APPLICABILITY OF ORGANON IN THE OPERATION OF ELECTRICAL SYSTEMS UNDER THE INFLUENCE OF RENEWABLE ENERGY RESOURCES AND DEMAND RESPONSE

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ABSTRACT

The aim of the paper is to analyze the operation behavior of the electrical and energy systems under real load and energy power conditions, considering the penetration of Distributed Energy Resources (DER), through simulations using Organon. The simulations consider case studies through the implementation of supply and demand energy alternatives, considering energy and electrical security in the interconnections of the Brazilian National Interconnected System (SIN) in the Southern subsystem under real conditions of electrical restriction. The paper shows applications of the concepts of Integrated Resources Planning (IRP) and the simulations consider the penetration of renewable energy sources, solar photovoltaic and wind power, and demand response. Organon software is also presented, highlighting the functionality of generating energy security regions. The results and simulations are shown, highlighting the security regions obtained and the conclusions reached through Organon.

Keywords: Organon, Brazilian National Interconnected System, Constrained-off, Demand Response, Distributed Energy Resources.

Introduction

The Brazilian Electric System (SEB) is constantly expanding, with new power projects and the increase in residential and industrial demand. The Brazilian National Electric System Operator (ONS) has an essential role in the coordination and operation of the National Interconnected System (SIN), with the objective of guaranteeing the security and optimized supply of electricity throughout the country. Energy security is a priority, and the ONS performs pre-operational and real-time studies to avoid load shedding, using computer programs such as Organon from HPPA (High Performance Power System Applications) to analyze risks and provide critical information [1][2].

The supply of electricity from renewable sources in the SEB is growing, but can be limited by the reduction in the energy flow in the transmission lines. These limits cause constrained-off and curtailment-off events, which are increasingly common in SIN. In this way, the motivation of the paper is to analyze the impact of this growth on the operation network, checking the need for improvements before implementing new projects, and the impact of energy frustrated by constrained-off. Therefore, the Organon modeling proposes a link with the use of surplus energy and the replacement of conventional energy with non-conventional alternatives. Thus, the objective of this paper is to use Organon to implement alternatives linked to the Integrated Planning of Energy Resources (PIR) that may occur in strategic locations of the SIN and to analyze the constraints on the quality of energy supply or possible violations in the electrical system operation. This issue is very important for society, especially for the consumers and economic agents connected to substations in the analyzed regions, as the systemic security analysis prevents possible load cuts.

Integrated Energy Resources Planning

The Integrated Energy Resources Planning (IRP) is a process that checks all the real options to be carried out for a given location and horizon, selecting those options with greater socioeconomic sustainability [3]. And, it aims to verify alternatives on the supply side (e.g., fuels, electricity) and on

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the demand side (e.g., demand response), indicating ways to supply future demand in a sustainable, secure and cost-effective manner that balances the interest of the affected economic groups [3][4].

The IRP has a wide range of subjects, but this paper will present the consequences of energy complementarity, demand response, and cuts and limitations in renewable sources under real operating conditions:

- Energy complementarity is a state or system that involves intermittent renewable energy sources (wind, solar and water resources). Complementarity should be understood as the ability of these sources to work in a complementary way (wind-solar, solar-hydro, solar-wind-hydro) with energy security and systemic flexibility [5][6].
- Demand response aims to encourage a reduction in energy consumption. However, unlike energy efficiency programs, demand response programs change consumer behavior in relation to energy consumption, realizing short-term reductions in demand. For example, shifting the load to a time when the energy consumption in the system is lower or reducing the load at the request of the electrical system operator [7][8].
- Constrained-off in renewable sources are events of operation restrictions that reduce or even completely interrupt the production of electrical energy for a certain time to meet the requirements energy or electrical criteria of the electrical system [9]. Curtailment-off events are cuts in generation to reduce the total power of a power plant [10].

Organon

Organon is software that belongs to HPPA and aims to assess the power systems security in problems of both static nature (Voltage Stability Assessment - VSA), and dynamic nature (Dynamic Security Assessment - DSA). This tool employs high-performance computing and algorithms with great numerical robustness, enabling a detailed modeling of the electrical network in a distributed processing environment [11]. One of Organon's functionalities is to draw security regions (Fig. 1) to facilitate visual analysis. To draw the security region, it is necessary to have three power energy groups, in which one group works as a swing bar while the other groups defined by the user can vary the generation. In this way, the program will verify the security of the electrical and energy systems for different scenarios of power production with constant load (at the same point of operation), that is, even if some contingency happens (pre-defined) all demand will be supplied without violation of restrictions [11][12].

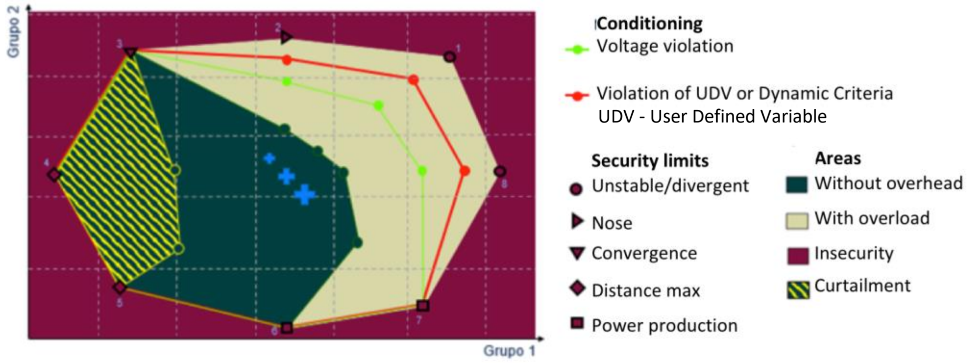

Figure 1 – Example security region nomogram in Organon [2].

Hypotheses and Simulations

The hypotheses were defined according to the Instructions for Normal Operation and Instructions for Special Schemes of the ONS Network Procedures referring to the South subsystem. These documents present admissible occurrence situations in the SIN. The simulations were carried out with the addition or reduction of active power in plants or buses, using the dynamic security regions (Dyn) of the Organon operation history for implementation and analysis of results. The simulation horizon lasts 24 hours in real time, considering the entire historical data of load and power production behavior on typical days, with or without equipment outages that cause electrical and energy boundary situations for the integrated planning exercise. However, each security region has specific power production groups and contingencies pre-selected by ONS, with the objective of representing the security regions in the best possible way.

A. Floating photovoltaic solar plants as energy complementarity

Depending on the conditions of the SIN, in normal operation, some transmission lines may exceed the current limit established in permissible overload. Thus, contingency situations can cause the disconnection of this transmission line. Considering this condition, the case of the 230 kV line Guarita / Santa Rosa 1, according to the Normal Operation Instruction of Rio Grande do Sul [2] may go into overload when there are power increases at the hydroelectric plants of Foz do Chapecó and Quebra Queixo and the power export increases of energy by Converters Garabi I and/or II, causing an increase in the flow of power to Rio Grande do Sul. One of the procedures for reducing the overload on the system under these conditions is the power increase at the Passo Real hydroelectric plant. However, if the hydroelectric plant has maximized power production or is unable to increase due to restriction of water resources, it will be necessary to use other resources such as reducing power production in plants through water spillage or reducing exports.

In this way, the energetic complementarity of photovoltaic solar plants would be important. According to [13], it is possible to install a floating photovoltaic system as an energy complement in the Passo Real hydroelectric plant with a capacity of 14,123 MW, considering the space of 30% under the reservoir. Thus, using Organon, the implementation of a floating photovoltaic solar plant was simulated with an increase in load of 14,123 MW at the Passo Real plant. The real scenario chosen was the case of overload on the 230 kV Guarita / Santa Rosa 1 line in a contingency of the 230 kV Passo Fundo / Santa Marta LT (Fig. 2).

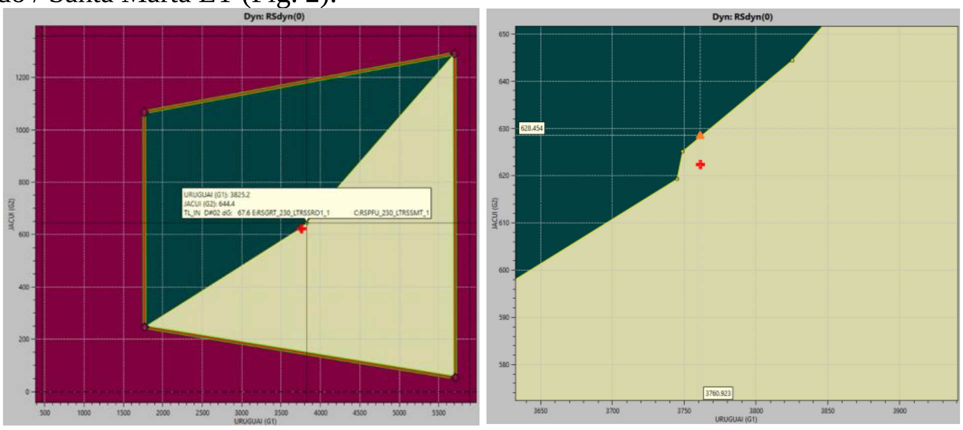

Figure 2 – Nomograms for Floating photovoltaic solar plants case.

In Figure 2, the necessary power production in Group 2 (Jacui) allows moving the operating point of the region with overload, which should be greater than 628.454 MW and considering that the operating point (red cross) is at 622.4 MW. So, it is necessary to increase more than 6,054 MW in the Jacuí plants. That is, if a power production of 14,123 MW is implemented at the Passo Real plant, the system's operating point would enter the region without unacceptable overload, avoiding reducing exports or generation at the Group 1 plants (Uruguay).

B. Demand Response

In another scenario, two other transmission lines may be overloaded depending on SIN conditions: the C1 and C2 of 230 kV - Bateias / Campo Comprido transmission lines [2]. However, due to the conditions of the hydroelectric reservoirs, it is not always possible to carry out a new dispatch of the hydroelectric plants. In this way, it is necessary to carry out the dispatch of the Araucária thermoelectric plant, but with high cost. One solution would be to encourage demand response from industries in the Curitiba metropolitan region to reduce energy demand at times of high load, shifting consumption to other times. If the incentive for industries were lower than the cost of the Araucária plant, there would be gains for the system. Thus, using Organon, a condition was simulated in which there would be an overload in the 230 kV Bateias / Campo Comprido C2 in the contingency

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of C1 (Fig. 3) and after the load reduction of 10 MW (demand response) at the same point of connection of the Araucaria plant. The simulation indicates that the security region was redrawn (Fig. 3) with the operating point in a security area, confirming the effectiveness of load reduction in this situation.

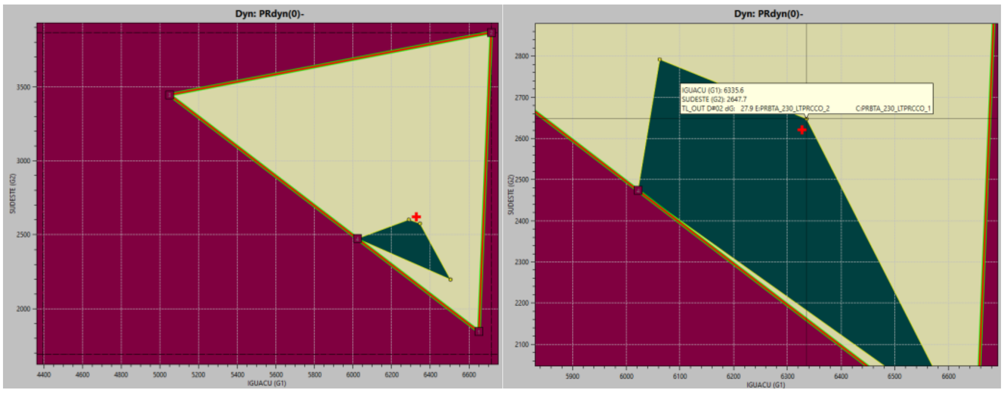

Figure 3 – Nomograms for demand response case.

C. Increases of wind power production – curtailment-off and constrained-off

According to [14] in Rio Grande do Sul there is an offshore wind project with an environmental license, in planning, with an installed capacity of 3 GW and with connection to the 525 kV Capivari do Sul substation. The simulation verifies the amount of power energy that can be connected in the coastal region of Rio Grande do Sul, without considering the input of the 525 kV substation and keeping the system in energy security. This would reduce possible work delays and occurrences of constrained-off and curtailment -off, in case a part of the wind farm is released for operation. Through Organon, the simulation applied the maximum power production of the wind farm available in the coastal region of Rio Grande do Sul. This produced a security region without violations, then an amount of 370 MW of power production was increased in the Atlântida 2 substation, simulating 12.33% of the generation of the predicted offshore parks. After the power increase, an area with overload appeared, informing the disconnection of the 230 kV Osório 2 / Taquara transmission line due to overload in the 230 kV Fibraplac / Osório 2 transmission line (Fig. 4), but with the operating point in a security area.

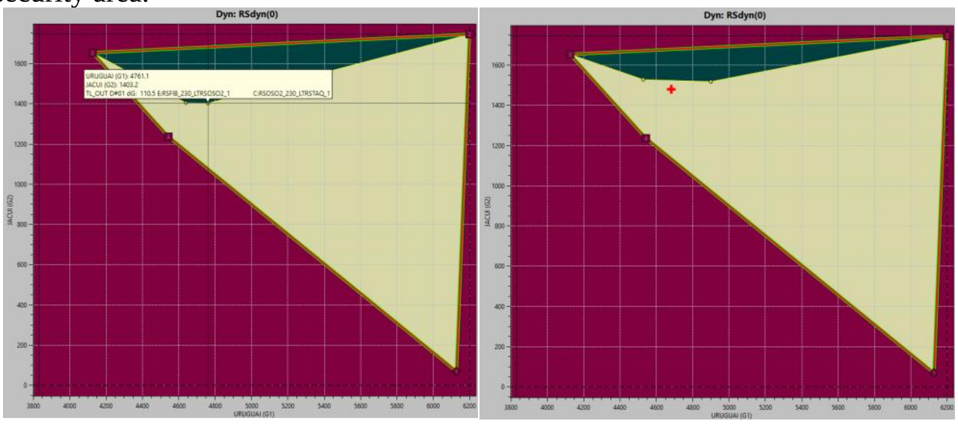

Figure 4 – Nomograms for increases of wind power production.

Then, another 5 MW of generation was increased, but the operating point was still in the overload area. Thus, for the studied scenario, it is concluded that the maximum generation that can be increased in the region to avoid curtailment-off and constrained-off is 370 MW. However, wind power plants suffer more from constrained-off and curtailment-off. Therefore, an alternative is to harness this frustrated energy for the production of green hydrogen. Hydrogen is an example of how cross-sector coupling can work, as it can be produced from renewable energy (through water electrolysis), used for energy storage, or as fuel in various sectors. Thus, it serves as a kind of "bridge" between different energy sectors, facilitating the integration and optimization of energy resources [15]. Production can take place directly at the power plant, which is useful when the source is intermittent. Hydrogen can be stored and subsequently used as input and value aggregator for commodities or even for power energy during periods of high demand or low production to respond efficiently to demand fluctuations. However, the interpretation of hydrogen should not be limited to being just a commodity but rather as a production factor, that provides an economic perspective, because it adds value to commodities.

Conclusions

The simulations presented the conditions for the behavior of the operation of renewable energy resources according with the interconnected electrical system in the 24-hour horizon with real load and supply values. The results indicate the possibility of energy complementarity with energy security through intermittent renewable sources. However, there is a need for further studies on the true flexibility capacity of the electrical system to maintain voltage and frequency stability under dynamic conditions. It is also necessary to consider the possible increase in energy consumption in the long term. Furthermore, it would be very important to consider the response of green hydrogen plants with alternative energy storage and other options that may contribute to the inertia and energy security.

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References

[1] ONS. National Electric System Operator, *Sobre o ONS: O que é ONS*. Available: http://www.ons.org.br/paginas/sobre-o-ons/o-que-e-ons. 2022.

[2] ONS. National Electric System Operator, *Procedimentos de Rede - Módulo 5 Operação do Sistema.* Available: https://www.ons.org.br/paginas/sobre-o-ons/procedimentos-de-rede/vigentes. 2022.

[3] M. E. M. Udaeta, "*Planejamento Integrado de Recursos Energéticos – PIR – Para o Setor Elétrico (pensando no desenvolvimento sustentável)*". Ph.D. dissertation, Curso de Engenharia de Sistemas de Potência, São Paulo Univ., São Paulo, Brazil, 1997.

[4] G. M. Jannuzzi *et al. Planejamento Integrado de Recursos Energéticos: Oferta, demanda e suas interfaces*. Campinas: IEI Brasil, 2018.

[5] J. Jurasz, F.A. Canales, A. Kies, M. Guezgouz, A. Beluco, *A review on the complementarity of renewable energy sources: Concept, metrics, application and future research directions*, Solar Energy, Volume 195, 2020, https://doi.org/10.1016/j.solener.2019.11.087.

[6] J. Jurasz *et al*. "A review on the complementarity of renewable energy sources: Concept, metrics, application and future research directions". *Solar Energy*, vol. 195, pp. 703–724, 2020. Pergamon.

[7] Bakare, M.S., Abdulkarim, A., Zeeshan, M. et al. *A comprehensive overview on demand side energy management towards smart grids: challenges, solutions, and future direction*. Energy Inform, 2023. https://doi.org/10.1186/s42162-023-00262-7

[8] Silva, Tatiana B., Hollanda, Lavinia and Cunha, Paulo César F. , *Recursos Energéticos Distribuídos*. Ano 3, May 2016, Getulio Vargas Foundation: Rio de janeiro. 2016.

[9] U. M. Garcia Neto. *Constrained-off para as usinas solares*. Solar Energy Hub. Available: https://www.portalsolar.com.br/. 2021

[10] M. Godoi, S. Montenegro. *Aneel aprova regra sobre constrained-off de eólicas*. Energy Channel Magazine. Available: https://www.canalenergia.com.br. 2022

[11] Penna *et al*., "*Utilização da Ferramenta Organon nos Processos do ONS"*, in SNPTEE - Seminário Nacional de Produção e Transmissão de Energia Elétrica. Florianópolis: Cigré, 2011.

[12] P. Santos. "*Avaliação de segurança em sistemas elétricos de potência utilizando o programa computacional Organon"*. Dissertation (Curso de Engenharia Elétrica) - Universidade Federal do Rio Janeiro / Escola Politécnica, Rio de Janeiro, Brazil, 2010.

[13] Souza, L. ; Sica, Everthon T . *Avaliação do aproveitamento energético de plantas fotovoltaicas flutuantes em corpos de água doce: um estudo de caso da UHE de passo real*. In: Encontro Regional Ibero-americano do CIGRÉ, 2023, Foz do Iguaçu. XIX ERIAC. Paris/Rio de Janeiro: Cigré, 2023.

[14] EPE. Brazilian Energy Research Company, *Story Map Roadmap.* NT-EPE-PR-001/2020-r2. Ministry of Mines and Energy. Available: https://www.epe.gov.br/ 2020

[15] D. Gielen, E. Taibi, and R. Miranda, *Hydrogen: A renewable energy perspective*, Abu Dhabi, 2019. [Online]. Available em: www.irena.org