors, ANN, LSPMM, Predictive maintenance, Machine learning.

B-5.4-1

Analysis of Short-Circuit Considering Substation Busbar Schemes using PowerWorld®Simulator

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In recent years, the use of renewable resources for energy generation has been increased, with connections of different types of sources (Small Hydro, Wind, Solar) in substations, both transmission and distribution. These connections have different levels of current injection, which present a variability throughout the day. Among the functions sensitive to this situation is the

differential protection (function 87) of busbars. Short-circuit simulations are usually performed in softwares that represent the system using node-branch topology, such as the commercial softwares ASPEN and ANAFAS. However, when faults are simulated to adjust protection function 87, it is important to know the intensity and direction of the currents in the different substation busbar schemes. Therefore, it is necessary a simulation software with the capability to model the busbar scheme of each substation, creating a switch - breaker topological model. To ilustrate this, the IEEE-WSCC 9-bus Test System with detailed simulation model using three different substation busbar schemes (main-and-transfer; breaker-and-a half; five-switch-onebreaker) is used, using the owerWorld®software to calculate the levels and direction of short-circuit currents at the substation busbars scheme.

Keywords: Short Circuit, PowerWorld®, Busbar Schemes, Power System Protection, differential protection.

B-5.4-2

Automatic Demand Disconnection (ADD) of ET Malvinas 500/132 kV using the Load Shed and Restoration application associated with GE® PowerOn SCADA.

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This technical work was carried out by EPEC with the agreement and collaboration of TRANSENER S.A. and CAMMESA. The objective of the automatism is to avoid a partial collapse in one of the 3 nodes that link EPEC's network with the SADI, precisely in the Transformer Station Malvinas (500/132 kV), being a node of great importance due to the fact that it presents the highest demand in the area. The loss of one of the power transformers (300 MVA) in the Malvinas transformer station would cause, under high demand scenarios, the disconnection of the remaining transformers due to overload. The innovation lies in the implementation method of the automatism, since it was carried out through the adaptation and configuration of an application associated to GE's PowerOn SCADA called Load Shed and Restoration, which is dedicated to load shedding and restoration in events of rotating outages due to network saturation. The advantage of using it is beneficial in operational and economic terms for the companies in question, since it uses existing equipment and is quick to set up with great reconfiguration flexibility. The main disadvantage to be overcome was determined by the total time of de-energization, since it had to be less than the time of activation of the overload protection of the transformers of the Malvinas Transformer Station. The tests performed showed an acceptable total time margin, but with the need to replace the definite time protections by others with inverse time curves. The Automatism is configured under 3 important stages: determination of the necessary power to de-ballasted, evaluating the current configuration of ET Malvinas through the operating status of the circuit breakers in 132 [kV] of Transformers T1MA, T2MA and T4MA; and the power values measured in RealTime. Detection of the overload on the operating transformer(s) after one fails. This signal will be provided by a TRANSENER PLC and reflected in the Malvinas RTU (EPEC) for the unloading operation. Determination of the circuit breakers involved in the load shedding operation. The

tests were carried out by simulating the loss of a transformer in Malvinas transformer substation, an action that activated the automatism, triggering the opening of reserve circuit breakers at 13.2 kV in EPEC's network. Five tests were carried out, using 51 circuit breakers belonging to 13 EETTs distributed in the city of Córdoba, which were key to define the adequate configuration and guarantee their correct operation. The analysis and interpretation of the results ensured that the automatism will work correctly, successfully fulfilling the main objective. In addition, it has the characteristic of being a selective de-disconnection because it will disconnect the minimum and necessary demand for each particular scenario, achieving maximum efficiency. On the other hand, its implementation is novel and opens the way to a new methodology in the management of the network, since up to now EPEC did not use the application in question.

Keywords: Load Shed, Automatic, Collapse, Transformer, SCADA, Disconnection, Overload, RTU.

B-5.4-3

Control Strategies using WECC Models of PV Systems for Enhanced Stability

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Generic Renewable Generator Model developed by Western Electricity Coordinating Council (WECC) seeks to capture the main dynamics of two types of PV systems: a model consisting of plant controller, electrical controls and grid interface modules, appropriated for large-scale PV plants, and a simplified model for dispersed generation, or aggregated PV plants, connected in distribution network. The plant-level control module allows the following power control modes to be represented: closed loop voltage regulation (V control), closed loop reactive power regulation (Q control), constant Power Factor (PF) and coordinated control of voltage and reactive power (Q/V). The dispersed model allows two basic reactive power control modes: constant reactive power, and volt/var control at the generator terminals, with optional line drop compensation.This paper investigates the impact of WECC two PV Models in the local and global voltage control and the influence on voltage and frequency stability when are used different strategy controls in WECC Models. The studies are performed using Powerworld®Simulator and IEEE 14 bus test system. The initial system configurations are without PV systems and serves as the base case. In the next step, large-scale PV systems and distributed PV Models are connected in some buses. The dynamic behaviour of the system is stutied by tripping of the PV plant, and by simulation of short circuits in selected buses, with and without open transmission lines under fault, in order to assess the system stability.

Keywords: WECC Models, Powerworld Software, Solar Photovoltaic (PV), Voltage Stability, Frequency Stability.

B-5.5-2

Data processing and evaluation of different combinations of dissolved gases in mineral oil for managing incipient failures in power transformers

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On asset planning and management, transformers faults prediction concurs increasing return on investment, allowing management of costs and risks that affect electrical system infrastructure and company business. Thus, dissolved gas analysis in mineral oil provides important information to diagnose incipient faults, essential to predictive and preventive maintenance. However, different interpretation methods might lead to different diagnosis to same analysed samples, moreover some methods show lower assertiveness rate and researchers and energy companies are developing new methods or enhancing existent ones to increase effectiveness. Machine learning is studied and applied on transformers failure prediction, and for good performance, it is necessary to extract the best characteristics hidden on data. Applying Cuckoo Search and k-nearest neighbour algorithms, this paper investigate data processing methods to determine gases concentration limits to remove outliers and choose best attributes to failure diagnostic. Results were compared to IEC 60599 and Rogers' methods and were adequate to help on failure management on transformers.

Keywords: Dissolved gas analysis, machine learning, Cuckoo search optimization, k-nearest neighbor, attribute selection, power transformer.

B-5.5-3

Tool applied to determine and mitigate the unbalance in distribution transformers in the city of Balcarce, Argentina

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his paper presents a methodology that allows the use of data loaded in a Geographic Information System (GIS) to determine the state of charge per phase and the current imbalance at a given point selected from the network. For this, real data of the low voltage electrical network of Balcarce city, Argentina, was digitized and configured in the AutoCAD Map software. Then, a simulation is executed, which allows obtaining the current per phase delivered by the transformer that supplies the low voltage network, for different moments of a period of time. Among the results obtained, the elaboration of an index that varies from 0 to 100% and takes into account a period of time considered, to reflect the degree of imbalance of the loads. Other parameters

related to unbalance are also calculated. Finally, the results of the calculations are clearly displayed in the GIS environment through the development of an information block.

Keywords: GIS, Distribution Network, Modelling, Load Balance.

B-5.5-4

Methodology for Prioritizing Investments in the Distribution Utilities with Electrical and Economic Focus

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The Brazilian electricity scenario is constantly growing. Therefore, the correct investment in new equipment and increasing the strength of the distribution line is of paramount importance for energy distribution companies remain competitive in the market and without regulatory reprimands. This work presents the methodology developed to prioritize investiments which improvements the distribution line is priority. All improvements were analyzed from an electrical and economic point of view and the AHP (Analytic Hierarchy Process) and DEA (Data Envelopment Analysis) methodology was used to apply the selection of priorities. These methodologies were chosen because they are widely used in portfolio optimization and because they have flexibility in their application. The contribution of this article is the development of computational tools that help the management of network improvements for distribution companies. An electrical reference system, IEEE 30 bars, was used, with economic data taken from a real distributor in Brazil to prioritize a set of works necessary for the operation of the system. The results obtained show that the method prioritizes investments in the distribution system using the electrical and economic data applied. In addition, it is possible to verify that the use of DEA to calculate the economic efficiency of the works results in a unique look at the problem.

Keywords: Optimization, DEA, AHP, energy distribution, investment.

B-5.5-6

Thermography Study In A Photovoltaic System: Case Study Of The Mirante Do Rio

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From the 19th century to the present day there are studies with photovoltaic models in the world, and there is modernization in the perspectives of installed photovoltaic systems, a with the technological increase, inspection models also accompany the process. The photovoltaic system analyzed in this work belongs to a university building called Mirante do Rio. The work aims to

evaluate the different forms of degradation present in the photovoltaic system, caused by weather and dirt. For this, 177 photovoltaic modules, a photovoltaic inverter and also a protection frame were analyzed, with the aid of a thermographic camera, thus seeking to identify problems involving the temperature variation of the components. Aspects of the study are based on quantitative and quanlitative analysis of the images obtained, in addition to working conceptually with thermography. The results show some anomalies along the photovoltaic system.

Keywords: Thermography, Photovoltaic Systems, Inspection Method, Solar Energy.

B-5.5-11

Performance Analysis With The Aid Of Thermography: A Case Study Of The Mirante Do Rio

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The thermographic technique is a good tool to determine possible corrections and improvements for photovoltaic systems, being more effective than the traditional method of maintenance and prevention. This study took place in the educational building Mirante do Rio which relies at Guamá campus of the Federal University of Pará as a reference in the Amazon region and it is focused on energy sustainable development. The study object was a photovoltaic power plant with 177 modules, a photovoltaic inverter and an alternate current protection board. The results show the comparison between measured and simulated data via software. In addition, the thermography records in the components of the photovoltaic system are presented.

Keywords: Comparative analysis, Photovoltaic systems, Solar Energy, Thermography.

B-5.5-13

Analysis Of Loss In A System Photovoltaic: Case Study Of Ceamazon

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The number of photovoltaic systems increases every year around the world and, consequently, there is an increase in methods and technologies of electrical systems maintenance that are applied in the areas of renewable energies, in order to guarantee a lower cost and greater operation effectiveness. This paper aims to carry out the thermographic study by applying

qualitative analysis of the installed photovoltaic components in scenarios with and without shading in photovoltaic modules in order to measure their impacts on the functioning of the photovoltaic system. Therefore, 3D modeling was used to represent the building and the photovoltaic plant present at the CEAMAZON, located on the UFPA. In this paper, the photovoltaic plant analyzed has three photovoltaic systems, each one with its operational particularities. In addition, the results demonstrate the causes of losses, expressing forms of correction in the medium and long term, in order to guarantee energy efficiency.

Keywords: Hybrid System, Loss Analysis, Photovoltaic Systems, Solar Energy, Thermography.

B-5.5-14

Power Transformers Health Index Assessment: An Asset Management Support Tool

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The power transformer is the main asset of a substation, as it plays an essential role in the transmission and distribution of electricity, being also the equipment with the highest individual cost. In Brazil, the model adopted to reward power distribution companies is based on the "bathtub curve", which predicts a constant failure rate during the normal operation stage or useful lif. Therefore, ANEEL – Brazilian Electricity Regulatory Agency, includes in the value of the energy tariff a portion referring to the annual depreciation of asset, which considers that a transformer will be fully refunded after 35 years of operation. The permanent failure of a transformer before the end of this period, besides losses and fines for interruption of the electric power supply, prevents the total remuneration of the damaged asset. In the academic literature and also in several international standardization associations, there are many studies and technical standards on reliability and evaluation of the integrity of power transformers. The objective of this paper is to present the method used by a Brazilian electricity distributor to calculate the "health index" of its power transformers. By analyzing the transformer failure modes, the three main components responsible for permanent failures are identified: (i) Active Part, formed by the windings, insulating paper and magnetic core; (ii) Condensive Bushings, and; (iii) On-Load Tap Changer (OLTC). For each component, a specific health sub-index is created. The sub-index of the "Active Part" has as variables the transformer design (whether it has regular or thermostabilized Kraft insulating paper), loading level, operating time and the results of analyses carried out on the insulating mineral oil contained in the main tank (dissolved gas analysis – DGA and physical-chemical analysis). The "Condensive Bushing" health sub-index has as variables the type of bushing used in the transformer, time in operation and electrical tests carried out preventively by the maintenance team, such as dielectric loss factor and capacitance. The health sub-index of the "On-Load Tap-Changer" has as variables the OLTC model, time in operation, number of monthly tap changes, means of extinguishing the electric arc generated during switching, loading level and the results of analyses carried out on the insulating mineral oil contained in the OLTC tank (DGA and physical-chemical analysis).

This paper presents in detail the steps of the methodology for calculating the “health index” used in the management of the company’s assets, and the analysis of the results obtained with power transformers installed in the distribution substations existing in its concession area.

Keywords: Asset management, electric power distribution, health index, power transformer.

B-5.5-15

Criticality Methodology for Power Transformer Maintenance Prioritization Through Multicriteria Methods

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Transformers play an important role and are assets with high added value, often higher than other equipment in distribution and transmission substations. However, even if this equipment presents a high degree of reliability, the natural process of degradation of the insulation system causes its lifetime to be limited, presenting failures intrinsic to its operation. Given this scenario, the objective of this work was to develop a power transformer criticality tool to prioritize maintenance or obsolescence, as well as investment in new assets, considering the comparison of empirical methods. To achieve the goal, data from predictive and preventive maintenance tests, such as gas chromatography and physical-chemical, as well as operational and nominal data from the equipment of a distribution utility were considered. To classify and determine the most critical assets, a multi-criteria hierarchical process analysis method was used, in addition to a principal component analysis (PCA) method, considering the specific characteristics of the company's transformer park. In addition, it was possible to implement the management of maintenance prioritization or investment allocation in new equipment, through the implementation of dashboards developed in a Business Intelligence tool, which help in monitoring and displaying key indicators for prioritization. The results presented demonstrate that the use of these multi-criteria methods, for the classification of the most critical assets, allows cooperation between different sectors of the concessionaire, since, in this case, it is necessary to establish criteria/indicators to determine the parameters of greatest impact, as well as to weight their respective values in decision making involving the transformer asset.

Keywords: Criticality, Power Transformers, Distribution and Maintenance, Multicriteria Methods.

B-5.5-16

Regulation of the Electric System through Capacitor Banks and Reactor Banks

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In recent years, the electric energy sector in Brazil has been experiencing an accelerated growth and as a consequence, difficulties have arisen in voltage control and variation of reactive power flow in transmission lines. These variations cause problems in the system operation when there is an increase in the loads on the transmission lines. These variations in the transmission networks can cause an increase in the level of harmonic currents, distortions and electrical energy losses along the path of their conductors and transformers. Wind farms have the capacity to absorb or supply reactive power, due to the characteristics of their wind turbines, which have capacitor banks inside the nacelle that allow reactive compensation. There are also some wind farms that have capacitor banks and reactor banks connected in parallel to the substation connection bars, to supply and absorb reactive power, respectively, to regulate the system when necessary.

Keywords: Capacitor banks, Reactor banks, Electric system regulation.

B-5.6-3

Coordinating distribution power system protection in a utility from Uberlândia – MG using a geographic database, QGIS and OpenDSS

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A distribution power system is designed to ensure the continuity, reliability, and supply flexibility. For this, having reliable protection is crucial. One of the most used and important equipment is the reclosers. This element must comply with the regulations and should be coordinated with each other, restoring fastly the electrical circuit which suffers an electrical fault. For this work, a real network has been analyzed: the ULAE714 feeder belongs to the Substation Uberlândia n. 7 in the city of Uberlândia, Minas Gerais, second city of the state in terms of population number. The public information was extracted from a geographic database of a local power energy concessionaire after requesting the Brazilian Electricity Regulatory Agency (ANEEL). In sequence, several attributes were used to apply the filtering using the QGIS open-source software and to choose the desired region, collecting data, such as, cable geometry, impedance and maximum current. The well-known OpenDSS program has been used to simulate the short-circuits in several electrical system nodes. The coordination of reclosers installed on the network also has been performed, calculating correctly all parameters (phase and ground). Detailed field inspections (more than 10 km), together with real and clear photographs of the installed devices have been taken to confront the database used in the computational simulation. With all the steps, the studies involving automatic protection and powerful technological software, which are very useful to several Brazilian companies, were carried out in this scientific paper. The satisfactory results are shown using several time-current curves involving several protective devices installed in the electrical system.

Keywords: Reclosers, Coordination, Protection, OpenDSS, BDGD, QGIS.

B-5.6-4

R&D ANEEL Project Management - The challenges of the hybrid methodology in building a backoffice management platform for energy contracts

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This article aims to describe details about the management of the Aneel P&D project code 08601-0320/2020, registered as "Software for operating blockchain energy contracts and automated backoffice management" and publicly as ´´Energy Intelligence Project applied to Backoffice It is carried out jointly by the companies Fohat Corporation and Eneva Comercializadora de Energia. Given the context regarding the scope detail presented in the project, it was decided to adopt hybrid methodologies for project management. The development of the platform sought to meet at least three areas of the company, which added complexity in detailing requirements and project management, demanding from the technical team of Fohat Corporation and Eneva Comercializadora de Energia, skills from the refinement phase and understanding of needs, until the delivery prioritization and validation stage. The management, using agile and traditional project methodologies, collaborated with the aspect of consistency and focus on the project's objective, while enabling the validation of deliverables with the project's stakeholders. The challenges with the pandemic were also taken into account and detailed in order to understand its impacts, opportunities and lessons learned.

Keywords: Gerenciamento de Projetos. Métodos Ágeis. Métodos Tradicionais. Métodos Híbridos. Desenvolvimento de Software.

B-5.7-3

Improvements for the Operation of Low Voltage Power Distribution Networks

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This study is focused on the analysis of improvement alternatives for the operation of low-voltage electrical distribution networks, with the aim of improving service continuity. Among the reviewed alternatives are those of automation incorporated for this type of networks, evaluating the improvement in the indicators of continuity of supply. The results show that it is possible to improve its operation by incorporating technology to the networks, however the cost evaluation does not always make it a profitable investment, if the possible associated fines are not valued.

Keywords: Power distribution, Low Voltage Distribution Netwoks, Reliability index, SAIDI, Automatic equipment.

B-5.7-6a

Connection Study of a Hybrid Back-to-Back Filter Applied to a Hot Strip Mill with Cycloconverters

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For years the industries employ non-linear electrical loads, from several nominal powers in their various production processes. However, when using these types of loads the Power Quality (PQ) of the electrical system is compromised due to the harmonic currents, which if not compensated can cause problems such as the increase of the system reactive demand, voltage fluctuations, that is, the PQ is compromised and with this there are high losses in the system, undue heating in rotating machines, interference that leads to malfunctioning of the control loops. Among the several types of industries that use non-linear loads, steel mills employ Hot Strip Mills (HSM) that stand out due to the presence of cycloconverters with high power ratings, which are used to drive synchronous motors. These power converters are switched and drain a distorted current from the grid, generating PQ problems. In most systems with HSM there is only one passive filter for harmonic filtering. However, there are other structures that can be used to soften the effects caused by harmonics in the electrical grid. These filters can be classified into three subgroups: passive filters, active filters, and hybrid filters. Passive filters are most often used as a combination of low-pass and high-pass filters, usually connected in parallel with the load, and providing a low-impedance path for the harmonic currents of the nonlinear loads. However, passive filters have limitations such as fixed compensation and resonance with the power grid, which can be eliminated by using active filters. Active filters are designed to compensate the disadvantages of passive filters by offering higher performance in compensating harmonic distortions. However, these are more expensive in high power applications. Currently, the hybrid filters are considered the best option to provide an improvement in the PQ, because they can obtain the best cost-benefit relation in the project and guarantee the best system efficiency with non-linear loads, because with the junction of the two filters the disadvantages of the isolated application of each one of them are minimized and the advantages stand out. In the series hybrid filter the active filter is connected in series with the passive filter, however, a major disadvantage of this system is the low performance for harmonic compensation at high frequencies. In the parallel hybrid filter, the passive filter maintains a low impedance path for harmonic currents and the active filter injects current in phase opposite to the load harmonic current, but with a converter of higher power rating. Knowing this information, the project aims to apply a back-to-back hybrid filter in a steel mill with HSM located in Grande Vitória, so that the beneficial characteristics of the hybrid filters previously mentioned are enhanced and that there is a reduction of harmonic components in the electrical system of this industry. It is important to emphasize that until the moment of the elaboration of this project the topology studied in this article was not found in any bibliographic research.

Keywords: Electric Power Quality, Hot Strip Mill, Harmonics, Hybrid Filters.

B-5.7-6b

Residents of Jardim Mônaco in Assis Chateaubriand - PR understanding energy efficiency in the conscious use of light bulbs in their residences

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The integration of information involving energy efficiency makes it possible to reduce energy consumption and impacts on the domestic economy. This work proposes awareness actions to the residents of Jardim Mônaco, located in Assis Chateaubriand - PR, regarding the correct use of light bulb technologies, promoting the dissemination of knowledge related to energy efficiency through virtual media and interviews. A total of 303 households were approached, of which 179 responded to the questionnaire. The results regarding the use of efficient lamps are satisfactory. Regarding the concept of energy efficiency, the interviewees showed a lack of information, resulting in difficulties in implementing actions to save electricity in homes through the application of daily practices. However, it is observed that the interviewees showed interest in how to use light bulbs correctly and in energy efficiency.

Keywords: Awareness, Electricity, Energy saving, LED lamp, Residential sector, Sustainability.

B-5.7-1

Proposal for the Creation of a Wind Farm for a Soccer Stadium

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This study aims to analyze the application of the Smart Energy concept in soccer stadiums and to propose the creation of a wind farm. This research is characterized as exploratory in its objective and qualitative-quantitative approach. The corpus of the research consisted of interviews, documents and data collection. It was found an average consumption of 132,909 kWh/year and R$ 175,033.65/year spent on energy. As a proposal for energy generation from renewable sources, the creation of a wind farm with two models of wind turbines was simulated and the generation of 12,330 kWh/month and 13,090 kWh/month was verified, enough to supply its average consumption. The return on investment was estimated to be between six and nine years. It is concluded that the Smart Energy concept is little known in soccer stadiums and its use is necessary to ensure comfort for fans, development of sustainability and economy.

Keywords: Energy saving, smart cities, smart energy, smart stadium, soccer stadiums.

B-5.7-7

Impacts Of Growth In The Use Of Solar Generation On Distributed Generation

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This work aims to evaluate the infrastructure of Brazilian cities as an inhibiting factor for a distributed generation model and the impacts on the distribution and transmission network. The methodology used in this work was qualitative in nature, with a literature review procedure and document analysis, with the purpose of reflecting on some articles, in which the technical parameters were removed, to enable a deeper consolidation of the proposed solutions. This way, with the use of some papers it was possible to demonstrate these problems more effectively based on the compilations of the norms adopted for the sector. We also have positive factors that can help Brazil to stand out in the race for the use of low carbon sources. From the results obtained in the analysis of the impacts of the amount of distributed generation in the utility networks, some points can be raised such as power quality, harmonic distortions and changes in power flow. In general terms the adoption of smart meters would be the best strategy to be the starting point in the load management of all circuits in order to distribute the load in a more uniform way during the day. We will not go into the merits of the solution itself because we would enter into a regulatory and consumer privacydebate, but when the solution would be effective. The change in the parameters of components such as OLTC On-load Tap Charger voltage regulators and capacitor banks could be a way to help regulate voltage in the circuits, as well as a reformulation in the future of distributed generation. In any case, the work is not exhausted in this report. It is only a diagnosis of the current national scenario with respect to distributed generation. It is necessary to continue the actions of all sectors so that the technical viability is acceptable and that DG becomes a reality for all Brazilians

Keywords: Solar Energy, Impacts on Distributed Generation, Barriers.

B-5.7-10

Characterization of Uses and Efficiency in Final Processes of Energy Conversion in the Brazilian Residential Sector

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This article estimated the annual electricity consumption of the three appliances that consume the most energy in the Brazilian residential sector: refrigerators, showers and televisions. For this, the database of the Survey of Possession and Habits of Use of Electrical Equipment in the Residential Class (PPH) was used, and the bottom-up methodology was adopted. Thus, consumption was estimated through equations, and based on the values obtained, the sample was designed to obtain values at the national level. The results show that the bottom-up method

was quite satisfactory, since all estimated consumptions were practically equal to the consumption percentages of each appliance - present in the PPH -, multiplied by the total annual consumption of the residential sector, informed in the Statistical Yearbook of Electric Energy. In addition, the replacement of CRT (tube) and Plasma televisions for LCD/LED televisions would reduce the consumption of such devices considerably.

Keywords: Electricity consumption, Energy efficiency, Bottom-up method, Energy modeling, Residential sector, End use of electricity.

B-5.7-11

Energy-financial and environmental analysis of energy efficiency strategies in the lighting system of a public building

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Considering the occurrence of environmental impacts on a global scale, increasing demand for energy and their costs are factors that generate debates about subjects related to sustainability. With this perspective, energy efficiency presents itself as a manner of reducing the consumption of energy and mitigating environmental problems without damaging the quality and comfort of human activities. The present paper consists of an analysis of actions relative to energy efficiency on an educational building in the state of Pará, in the Amazon region. To the objective of retrofitting the building towards efficiency through the energy perspective. The research conducted in this paper proposes an evaluation based on five retrofit scenarios, involve the substitution of illumination systems present and better use of natural lighting, which are gathered and analyzed through the perspective of The Technical Regulations for Energy Efficiency Labelling of Commercial Buildings (RTQ-C), which will be valid until the year of 2028. The methodology was developed using the lighting simulations accomplished through the Revit Architecture software, and RETscreen software, getting results about financial, environmental impact, and energy efficiency. As such, all five scenarios were, then, subjected to comparative analysis to determine the strengths and weaknesses of each answer, generating graphs of CO2 emissions, payback time, and decrease in consumption. Based on the analysis conducted, the results were satisfying, considering the environmental point of view, due to the decrease in CO2 emissions and energy consumption mitigation in all cases. The financial aspect was also positive, as noted by costs saved in all scenarios.

Keywords: Energy Efficiency, Retrofit, Natural Lighting Utilization, RTQ-C, RETScreen.

B-5.7-13

Chance-Constrained Mixed-Integer Programming Model for the Routing of Electric Vehicles with Uncertainties in Travel

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Electric vehicles have been widely adopted in society due to their environmental and operational benefits. However, these vehicles are associated to uncertainties of autonomy and time, compelling the development of robust approaches for the definition of the optimal route that include economic costs considering uncertain factors. Thus, a chance-constrained mixed-integer programming model is formulated to define the optimal route from the point of view of operational costs, while battery constraints are fulfilled. Due to uncertainties in travel time, time limits associated with clients are satisfied within a given robustness level through chance-constraints, assuming a normal distribution. The proposed model was implemented in the mathematical language AMPL and solved using the solver CPLEX. Tests in two instances were carried out to study the impact of uncertainties in the routes; different confidence levels were adopted to assist the decision-maker in selecting a convenient trade-off between economics and reliability.

Keywords: Chance constraints, electric vehicles, mixed-integer programming, routing problem, uncertainties.

B-5.7-14

Preliminary estimate of the potential energy demand of electric mobility in the city of Mar del Plata, Argentina.

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Given the exponential growth that the electric vehicle is having in the world's large cities, and its promotion by the states, given its high efficiency, low emissions and low cost per kilometer traveled, it is necessary to carry out evaluations of the current electrical networks in in terms of its ability to face a high penetration of this type of vehicle in the automotive fleet in the coming years. In this article, a preliminary estimate is made of the energy that the gradual incorporation of electric vehicles likely to be acquired in Argentina would be demanded from the existing electrical network, so that in future works this information can be used in the planning of empowerment works or network expansion. It is based on an analysis of the electrical consumption of a typical vehicle, and an estimate of the conditions of use in the city of Mar del Plata. Then it continues with a preliminary analysis of the projection of this new demand based on the particular characteristics of the city to end with a quantification of the energy needs that the existing network should meet.

Keywords: urban electric mobility, electric vehicle, smart grids, energy capacity, energy sustainability, Mar del Plata.

B-5.7-16

Influence of Distributed Energy Resources on Grid Voltage Quality using Model IEEE 13 busbars

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Distributed generation is already a technology used by a portion of consumer units in the country, that number promises to increase after the enactment of legislation pertinent to the subject. Therefore, is essential to observe the impact of the power flow changes in the characteristic of the others electrical measurements. The study seeks to put more attention on the effects related to voltage quality in the distribution network. Computational tools were used to simulate the insertion of generators at different points in the network, openDSS was the selected program for running the simulations, one of the benefits of it is the open source code, and the standard network model of thirteen bars of the IEEE was chosen to carry out the tests. The sources were modeled according to the load power associated with it and some scenarios were developed to analyze the voltage profile obtained in each of the proposed situations. In the first scenario sources were connected only at the ends of the network, in the second only at points that had not been covered yet, in a third all loads received associated generators. Finally, in the fourth scenario, spawn points were allocated at random places within a quarter of the third scenario. For comparison purposes, the standard system was also simulated at the same voltage parameters measure. The simulations performed showed significant improvements in voltage levels, mainly at the ends where the values tend to decrease, but each situation presented a different profile and some topologies proved to be more beneficial for the model. Thereby, with the expansion of distributed generation, there will be a need to evaluate the position of generation in the grid, in addition to the technical requirements already foreseen.

Keywords: renewable sources, IEEE 13 busbar, distributed generation, power quality, openDSS.

B-5.7-18

Experience In The Use Of Network Topology As A Basis For Electrical Calculations In Distribution Networks

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The experience in the use of network topology analysis tools available in geographic information systems (GIS), for the simulation of operations and determination of supplied areas in distribution

networks, is presented. This has allowed this research group to develop a software for the control of Quality of Service called SigreGIS and implement it in distributors in the Province of Buenos Aires. In this work we want to highlight the enormous potential that arises from taking advantage of the information available in the GIS to carry out electrical calculations of interest to the administrators of the distributors, such as the determination of quality-of-service indicators and the determination of the point of failure from records of voltage-current in feeders.

Keywords: Geographic Information System. Topographic Analysis. Power Quality, Fault Location.

B-5.7-20

Energy Losses Minimization Through Optimal Battery Operation in a Distribution Network with Photovoltaic Energy Penetration

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The penetration of renewable energy sources into electrical systems can significantly change the operation, particularly of distribution grids. As photovoltaic energy generation is increasingly abundant in networks, the need for solutions to maintain energy quality arises. The use of grid-scale battery energy storage systems (BESSs) is growing exponentially due to decreasing costs and flexibility to provide various services. BESSs can absorb and deliver active and reactive power with response times of less than one second and mitigate the intermittence of solar radiation in photovoltaic generation. In this work, a multi-period optimal power flow (OPF) is proposed for distribution networks with photovoltaic generation and BESSs. The main contribution of this work is to consider the operational limitations of the network, power flow restrictions and the operational limits of the BESSs. The proposed methodology was tested and validated in the IEEE 33-bus system. The solutions found present a proposal in the loading and unloading cycle for the daily operations of the BESSs. As a main result, we highlight the reduction in system losses and improvement in the voltage profile, especially in the case of allocation of distributed BESSs.

Keywords: Battery storage systems, Distribution systems, Optimal power flow, Photovoltaic systems, Power losses.

B-5.7-21

Analysis of The Regulatory Methodology to Define the Electrical Power Supply Continuity Indexes in Distribution System in Brazil

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In power sector regulation context, keeping the electrical power supply continuity indexes in adequate levels is crucial to guarantee the energy supply improvement to consumers as well the electric tariff affordability. In this article, the Brazilian regulation about collective power supply

continuity indicators elaborate by electricity regulator will be presented, from its implementation to the present day. Next, it will be analyzed how each regulatory change influenced in Brazilian electric power industry performance and evolution, especially in Pará State, which has differentiated collective power supply continuity indicators in comparison with the others states, due to electric utility area peculiarities, such as: access difficulties, long distances, low population density, high rainfall and high amount of lightning drop, factors that affect directly the occurrences quantities and the power outages service time.

Keywords: Electricity Distribution, Technical Regulation, Power Outage, Power Supply Continuity.

B-5.7-24

Probabilistic Optimization for Grid Reconfiguration in the presence of High PV Generation

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The widely adoption of photovoltaic (PV) generation encouraged by clean energy policies brought a numerous benefit in terms of economic and operational grid support. However, the rapid uptake of this low carbon technology increased the variability and uncertainties within the inherent stochastic nature of the distribution network. In this regard, traditional deterministic tools may lead to unrealistic outcomes of the true representation for system operation and planning analysis. Thus, the need of probabilistic tools and the optimal use of renewable sources becomes essential in a variable and uncertain grid operation ensuring a safe and efficient grid operation. An important feature of grid optimization is enabling grid reconfiguration that provides voltage improvement, relief lines congestion and loss reduction. In this regard, this paper proposes a probabilistic algorithm to integrate a more realistic analysis of the optimal grid configuration considering voltage statistical information evaluated and issued by a probabilistic power flow analysis. The proposed method is based on the Monte Carlo simulation to cater for the uncertainties, for the probabilistic power flow, a voltage confidence interval to meet minimum allowable voltage, and an analysis of the impact of the PV generation as well as their optimal reconfiguration analysis in terms of expected and standard deviation of loss reduction. Tests carried out with the IEEE 33-bus system with PV generation yields an analysis and the efficiency of the proposed method for the optimal grid reconfiguration based on voltage confidence level restriction while harnessing the maximum PV generation to obtain the optimal probability density function for voltages and energy loss reduction.

Keywords: PV generation, voltage probabilistic restriction, probabilistic power flow, optimal grid reconfiguration.

B-5.7-27

Estimation of Non-Technical Losses by Region via Geographically Weighted Regression

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Non-technical losses are present in all electric power distribution systems. They cause substantial financial losses to electric power utilities and consumers who share the same distribution network. Most of the previous studies on non-technical losses applied soft computing techniques to detect irregular consumer units. However, the detection of the most vulnerable subareas to non-technical losses a priori could increase the success rate of the techniques for detecting irregular consumer units. In this context, this study aims to estimate the most vulnerable subareas to non-technical losses via geographically weighted regression. Crucial to spatial regression success is the applied neighborhood structure. In this sense, this study shows a qualitative and quantitative comparison between two neighborhood structures between subareas: the neighborhood based on Euclidean distance and the neighborhood based on similarity of attributes. The main result of this study are thematic maps with the most vulnerable subareas to non-technical losses.

Keywords: Commercial Losses, Electric Power Distribution, Electricity Theft, Geographically Weighted Regression, Non-Technical Losses, Spatial Data Analysis.

B-5.7-28a

Theoretical analysis of the implementation of residential photovoltaic systems in order to mitigate losses in transmission systems

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Brazil has one of the largest electricity transmission systems in the world with more than 140 thousand km in length, a system that, in the last 5 years, has recorded losses of over 15%, which are equivalent to the generation of the second largest hydroelectric power plant in the world, Itaipu. Aiming to mitigate the problem of transmission losses, this paper analyzes the current situation of generation and transmission systems in Brazil, identifying the main regions where there is the production and consumption of electricity in the country, so that it is possible to point out the main points where is able to act to enable improvement of the existing system. Once the regions were identified, estimates were made of residential distributed photovoltaic solar power generation and its impact on reducing losses.

Keywords: Energy Efficiency, Energy Planning, Solar Energy, Brazil, Economy.

B-5.7-28b

Electric Vehicle Charging Infrastructure (EVCI) Road Map Development with Energy Management

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Conventional internal combustion engine vehicles contribute to greenhouse gas emissions and electric vehicles (EV) comes with the promise to eliminate greenhouse gases at the point of use however greenhouse gas emissions during the generation of electricity may offset the benefits unless the entire energy generation to consumption cycle is taken into consideration. Today we need to consider profits and the environmental impact at every stage of EV infrastructure development and operations. For sustainable solutions, the energy management approach is the best path to follow. The paper presents why we need to plan for the upcoming EV boom, how much electrical energy we need to achieve a goal, useful trends for policy making, useful consumer behaviors for policy making, and tips for planning based on case studies from around the world.

Keywords: electric vehicle charging, battery powered vehicles, energy management, energy efficiency, sustainability.

B-5.8-2

Technical and Budgetary Study of Electric Energy Transmission in the parameters of ANEEL auctions

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This work seeks to outline minimum procedures for the budget calculation of electric energy transmission projects according to the technical parameters of the National Electric Energy Agency (ANEEL) auctions, presenting the most relevant aspects for the composition of pricing and an analysis of financial returns. Until 1999, when the structure of concession models through auctions began, the sector faced difficulties related to government funding and had to be remodeled. Since then, the government's role began to be just regulatory, and the opportunity to invest in a project with guaranteed revenue from the beginning of the venture's operation until the end of the current 30-year concession period was given to the private sector. The auction system works in such a way that the participants must present the value of the annual revenue, which must comprise the total amount of costs to carry out the project, the costs of operation and maintenance during the whole period and profit expectations. Therefore, the winner is the one with the lowest annual revenue for the project in its operational phase, which highlights the importance of a complete budget study, which portrays all the technical items necessary for the implementation of the enterprise, with the risks involved and, even so, be competitive. The expectation of this work is to establish a plan of activities to be carried out by the transmission

companies, from the technical to the financial point of view of the projects, focusing on establishing an orderly guide of actions. Therefore, the consolidation of this material will help transmission agents in the detailed elaboration of projects, especially with regard to regulatory aspects, as well as serving as a didactic guide for those who enter this area.

Keywords: electric energy transmission, budgets, ANEEL transmission auction, CAPEX/OPEX, infrastructure investments.

B-5.8-5

Formulation and Analysis of a Novel Scalable Supply Cost Function to Demand Management

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The bilevel optimization is a new approach to demand-side management that involves a supplier-user interaction. In this optimization procedure, there is a hierarchical relationship between users and a supplier, where their objective functions usually present some antagonism. The supplier maximizes its profit, while the users' objective is to reduce their electricity bill cost. In the upper level, the supplier needs to know its supply cost and its revenue to determine its profit and propose a reasonable pricing scheme. Its revenue is the sum of the users' electricity bill payments. Whereas in the literature, the supply cost was obtained using a quadratic function or the spot market price, without a proper study of its real application and scalability. In this article, a novel scalable quadratic supply cost is proposed and compared with the existing supply cost using the break-even cost, which is the cost that makes the profit zero. Then, a non-optimized situation and the bilevel optimization, for 10, 20, and 30 users, are performed to compare the supply cost functions. The results demonstrate that the existing supply cost cannot be scaled and applied in a real bilevel optimization model and that if the spot market price is the supply cost, the users' response does not directly affect the price. Finally, the novel supply cost formula shows its flexibility and its advantage of being easily scalable when the number of users and the demand increase.

Keywords: Cost of power supply, Demand Side Management, Electricity Pricing, Day-Ahead Pricing, Microgrid, Bilevel Optimization.

B-5.8-6

Bibliometric Study on Tariff Framework in Photovoltaic Systems

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The growing demand for electricity associated with sustainable development encourages the need for studies on the application of renewable sources and analysis of their technical-economic impacts. It is known that the intermittence of these systems has encouraged the development of hybrid systems with management. The industrial class corresponds to only 8% of the total in photovoltaic renewable energy in Brazil, however it has the highest demand for electric energy 36.3%, this class needs large investments for the implementation of photovoltaic systems and interconnection with other generating systems to supply the demand. full-time. This article presents a bibliometric study on the insertion of photovoltaic systems for industries related to the tariff framework in the last ten years, with qualitative and quantitative analyses, highlighting prominent authors and works, institutions and countries with greater influence. The evolution of the theme over time was established and current areas of interest for future research were identified.

Keywords: Sustainable Energy, Renewable Sources, Industry, Photovoltaic System, Tariff.

B-5.8-7

Analysis of electric power distribution aiming a tariff based on the geographic zone

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The current Brazilian electricity pricing system is a large and complex system, which divides the users within subgroups according to their voltage level and distribution grid resources. It also has different tariff rates according to the hourly and seasonal characteristics of the load and consumer choice. The tariff is constructed considering the costs of power generation, transmission, distribution, sector charges, losses and taxes, what results in different tariffs for each different distribution companies. The proposed zonal model is an enhancement of the current one, which is based on isonomy, enabling a tariff differentiation according to regional specifications, searching more equity between the users. In this way, it aims to decrease the asymmetries between consumers by dividing them in geographic zones with homogeneous characteristics within the distributor's heterogeneous area. Several criteria can be adopted to classify the company's areas, according to the intended benefit, such as the type of network, energy quality, system losses, user income, population density, among others. The work starts with the state-of-the-art tariff models, describing the current tariff model and the proposed one, establishing a comparison between them. To this end, a case study was carried out with several customer units, simulating the application of the zonal pricing tariff. The criterion adopted for dividing the distributor's total area for the application of differentiated tariffs were the DIC/FIC energy quality indicators – individual continuity indicators per municipality, obtaining four distinct areas. In this way, it is possible to observe the disparities between consumers according to their location and quality indicator. The simulations show the model's adherence, since the total average of the concessionaire's area is close to the calculated values.

Keywords: Distribution, Tariff equity, Tariff modalities.

B-5.8-8

Transmission System Tariff calculation in Brazil via optimization considering the wind generation intermittence

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The methodology currently used in Brazil to calculate the transmission system tariff is the nodal methodology, applied through the Nodal Program, adopted by the National Electricity Agency (ANEEL). This methodology considers only a single operating scenario, through the proportional dispatch. Also, it is indifferent as to the plant type, thus disregarding the intermittence of renewable sources, such as wind and solar, which makes the tariffs for these generators to be unfair. The objective of the present work is to propose a methodology for the calculation of transmission tariff, which takes into account a variety of scenarios and the intermittence of wind generation, to reach the operational reality of the system and obtain fairer tariffs for the network users. This methodology consists of an optimization model, with the objective function aiming to minimize the transmission cost. The locational component of the tariff is obtained by the Lagrange multipliers. To verify the effectiveness of the proposed approach, the IEEE-RTS system is used, and the results obtained are compared with the results provided by the Nodal Program. The results demonstrate that the proposed methodology is close to the operational reality of the system, reflecting the real use of the network for various scenarios and providing an adequate locational signal. The tariff values obtained for wind turbines through the proposed methodology are lower than those obtained by the Nodal Program. This is because the proposed methodology considers the intermittence of this source, evaluating different wind speed scenarios, while the Nodal Program only considers the maximum generation capacity. The proposed methodology showed good results and proved to be promising, in addition to presenting an intensification of the locational signal.

Keywords: Wind Energy, Trasmission tariff, Transmission price, Optimization, Nodal methodology.

B-5.9-2

Assessment of Prosumer Business Models in the Brazilian Electrical System

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After the Paris agreement at COP 21, most countries have greenhouse gas reduction targets. The European Union, for example, should reduce the greenhouse gas emissions by at least 55%

compared to 1990. In order to achieve these objectives, the consumer should play an active role, either through demand response programs (DR), or through the installation of distributed generation systems (GD). In this context, the prosumer, an agent that consumes and produces energy, is a key player in the pathway through a sustainable electrical systems development, allowing greater use of renewable energy resources, increasing efficiency and reducing the need for system expansion. To achieve all these benefits, the prosumer needs to beat the center of the energy market, through demand response programs, within a market structure that allow them to actively participate in the electricity market, buying and selling energy and expressing their interests, as is the case of peer-to-peer (P2P) market structures. This article aims to present the current business models applied in Brazil, and to analyze levers of improvements to reach international prosumer's activity models. The results indicate that the Brazilian business models used by prosumers are still traditional models, such as self-consumption and net metering. More innovative forms of business such as RD and P2P platforms are still little used, or in an embryonic way in academia. In addition, numerous opportunities for developing conditions for more innovative models have been identified, requiring an evolution in regulation and market structures.

Keywords: Prossumers, Demand Response; Tariffs of Electricity; Distributed Generation, Peer-to-Peer Trading, Business Models.

TOPIC 6 - Computational Systems and Signals Processing

B-6.1-6

Resistor applications for reducing numerical errors in transient simulations on HVDC transmission lines

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It has been investigated the application of damping resistors to minimize numerical oscillations in transient simulations at two-phase transmission electrical systems. In this study, a HVDC line has been used as an example for the application of the proposed model. It has been used phase-mode transformations to represent a two-phase system as two independent mode lines. These independent transmission lines can be represented by cascade of circuits with concentrated elements and this representation has been solved using the trapezoidal rule. This representation, as showing in other cases, has led to simulation results with undesirable numerical oscillations in transient simulations. Searching for reducing these numeric problems and reducing the computational time in transient simulations, damping resistors and sparse matrix techniques are applied. In case of this paper, two different types of damping resistors are applied. One of these damping resistors is inserted in parallel to the elements that represent longitudinal line parameters. The other damping resistor type is inserted in series to the elements that represent the transversal line parameters. These damping resistances can be determined as a function of the inductive reactance of the line longitudinal of the circuits or capacitive reactance of the transversal branch of the π circuits. Considering time step, the number of π circuits and proportional factors for calculating of damping resistor, time-independent three-dimensional graphics were applied for obtain the most accurate configurations of these parameters that had led to simulations with desired accuracy. Additionally, there is a reduction in computational time due to the application of sparse matrix techniques.

Keywords: Electromagnetic transient, linear system, numerical simulation, time-domain analysis, transmission line.

B-6.1-7

Reducing the Ground Potential Rise Using Square Plates in Grounding System of Wind Turbines

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This paper proposes a grounding system (GS) composed of square plates added to a vertical rod to reduce the transient ground potential rise (TGPR). Three plates of 0.25, 0.5, and 1.0 m and rods varying from 10 m to 100 m were considered. The harmonic impedance (HI) is computed by

the full-wave electromagnetic software FEKO for a frequency range from 100 Hz up to 10 MHz. The HI is compared with those obtained with the simple rod. The TGPR is computed for an impulsive current with four wavefront times. Then, the proposed GS, composed of a ring with 20 rods with the plates, is employed in a wind turbine and the TGPR is assessed. The current is injected at the tip of the blade and TGPR at the tower base is computed. Results indicated that a significant reduction in the peak values of TGPR was obtained for this proposed GS.

Keywords: electromagnetic transient, frequency-dependent soil parameters, grounding electrodes, lightning

B-6.1-10

Machine Learning Python Supervision System for Quality Control

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With the advance of Industry 4.0 in the most varied industrial sectors, the use of Machine Learning techniques emerges as one of the main tools. As processes become faster and more assertive, the requirements for data acquisition for monitoring, classification and product improvement increase.

Automatic and faster decisions have become desired in many stages of the industry. Among the various types of industrial production are the rolling processes. Currently, a rolling mill has many sensors for acquiring data related to the product and it is especially important that these are accurately captured and critically analyzed, as any variation in the manufacturing process can lead to serious defects in the final product. This paper proposes the implementation of a Machine learning Pyton Supervisory System that is capable of helping the specialist to make the appropriate decision, integrating the data from the rolling processes to an automatic classification of the material.

Keywords: Machine Learning, Python, Supervisory System.

B-6.2-2

Medium voltage distribution network elements classifier system using Deep Learning

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In this work, an efficient way to detect and store the geographical location of electrical distribution network equipment in feeder routes using RGB images obtained from a mobile device is proposed, which allow subsequent processing of the images and detection of possible problems maintenance of the electrical network. The objective of this work is to automate the processes of review, verification and detection of elements that require maintenance by distribution

companies using Artificial Intelligence (AI). SSD-MobileNet is used to detect different electrical elements typically used in distribution networks. For the training of this neural network, a database of 1926 images were created corresponding to the classes: electric pole, transformer, public lighting, traffic light and tree. The obtained model was exported using TensorFlow Lite and Android Studio, to generate an application (APK) that can be installed on the mobile device with GPS information. The model was tested in the field, obtaining 284 unseen images and real-time detection tests were also performed, achieving an accuracy of 91% for the 5 classes.

Keywords: Deep Learning, Medium Voltage Distribution, Object Detection.

B-6.2-4

Artificial Neural Networks for Voltage Sag Detection and Classification in Distribution Systems

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Considering the results of the studies performed by companies of the electrical sector, an increase in consumer demand as well as a higher level of distribution generation are expected. Therefore, by increasing the level of renewable resources, different types of connected loads, and nonlinear devices the distribution systems will be more complex. In this context, voltage sags become a critical issue as they affect many consumers numerous times a year, impacting industrial, commercial and residential activities. Considering this scenario, currently different artificial intelligence techniques have been proposed to address the voltage sag characterization issue. Many of these proposals use voltage waveforms to characterize voltage sags in distribution systems, by processing the signals stored in digital relays. This work analyzes the use of different types of artificial neural networks for voltage sags characterization in distribution systems, considering the following possible situations: transformer energizing, motor starting, and faults. The proposed method can precisely characterize the voltage sag, regardless of the operational condition of the distribution system, thus providing an important support for operators during the decision-making process.

Keywords: Artificial Neural Networks, Power distribution networks, Voltage sags, Extreme learning machines, Matlab, Power system analysis computing, Power quality.

B-6.2-5

A Hybrid Method for Short Term Load Forecasting Using Soft Computing Techniques

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Short-term load forecasting is very important for the well-functioning of the electric power system, being used specially to assist the balance between energy generation and demand. For

this reason, several methods were developed and applied to perform this forecast. Among these methods, artificial neural networks stand out, being able to provide results with good accuracy using different types of inputs sets. However, the performance of the artificial neural networks is strictly related with its architecture, i.e., with the selection of its parameters as the number of hidden layers, the number of neurons in each layer and the learning rate. This selection is normally made by the network's designer in an empirical manner, which results in a high-cost process that is dependent of the designer's experience since a poorly configured network can result in phenomena known as underfitting and overfitting. To overcome this issue, in this paper an optimized forecasting model is proposed. In this model, the particle swarm optimization algorithm is implemented towards determining the best architecture for the artificial neural networks so that they present low complexity and great generalization capacity. Therefore, the architecture definition becomes an automated and optimized process, instead of relying in an empirical process. The obtained results indicate that the proposed method outperforms the traditional approach when applied in the forecast of a load time series, proving to be a useful tool for artificial neural networks designers, since it allows expanding the search space of architectures for artificial neural networks without making their application unfeasible, in order to find good results in more complex problems.

Keywords: Artificial Neural Networks, Hybrid Method, Load Forecasting, Particle Swarm Optimization, Soft Computing Techniques.

B-6.2-6

Development of a thermal image processing interface for overhead power distribution networks inspection

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The components of overhead power distribution networks are susceptible to weathering, pollution, and aging degradation, which may lead to inefficiency and interruptions in energy supply. Additionally, electricians perform routine operations that often do not occur as intended, causing poor contacts in fuse cutouts and overhead switches that lead into heating. Currently, energy distributors inspect their distribution networks through land patrols, capturing thermal photos of the conductors and structures, from the ground, for further analysis. However, the extension of the energy grid makes it difficult to carry out inspections covering the whole distribution networks periodically and efficiently. Consequently, predictive maintenance becomes infeasible and the quality of energy supply is compromised. This work firstly documents the difficulties faced by technicians and energy distributors in the land patrol inspections of distribution networks. Then, the development of a web interface, provided with artificial intelligence, to process the thermal images captured by technicians is described. The developed web interface, composed of a front-end and a back-end, assists technicians in both component malfunctions identification and generation of reports concerning the inspections that have been

done. Through direct text and a bounding boxes color scale, the reports generated at the interface automatically highlight the electrical components in the photos, their temperatures and the problems identified. The technicians can also edit the reports, improving the analysis, before submitting them to maintenance teams. At last, this paper addresses the main challenges faced by the application of machine learning tools in overhead power distribution networks and some alternatives to overcome them.

Keywords: Web development, Artificial intelligence, Neural network, Inspection, Overhead power distribution networks.

B-6.2-7

Machine Learning for Power Line Inspection: An Automated Object Detector Based on CNN

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Electrical insulators are widely used in power lines and can be composed of different types of materials. Visual inspection of these assets is a methodology that has been used for decades, but it is a slow, expensive and potentially dangerous method, with its validity limited to the visual ability of field agents. In this context, UAVs (Unmanned Autonomous Vehicles) have been adopted as a tool for inspection in transmission lines thanks to their versatility, low operating cost and the wide variety of sensor options with which they can be equipped. The application of computer vision techniques combined with the use of Deep Learning (DL) algorithms make it possible to classify insulators. This article describes an ongoing development of an object detector based on Deep Learning (YOLO — You Only Look Once) that can be used to detect isolators present in images. A regression algorithm is applied with the YOLO algorithm to predict the probability of the classes of objects detected in the image.

Keywords: CNN, Object Detector, Power Line Inspection, UAV, YOLOv4.

B-6.2-12

Preliminary results of applying generative models on nuclear fusion images

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There are several thermonuclear devices in which experiments are carried out to understand and control the process of nuclear fusion. In the TJ-II nuclear fusion device located in Spain, an experiment called Scattering Thomson diagnosis is carried out. This experiment obtains images to measure the temperature and density profiles of the plasma, which is the state of matter where

the particles are ionized or charged, which is heated to very high temperatures to achieve nuclear fusion reactions. Executing this type of experiments and obtaining the different data is a highly costly process, for this reason, in this work we propose the construction of a nuclear fusion database image generator, through the application of deep learning generative models and thus be able to balance existing databases.

Keywords: Nuclear fusio, GAN, images, models, neural networks.

B-6.2-14

Obtaining Post Contingency Loading Margin in Electrical Power Systems via Artificial Neural Networks: Multilayer Perceptron and Radial Basis

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This work presents ANN's (Artificial Neural Networks) approach to obtaining complete P-V curves of electrical power systems subjected to contingency. The differential of this methodology is in the speed of getting all the P-V curves of the system. The great advantage of using ANN models is that they can capture the nonlinear characteristics of the studied system to avoid iterative procedures. The applicability and effectiveness of the proposed methodology have been investigated on IEEE test systems (14 buses) and compared with the continuation power flow, which obtains the post-contingency loading margin starting from the base case solution. From the results, the ANN performed well, with a mean squared error in training below the specified value. The network was able to estimate 98.4% of the voltage magnitude values within the established range, with residues around 10-4 and a percentage of success between the desired and obtained output of approximately 98%.

Keywords: Artificial intelligence, Contingency Analysis, Continuation Methods, Load Flow, Maximum Loading Point, Voltage Collapse, Voltage Stability Margin.

B-6.2-15

Estimation of Rural Populations without Access to Electricity Through Satellite Images and Deep Learning

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In planning access to rural electrification, it is essential to have full visibility of the unelectrified population and the complexities of providing affordable, reliable, and sustainable energy service. Based on this understanding, the distribution network planner can propose expansion alternatives and appropriately target the investments. High-resolution satellite images, increasingly available

to utilities, are powerful tools for this planning purpose. Thus, a method is proposed to identify non-electrified homes using satellite images and deep learning techniques as well as the information available on the georeferencing of the electrical network. A model based on a convolutional network architecture was trained to detect the footprints of existing houses in such a way that the non-electrified homes correspond to those that are outside a spatial buffer of the grid. With these results, a rural electrification metric can be quantified to establish coverage goals by geographic region; as well as generate temporality for its follow-up. The performance of the proposed method was evaluated with a real system of an Ecuadorian power utility. This decision-making tool for network expansion could be adopted relatively easily by distribution utilities.

Keywords: Convolutional Neural Network, Deep Learning, Distribution Planning, Mask Region-based Convolutional Neural Network, Rural Electrification, Satellite Images.

B-6.3-1

Pattern Recognition Tool to Assess Transformers Failures by Acoustic Emission Analysis

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Power transformers play a significant role in the electrical power system, and their failures can impair the quality indices of the electricity supply. Therefore, systems with the objective of diagnosing incipient failures in transformers have been developed to guarantee efficiency and avoid financial losses with punctual and planned maintenance. In many cases, transformers can suffer unexpected thermal, mechanical, electrical, or environmental stresses that can induce a slow dielectric degradation. This unconformity can induce full discharges between the transformer's windings, or partial discharges in bushings. In this scenario, the development of methodologies that culminate in the differentiation of types of failures is extremely important since each type of failure requires different maintenance actions. Thus, the objective of this article is to present the acoustic emission technique as a tool to differentiate internal discharges in the core, and external partial discharges in the transformer's bushing. A piezoelectric sensor was attached to the wall of a distribution transformer to capture the acoustic signals from these faults. By extracting the energy and the average band from 600 fault signals, it was possible to perform the correct distinction between the faults. Therefore, the developed system can be a promising tool to perform pattern recognition of transformers' failures.

Keywords: Transformers, Acoustic Emission, Pattern Recognition, Computational Systems, Signal Processing.

B-6.3-3

Corona discharge feature extraction in HVDC systems using the frequency spectrum of electrical current signals

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The corona discharges of the HVDC system occur due to the ionization of the air surrounding the high voltage conductor of the transmission lines, which could cause radio interference and electrical energy losses. Therefore, the study of corona current in HVDC systems plays a fundamental role in providing information about corona discharges, electromagnetic interference, and electric current intensity, among other relevant features. In this context, the present work aims to explore an alternative methodology for corona discharge feature extraction based on the frequency spectrum of the electrical current signal using the power spectral density (PSD) technique. Corona discharge tests were performed through a DC source applying high voltages varying from ±30 to ±100 kV. The electrical current signal proportional to the s corona discharge surrounding an experimental conductor was collected and subject to digital signal processing analysis through PSD metric. The results indicate that the proposed approach was able to extract relevant information related to the corona phenomenon from the narrow frequency ranges, contributing to the detection activities in HVDC systems.

Keywords: HVDC; corona discharge; digital signal processing; frequency spectrum; feature extraction.

B-6.3-5

A New Technique for High Impedance Fault Detection Based on Buildup and Shoulder Stage Detection

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A high impedance fault (HIF) occurs when an energized conductor comes into contact with a highly resistive surface, resulting in a low fault current and, consequently, not causing conventional protection devices to trip. Since the system protection does not detect the occurrence of this type of fault, the conductor remains energized, putting the physical integrity of people and animals at risk, besides to being able to cause fires. This work proposes a new method for the detection of HIF which consists of calculating the area of the current signal, whose behavior will be used to extract information about the load disconnection, buildup and shoulder waveform stages. For the validation of this method, a test system and three arc models were implemented in ATPDraw, enabling the simulation of different HIFs and other transients common to the electrical distribution systems.

Keywords: Electrical distribution system, high impedance fault, distribution system protection, arc models, signal processing.

B-6.3-7

A Proposal for Detection and Correction of the Secondary Waveform of Current Transformers through Artificial Neural Networks

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The protection relays depend on the reliability of the current transformers (CTs) output signal for their correct operation. However, under some conditions, the increase in flux in the CT core can lead to core saturation, a phenomenon that distorts the CT secondary current waveform, leading to a wrong reading of its RMS value, thus causing many problems in the protection of Electric Power Systems (EPS). Due to the effect of saturation, this work presents a methodology for detecting and correcting the secondary waveform of a CT saturated with transformation ratio 2000:5. The correction algorithm is based on the use of Artificial Neural Networks (ANN), whose output is the unknown parameters of the fault current coming from the Least Multiple Squares Method. A method to detect the instant when saturation occurs is presented and is based on the third difference function technique. The analyzed signals were obtained via simulations from a test system implemented in software ATPDraw, where different saturation conditions were studied. A database was generated to use in ANN training, containing 144 cases, which was provided based on changes in the test system, such as: type of short circuit, remaining flux and CT load. The methods were implemented in software MATLAB, in which the preliminary results point to a robust algorithm capable of reconstructing the distorted signal even in cases of severe saturation and changes in system parameters. Therefore, the proposed methodology will contribute to improve the EPS protection systems, increasing the reliability of the secondary current signals of the CTs.

Keywords: Current Transformers, Electric Power Systems, Artificial Neural Networks, Saturation, Detection, Correction.

B-6.3-8

Traveling wave fault detection and location : An approach based on the Hilbert-Huang transform method

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This work presents an application of the Hilbert Huang Transform (HHT) to analyze the high frequency transients in a transmission system generated by a fault situation, with the purpose of

determining its location. The methodology of fault location used is based on the traveling waves theory, where, as a function of the propagation time of the signals between the fault point and the terminals of the line employing the HHT, the fault location is determined. The fault location problem is implemented using ATP and MATLAB softwares. The fault location technique uses registered data from one transmission line terminal. The implemented algorithm presents promising results for fault location in transmission systems, not suffering significant interference in the variation of fault parameters such as fault type, fault resistance and fault incidence angle in the transmission line.

Keywords: Hilbert Huang transform, traveling waves, fault detection, fault location, transmission lines.

B-6.3-9

Identification of vegetation close to the distribution network using LiDAR and computer vision

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This paper presents a system for identifying vegetation close to the electrical distribution network, using computer vision, classification algorithms and LiDAR. The identification is carried out through a prototype of an embedded system installed in the company's cars. The computer vision was done through You Only Look Once (YOLO) and a convolutional neural network, the VGG-16, was also used to determine the presence or absence of wires close to the tree using images. Finally, heuristics were developed to align this computer vision information with the distance data provided by a LIDAR installed in the vehicle. Thus, the embedded system obtains data from camera, GPS, gyroscope and LIDAR, performs the identification of life form, species, determines if there are wires close to vegetation and calculates the touch distance. The results demonstrate the feasibility of using this system to identify vegetation close to the electricity grid.

Keywords: computer vision; k-means; LiDAR; vegetation identification.

B-6.3-10

Simulator Based on Ray Tracing with UTD for mm-Waves frequencies for indoor corridors

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Millimeter waves are the big keys to Future Generations of Mobile Technology as of their wide radio frequency range, low latency, and bandwidth in GHz. However, since they are highly dependent on the environment, they suffer significant power losses due to obstacles between transmitter and receiver. To predict the behavior of the signal and analyze the attenuation that

the waves can suffer, we created a simulator based on Ray Tracing for a corridor with 90º corners to characterize the channel in millimeter waves. We validated the simulator with data measured at 28 and 60 GHz frequencies, analyzing path gain values in a corridor in line-of-sight and non-line-of-sight situations. With the Geometry Optical (GO) method, we defined 11 refracted rays for the LOS situation and six rays for the NLOS situations using the Uniform Diffraction Theory model. The results showed that when the line of sight between the antennas changes, the power loss is about 20 dB.

Keywords: mmWave, Ray Tracing, simulator, 5G, 6G.

B-6.3-12

Loss of Excitation Detection Technique Based on Waveforms Envelopes Analysis

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The synchronous generator operates with constant frequency and its operation depends mainly on the continuous use of excitation systems. These systems are suscetible to problems such as short-circuit, which can cause partial or total inactivity, causing the machine to operate incorrectly. The operation of the synchronous machine in this state can cause irreversible damage to its structure and also to the electrical system to which it is connected. several techniques have been proposed to detect the loss of excitation, among which the Mason and Berdy methods stand out, which are widely used, although they present selectivity problems in some situations, causing new techniques to be proposed to improve their performance in these situations. Thus, this work proposes a new methodology for detecting loss of excitation (LOE) in synchronous generators, which is able to distinguish LOE events from other recurrent transients in the electrical system such as power swing and short-circuit. This technique is based on the analysis of the envelopes of voltage and current signals, having been tested for different operational conditions of the network, which were simulated in the ATPDraw software. The proposed method presented a high degree of reliability and robustness, acting correctly for the LOE cases tested, without operating improperly for the cases of power swings and faults, proving to be a promising technique to aid the synchronous generators protection.

Keywords: generator, synchronous, excitation, protection, stability, methodology.

B-6.4-1

Design of an Ultrasonic Anemometer for the Study of Urban Wind Turbines

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In the framework of smart grids, the incorporation of renewable energies in urban environments is a subject under constant study. In particular, developments in wind turbines and their associated power electronics lead to a better use of the energy of the bursts of wind. These turbines produce rapid changes of torque in the rotor of small wind generators, increasing significantly the efficiency of this type of installations and attractiveness for use. However, the wind resource of the urban environments is characterized by high turbulence, instability, and rapid changes in wind speed and direction. This behavior is the product of the interaction of the flow of air with surrounding buildings and other obstructions of its own of the urban environment. An inadequate analysis of the resource (which can originate from the choice of an anemometer and monitoring system inadequate sampling that do not evaluate the high dynamics associated to these sites) can cause damage to the facilities or poor estimates of the wind potential of a location under analysis. In this context, ultrasonic anemometers are elements adequate. This is due to its response speed, according to the study of this urban resource. On the other hand, commercially available ultrasonic anemometers are of higher cost. This paper presents the development and implementation of a low cost ultrasonic anemometer associated with a high sampling rate data acquisition for the study of the wind potential of highly dynamic urban sites detailed the mechanical design (the associated electronics would be developed in other work) of this instrument capable of recording in multiple locations wind flow over a building, thus allowing identify the most interesting locations.

Keywords: Grid-connected wind power systems, Ultrasonic anemometer, Energy efficiency, Renewable energy.

B-6.4-6

Energy Consumption Meter Applied to a Direct Current Nanogrid in the Amazon Region

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Direct current distribution systems gain more prominence in academic and professional circles due to its easy integration with distributed generation and the possibility of supplying communities isolated from the conventional grid. The Grupo de Estudos e Desenvolvimento de Alternativas Energéticas (GEDAE) has implemented an isolated Direct Current Distribution Nanogrid (DCDN) supplied by photovoltaic generation in a riverside community not supplied by the conventional distribution grid. To characterize the energy flow between the DCDN and the consumer units, an energy meter was developed that allows for the collection of current and voltage values. Current values are obtained through a hall effect sensor, and voltage values are made suitable for the Arduino's operation range and then collected. The Arduino calculates the energy flow and instantaneous power demanded and stores it on an SD card for further data processing. The circuit also has an LCD for real-time visualization of the collected electrical quantities.

Keywords: DC Energy Meter, DC Nanogrid, LVDC, Riverside Community, Rural Electrification.

TOPIC 7 - Environmental and Ecological Issues

B-7.1-2

The Role of Renewable Energy in Sustainable Economic Development

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This article is a comparative study between the concept of sustainable development and greenhouse gas emissions from the energy sector, specifically focused on the electricity generation and transport sectors. The research explains the deployment of sustainable development on the global stage and demonstrates how key countries presently participate in advancing sustainable development. In addition, it presents an analysis of the primary energy matrix profile and the electricity production matrix worldwide. The article finds that electricity generation and the transport sector are the main emitters of CO2, principal gas to cause the climate changes. The study focuses on how renewable energies could mitigate the harmful effects of environmental pollution from the ever-increasing use of fossil fuels. The study finds that large-scale replacement of fossil fuels with renewable energy sources would be impossible in the short to intermediate-term. The energy production costs and technology available within the renewable energy sector do not yet provide a viable alternative to offset the current demand for fossil fuels. Even in the case of Brazil, which has a substantial capacity to produce power clean, renewable energy, it would be difficult in the short term to cease using fossil fuels since the transport sector is almost entirely dependent on petroleum derivatives. Nevertheless, there is also a vertiginous growth of renewables, especially in the power sector, where the drop in electricity production costs together with an evident improvement in energy transformation technologies have made renewable sources attractive and competitive, Besides, recent shifts in public policies are also incentivizing the shift to adopting renewable energy and encouraging their use.

Keywords: CO2 Emission, Renewable Energy, Incentive Policies, Sustainable Economic Development, Energy Markets, Competitive Price, Power Sector, Bruntland Commission, Transportation Sector, Climate Change.

B-7.1-3

Comparative life cycle assessment of hydrogen production from steam reforming of sugarcane ethanol and biomethane from vinasse

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In order to decarbonization of the energy matrix, the use of steam reforming of ethanol and Biomethane from vinasse for hydrogen production is shown to be an energy alternative with low

environmental impact. The objective is to compare the carbon footprint of hydrogen from the steam reforming of ethanol from sugarcane by hydrogen from biomethane from vinasse. The Life Cycle Analysis (LCA) was limited by the cradle-to-gate boundaries, using the unit works kg of hydrogen. The steps of the methodology consisted of surveying indicators for the composition of the Life Cycle Inventory – LCI. In possession of the indicators to produce hydrogen, the mass and energy balance of the stages was carried out and the carbon footprint related to the adopted processes was calculated. Several bibliographic sources were used in the inventories of the agricultural and industrial stages. The emission factors used were acquired from Renovacalc. The results show that the carbon footprint for hydrogen from the steam reforming of sugarcane ethanol is 3.14 kg of CO2 equivalent for each kg of hydrogen. The carbon footprint of Hydrogen from Vinasse Biomethane is 863.2 kg.CO2eq

Keywords: Carbon Footprint, Ethanol, Hydrogen, LCA, Vinasse.

B-7.1-4

Environmental Impacts Analysis of Energy Storage Processes by Pump Hydro Storage and Hydrogen

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The objective of this work is to comparatively analyze the environmental impacts of energy storage technologies, considering two alternatives with the greatest potential for large-scale application in the Brazilian power grid system, namely Pump Hydro Storage (PHS) and Hydrogen (H2). Two energy routes were idealized for PHS and H2, starting from power generation by intermittent renewable sources, producing more energy than demanded in periods out of high-end, and the usage of the surplus energy, respectively, to pump water from a lower to an upper hydropower powerplant reservoir or to produce hydrogen by water electrolysis. Both routes follow with power recovery (re-electrification) step, first by conventional hydroelectricity technology and second by H2 combustion using modern gas turbines, when it is demanded, for final consumption. The Life Cycle Assessment (LCA) method coupled with recently developed exergy-environmental theories and published data were used to analyze the resources and emissions of both energetic routes (PHS and H2). For PHS case, it was assumed that the same amount of pumped energy will be re-electrified afterward. For a proper comparison, it was also assumed that the same amount of energy available to be pumped by PHS is electrically available to be stored as H2. Numerical and comparative results on the Exergy Cost of Renewable, Non-Renewable, and Total resources, as well the Cost of CO2 emissions of both studied energy storage possibilities were obtained and presented. Exergy environmental analyses results for this given scenario indicate that PHS has advantages over H2, presenting 84% of the exergy cost of total resources and 23% of the CO2 emissions of the H2 alternative.

Keywords: Energy Storage, Environmental Impacts, Exergy Environmental, Hydrogen (H2), Pump Hydro Storage (PHS).

B-7.1-5

Impact of Winds on the Pollutant Deposition in Insulators of Electric Power Transmission Systems

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The adhesion of particles to the surface of insulators is affected by several factors, such as relative humidity, wind speed and electric field strength. The focus of this work is to evaluate in an integrated way how the influence of winds and other meteorological data impact the accumulation of pollutants in insulators of electrical energy transmission systems. The originality of the developed method lies precisely in presenting a consistent model, based on machine learning, which evaluates in an integrated and fully georeferenced way how the concentration of pollutant deposits increases with wind speed, also taking into account the dependence in relation to the geometric shape of the insulator disk, as well as the other meteorological attributes. Based on the model developed, thousands of simulations were performed taking into account the characteristics of a real transmission line located in the ARGO Energy concession area. For each insulator (2248 in all) 86904 simulations were performed. Each simulation is equivalent to the contribution of 1 hour of environmental conditions on the deposition of dirt in the feeders. Thus, there is an overview of the deposition of dirt on the insulators for a horizon of 10 years with a resolution of 1 hour. Then, the responses provided by the proposed system were compared with the available history of the ARGO system's concession areas, which were also stratified by line. The information for each attribute is counted against the length of the line. In addition, a set of insulators was removed from the LT 500 kV Bacabeira – Parnaíba III (ARGO), in order to carry out physical-chemical tests to verify the adherence of the results provided by the developed methodology.

Keywords: Transmission insulator, pollutant deposition, meteorological factors, contamination particles, partial discharges.

B-7.1-6

Environmental performance of biorefineries with methanol production alternative

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The technology for capturing and using carbon dioxide (CCU) is an alternative for recycling carbon dioxide (CO2), using it as a raw material for synthesizing chemical inputs and as an alternative to reduce carbon emissions CO2and the depletion of fossil resources. CO2 can be captured from several sources, such as from the fermentation vats of sugarcane ethanol plants, whose gaseous

flow approaches that of saturated gas. A possible use for CO2 is the synthesis of methanol (MeOH) through the hydrogenation reaction. Given the importance of biofuels in the Brazilian energy matrix and the search for sustainable energy sources, this work focuses on studying the carbon footprint (PC) of a biorefinery with alternative production of MeOH. The research investigated the possibility of diversifying the portfolio of products obtained from sugarcane biomass by integrating new processes with biorefineries, obtaining products that go beyond ethanol, sugar, and electricity. Life Cycle Assessment (LCA) was used to identify the PC of the biorefinery. The LCA results demonstrated that integrating the production of MeOH decreases PC if the H2 is obtained from a renewable energy source.

Keywords: bioenergy, carbon capture and use, ethanol, methanol.

B-7.1-7

Efficacy of hypoxanthine-3-N-oxide as an alternative method to protect ichthyofauna in hydroelectric plants

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Alarm substances, released after damage to fish epidermal cells, is one of the most effective signals in the Osteriophysan group, which represents 72% of freshwater species. Hypoxanthine-3-N-oxide is indicated as one of the possible active components of these substances. Tests were conducted with the species Matrinxã and Tambaqui using 100 L capacity aquariums, instrumented with sample introduction and remote imaging systems. The results indicated at the concentration of 6.0 µg L-1 unusual behavioral changes such as lethargy, bottom foraging and seizures, which support the premise that hypoxanthine-3-N-oxide is effective in inducing alarm signals. Hypoxanthine may in the future be a good management method for protecting ichthyofauna, especially in the hydropower sector, because it has proven efficacy, is a synthetic, commercial, and non-toxic substance to biota and the aquatic environment.

Keywords: behavioral changes, epidermal cells, repulsive response, alarm substances.

B-7.2-1

Extrusion Blow Molding Process Set up Electric Energy Economy with Plastic Drop in Material at AdBlue and Diesel Fuel Tanks

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The increase demand to produce components following global premises as an Environmental, Social and Corporate Governance (ESG), reducing the Greenhouse Gas (GHG) emissions at raw material production process and at component production process should be implemented

according to UN Climate Change Conference 2021. The ESG agenda is used to minimize the environmental business impact in order to build up a better world with responsibility around administration process, investments and sustainability criteria. Motived by this, the research presents the use of Green Polyethylene (GPE) to produce AdBlue tanks as a drop in material in replacement at fossil High Density Polyethylene (HDPE). The biomass used as a bio base for GPE production is the sugar cane leaves. And as it has some differences proprieties from the blend of HDPE current applied on the line production, a series of analysis and tests were made in order to adjust extrusion blow molding process parameters and ensure the feasibility in the field. The extrusion blow molding machine have electric resistors used during the set up and during the normal production as well. When comparing both materials, the main aspects of reometry as a shear stress and shear rate results in a distinct flow speed inside of machine extrusion process, especially due to the different flow index, variable that has high influence on the process. The supplier set up his process four times per week and represents a 16 hours per week and the total expanding time is 800 hours per year. Considering the situation that all the current PE-components produced change to GPE as the raw material, the calculated set up reduction is 1600 hours/year. To validate de GPE tanks before assembling in vehicles it passed through a battery of mechanical tests, following International, Brazilian and internal enterprises standards, such as, Pressure, Impact, Sled and flammability. The positive results are mandatory requirements allows the GPE as a raw material, which could reduce around 180.000 ton of CO2/year at Latin America market, considering only commercial vehicles tanks (fuel and AdBlue) and the volume of reprocessed material increase as well improving the circular economy. Fuel tanks and AdBlue tanks produced with GPE should be approved at development and validation tests in the durability tests and in the field as well. GPE is a drop in material usually used in commodity chemicals and polymers with large scale production volumes and normally is more expansive than petrochemical ones. However, with increased volume, same as the fossil-based produced nowadays, the price is likely to decline. Moreover, this penalty can be offset by carbon credit commercialized and electric energy reduction during the set-up machine process. Regarding a green plastic, the raw material and patent to produce the GPE in high scale are previewed to start in 2023 and is important the demand and application approved. It can Reduce the impact of the CO2 on the planet through the change of the HDPE source and start a new trend to achieve the low emissions.

Keywords: AdBlue tanks, Decarbonization, extrusion blow mold set up, Green polyethylene.

B-7.2-2

Environmental Comparison of the Life Cycle of Biodiesel and Green Diesel (HVO) produced from palm oil in Brazil

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The present study presents a life-cycle analysis (LCA) of renewable fuels that have the potential to replace fossil diesel, being them biodiesel and green diesel from palm oil. The assumed impact categories measure global warming, human toxicity, and water eutrophication. Production routes

have been selected according to industry trends, making transesterification and hydrotreating the most viable processes. The hydrogen for the hydrotreatment originates from the steam reforming of natural gas, with capture and storage of carbon, blue hydrogen. The results are obtained as a function of the production of 1 MJ of energy from biofuel burn and point to a reduction of 10% carbon footprint of biodiesel compared to HVO. In the other impact categories, there were similar results for both biofuels. Finally, a sensitivity analysis is complete.

Keywords: Biodiesel, Blue Hydrogen, Green Diesel, Hydrotreatment, Life Cycle Analysis, Transesterification.

TOPIC 8 - Social and Economic Issues

B-8.1-2

Analysis Of Sustainable Development Indicators Of The Electrical System Of The State Of São Paulo

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Faced with the need to measure and implement sustainable development, when people speak at a global level about protecting limited natural resources, reducing pollutant emissions, seeking social equality and achieving economic growth without harming the environment, monitoring becomes necessary to feel it in the short, medium and long term. Understanding the concept of sustainable development involves the following aspects: environmental, economic, social and institutional, requiring a comprehensive sustainability indicator model with associated indicators to measure a broader and more complex reality. The objective of this study is to evaluate sustainable development based on indicators that demonstrate sustainability from factors determined in the scope of the local electrical system, considering, in this sense, the state of São Paulo as the basis for analysis. In this way, this article seeks to answer: How are the results of the Sustainable Development Indicators of the electricity system in the State of São Paulo, in the period 2021-2022? And, starting from this key question, answer: What is sustainable development and what are its determinants? What are the sustainability indicator models for measuring sustainable development? What are the results of the analysis? The study's main methodological reference is the indicators provided by the Socio-Environmental Parliamentary Group with support from several UN agencies, adapted to national circumstances and using data from the Brazilian Institute of Geography and Statistics; o Diagnosis of indicators for monitoring the Sustainable Development Goals (SDGs) in the State of São Paulo; in addition to a comprehensive analysis of sustainability indicators provided by the National Electric Energy Agency (ANEEL) on clean and affordable energy residential lighting data, renewable and non-renewable energy production, renewable energy consumption and energy intensity.

Keywords: Keywords: Sustainable Development, Sustainable Development Indicators, Sustainability Panel, Brazilian Institute of Geography and Statistics (IBGE), National Electric Energy Agency (ANEEL).

B-8.1-4

Economic Feasibility Of Integrated Battery And Photovoltaic Systems From The Perspective Of Low Voltage Consumers In Brazil

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The objective of this paper is to analyze the economic viability of PV systems with batteries, in the short term, in a "behind-the-meter" configuration, for Brazilian low voltage consumers, using current regulations and tariff mechanisms. The main contributions are cost projections of the technologies involved and analysis of the economic viability of the PV array and storage. Traditional economic analysis metrics and the System Advisor Model computational tool are used. The main conclusion is that the battery system reduces the economic attractiveness of the PV system. Instead, the overall viability is positive. This means that, in an eventual future context in which there are restrictive rules about the injection of power by PV systems into the grid, batteries can be integrated, readjusting the power flow without making the project unfeasible. Possible regulatory improvements in Brazil are pointed out to take advantage of multiple functionalities of battery systems.

Keywords: Batteries, Distributed power generation, Energy storage, Photovoltaic systems.

B-8.1-5

Assessment of the social energetic factors about wind energy in the south American energy transition

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The objective of this work is to analyze the energetic factors that will determine the social dimension of the impacts in the energy transition considering the local introduction of wind energy source. In this sense is considering specially wind energy projects developing (or will be realize soon) in the Colombia´s department of La Guajira. This paper aims to analyze possible social benefits of the wind energy sector upgrowth based on other countries experience like Brazil (including official data of the BNDES). Employment rate is the center of the discussion considering possible direct and indirect employment generation. Official data provided by the DANE will be compared to the possible scenario determined by the current approved projects

Keywords: Energy, Energy resources, Government policies, Renewable energy, Social implications, Social factors, Statistics, Unemployment, Wind Energy, Wind farms.

B-8.2-1

Simulation Tutorial in ATPdraw – IEEE 4 Node Test Feeder – Part 2

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The use of computational tools to model the reality that surrounds the world has become, over the years, a common and indispensable practice, being widely used in several areas. For this wide

dissemination, there are several reasons, among which can highlight: the possibility of verifying possible failures of an electrical system before it is even implemented, in addition to the possibility of dimensioning safety devices, capital savings, greater understanding systems, greater efficiency of system equipment, among others. Within Electrical Engineering, the use of free softwares as a simulation tool is growing and within this context, the Alternative Transients Program (ATP) stands out, one of the most respected and known power systems simulation programs, which has as its main uses in studies of electromagnetic transients and modeling of transmission and distribution of electrical power systems. Considering the high interest and demand of engineering students and professionals in this subject, this work represents, therefore, an extension of the content presented in [1] and, then, this paper will explore the resources of Plotting Tools and Graphic Analysis.

Keywords: ATPDdraw, distribution line, simulation, tutorial, 4 node test feeder.

B-8.2-4

Computational Interface Applied to Distance Protection in Transmission Lines

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This work aims to present a graphical interface, developed in C# Language, as an alternative for visualizing the impedance vector, applied to distance protection in transmission lines. In this interface, the Discrete Fourier Transform (DFT) of one cycle was used to calculate the fundamental phasors, from the voltage and current signals measured at the local terminal. With these fundamental phasors, the value of the apparent impedance or measured impedance for the phase or neutral distance elements is calculated. An interface was also developed to input the adjustment values for the MHO and Quadrilateral operation characteristics, typically used in protection relays. The results obtained from this computational interface allow a better understanding of the impedance vector trajectory and its final stabilization, within the operating area for each protection zone, defined by the adjustments of the 21/21N function. The good results demonstrate the importance of the Interface developed, both in the professional and academic scope, for a more detailed analysis of the distance function of a protection relay.

Keywords: Computational Interface, C# Language, Distance Protection Relay, Electric Power Systems.

B-8.2-6

Maker Culture Contributing to the School Community: Liquid Alcohol Dispenser

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The digital culture applied in the community is a way of sharing the knowledge developed in the Engineering courses with high school students. Through the development of a project, students are encouraged to apply technology to help the common good. Given the sanitary crisis due to Covid-19, liquid alcohol should be used in the school to sanitize hands. Thus, a project using robotics was formulated to efficiently distribute liquid alcohol so that students could sanitize themselves at the entrance to the school. The liquid alcohol dispenser was made of cardboard, a plastic holder containing the liquid alcohol, an ultrasonic sensor, and the microcomputer 'micro:bit' to activate the dispenser. The 'micro:bit' is easy to use and aims to arouse the interest of children and adolescents in programming, inspire young people to develop digital creativity and thus contribute to the creation of a generation of innovative entrepreneurs; thus, students are encouraged to develop critical thinking, creativity, and new ideas. The project was developed through a team problem solving strategy to contribute to the school community. In order to introduce basic programming language concepts in a more playful and accessible way to high school students, the block programming approach was adopted using Scratch. The development of the project contributed to expand skills and competences connected to the real needs of society. In addition, with this technology present in classrooms, students are encouraged to apply theoretical knowledge in practice. Furthermore, there will be a significant increase in student engagement during the learning process required to build the liquid alcohol dispenser.

Keywords: Engineering educations. Programming. Robotics. Sustainability.

B-8.2-7

Object-oriented programming for game production in SuperPython

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The so-called GECET (Girls in Engineering, Exact Sciences and Technologies) extension project, coordinated by professors Wallace Casaca and Marilaine Colnago, aims to encourage the women's inclusion and equity in Exact Sciences, Engineering and Technology fields, thus reducing the gender gap in these areas. Since 2020, we make use of social networks, promoting events such as mathematics, engineering and computing weeks, round tables, chats and scientific dissemination. One of the highlight activities conducted in 2021 was the partnership established with the SuperPython Program from UFRJ – Federal University of Rio de Janeiro. This extension

program consists of developing games and programming-related projects by using Python language for children and young people. The SuperPython was created to harness the talent and creativity of children and young people towards producing computer-driven interactive stories as well as games. For example, by creating games, the project's members can feel the satisfaction of realizing their playful world while still producing exciting material that can be appreciated and enjoyed by their peers. The programming language used in SuperPython is easy to learn and paves the way for programs of professional quality, equivalent to what you find in the real world. Motivating young people to commit themselves to the programming task is a challenge, as they seek an immediate high-quality result that actually requires a long period of learning and training. SuperPython students need to deliver tangible results very quickly so that they stay motivated and persist in acquiring increasingly complex programming skills. In this proposal, games were developed in the Python language, telling a little of the stories of women scientists with a group of basic education students. The target audience was high school students who were interested in developing programming skills and problem-solving abilities. In this paper, we will highlight the game that tells the story of Ada Lovelace. Object-Oriented Programming was used to control the virtual person as well as some items collected along the scenario.

Keywords: Engineering education. Empower women. Game. Programming.

B-8.2-10

Modeling and simulation of the control of a double fed induction generator

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The present work introduces, in a didactic way, the mathematical modeling for the double-fed induction generator (DFIG), as well as its control strategies observed purely from the machine's point of view. The electric dynamic equations of the model are modeled in Park's rotating frame. This model enables one to demonstrate the construction of an equivalent circuit for the machine in steady state along with the realization of multiple control strategies for the DFIG, for instance, speed and stator reactive power controls. In this approach, it is intended to explain how an analysis of the induction machine can be carried forward without the need to delve into details of the electronic power converters. The results show the validity of the implemented control stategy. All models were written in Modelica language and simulated in OpenModelica simulation platform.

Keywords: Control, DFIG, Dynamic Modeling, Electrical Machines, Wind Turbine.

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