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Influence of transformation capacity expansion of a substation on the distribution network resilience: a study of a substation in the metropolitan region of Recife-Brazil.

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In face of the climate changes caused by global warming, the energy transition became a relevant aspect in the energetic planning to be less dependent on fossil fuels. The Brazilian energy mix is already predominantly renewable, and until the end of the decade more investments in renewable energies expansion are expected. So, the electrical system must be structured to operate safely, efficiently, and reliably, to ensure the continuity of the electrical and energy supply. For this, the expansion and implementation of substations is essential since they contain the equipment responsible for the continuity of the power flow and voltage transformation that will be distributed. Thus, addressing these requirements in the system's planning, the concept of resilience is highly appropriate to tackle them. Specifically dealing with substations, which are responsible for the transformation, protection, control, and manoeuvre of electrical energy supply until the final consumer, is a way of mitigating problems related to the supply discontinuity, making necessary to carry out studies in order to investigate the resilience of the substation and the power transmission network to which it is inserted. In this context, a metric to assess the reliability in this context is proposed and is applied in a real substation considering disruption scenarios.

Keywords: Resilience; Energy transition; Reliability; Substations.

1. Introduction

The steep expansion of the Electric Power System (EPS) as well as the advance of non-dispatchable renewables, have imposed on the Brazilian Electric System (BES) several challenges associated with energy security, overload in transmission lines (TL) and extreme weather events, which although rare in Brazil, have devastating effects on the public services sector, whose recovery can take months. Still, EPS must also have enough flexibility to adapt to severe disturbances without losing its full version. This behavior matches with the resilience concept, although in the power grid context there is no consensus over a definition (Ghiasi et al., 2021). Therefore, it is essential to study the need to implement new substations (SE) and expand existing SEs, we have to assess its resilience in order to understand the situation. To implement a resilience metric has the potential of gathering more professionals in the discussion.

2. Methodology

This article presents the contingencies foreseen in (ONS, 2022), focusing on SE Bongi, responsible for serving the metropolitan region of Recife, which will undergo expansion (EPE, 2020). The modeling in permanent regime of the power flow problem, being this a pillar that bases the decisions regarding the expansion of the network and the improvements that must be carried out for certain time intervals. The ANAREDE program was used, due to its speed in the simulation of power flow in extensive systems, such as the Brazilian one. To assess SE Bongi resilience in face of violations of operational criteria, that is, disruptive events, the section Frontier Transformers from (ONS,2022a) was used as a reference, which relates the loads with the operational capacities of long and short duration, in the conditions of contingency and normal operation. The relationship between loading and operating conditions are in Table 1.

Table 1. Classification found in (ONS,2022b)

μ	Network states
	Loading exceeding **long-term (LT)** operating capacity under **normal** operating conditions
	Loading exceeding **short-term (ST)** operating capacity under **contingency** conditions
	Loading higher than **LT** operating capacity, but lower than the short-duration operating capacity, in **a contingency condition.**
	Loading **below LT** operating capacity under **contingency** conditions

From these network states and considering LT and ST operational capacities for each one and the remaining capacity of the line in front of contingencies are used to create Table 2, which allows to generate a quantitative assessment of the resilience of an electric grid with performance both in integral network and in contingency. For the metric proposal, a situation when the integral network violates ST and LT limits is included only from the theoretical point of view, since the planning of the BES never allows an integral network to violate the normal and emergency capabilities of the system.

Table 2. Quantification of resilience

Remaining flow (%)	Resilience performance
[0]	Integral network and potential load shedding
[0,10)	Deficient
[10,20)	Poor
[20,40)	Regular
[40,50)	Good
[50,100)	Optimal

3. Results

The cases selected for the power flow analysis were the Contingencies in the LT 230 kV Bongi – Joairam – involving two lines of double circuit and the transformer 04T2 230/69 kV of 100 MVA. The results obtained can be seen in Tables 3 and 4.

Table 3. Double Loss in TL 230kV Bongi-Joairam

Network state		Remaining capacity	Resilience
Performance under contingency		43%	good
		13%	poor
		-75%	null
Integral network		-2%	null
Integral network violating ST-LT		-10%	null

Table 4. Transformer Loss 04T2–230/69kV 100MVA

Network state		Remaining capacity		Resilience
		LT	ST	
Performance under contingency		8%	14%	deficient
		-21%	-14%	null
		-95%	-84%	null
Integral network		-5%	1%	null
Integral network violating ST-LT		-25%	-18%	null

4. Conclusion

We suggest a metric to quantify resilience, using as reference BES's own documents regarding its planning and expansion. The results obtained show a metric consistent with the applications made in ANAREDE, involving power flow. We plan to extend the use of the metric, considering the influence of renewable generations, especially wind and photovoltaic, which are expanding in Brazil, especially in the Northeast region, where SE Bongi is located.

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