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# Control model for distributed generation and network automation for microgrids operation

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ABSTRACT

This paper describes a model for power distribution grid simulation with distributed generation, designed to be a simulation environment of two proposed elements: (1) an algorithm to reconfigure the circuit topology to enable a microgrid during an outage of power supply, and (2) a specific limiter to allow safe operation of distributed generation in the network. Moreover, an interface of the simulation model with a SCADA was designed to suggest possible operational screens for both: the generator and the utility. The simulation model was designed with a synchronous generator with all cogeneration typical controls: speed, active power, voltage, reactive power and power factor. Thus, it is possible to simulate critical situations with all control modes available in a typical cogeneration plant in addition to the proposed limiter. Due to the immense number of possible combinations of circuit breakers in the grid, the proposed algorithm is based on genetic algorithms to enable a fast enough autonomous reconfiguration to avoid the outage perception by the customer.



## 1. Introduction

Electric distribution companies have been facing tough challenges year after year to enhance the quality of its services to society. The Brazilian Electricity Regulatory Agency (ANEEL) evaluates the quality of services of each utility by using a set of indicators, and defining goals for some of these. The Customer Average Interruption Duration Index (CAIDI) and the Customer Average Interruption Frequency Index (CAIFI) are two major regulated indicators for any utility in the country [1]. As its name suggests, the CAIDI measures the average time that each consumer unit did not have power supply, while the CAIFI is the average number of interruptions each customer was exposed to.

AES Eletropaulo is a major utility in Brazil that provides electricity distribution services to 20.1 million customers and 6.7 million consumer units to 24 cities in the metropolitan area of the city of São Paulo. This is a highly power intensive region, responsible for 10.5% of all electric energy consumed in Brazil, which makes AES Eletropaulo the utility with the highest energy consumption in the country. Figs. 1 and 2 illustrate the evolution of the mentioned indicators in AES Eletropaulo utility over the last 4 years.

As can be inferred from Fig. 1, the CAIDI of AES Eletropaulo has decreased to around 8 h, while the CAIFI has been around 4.5, and both have been steady on these values ever since. Based on the experience of the Operations Department of the utility company, increasing the number of emergency response teams on the streets does not significantly reduce either CAIDI or CAIFI anymore. It means that these values have saturated over the existing infrastructure of the company. Therefore, in order to continue improving the quality of services provided, i.e., reducing the CAIDI and CAIFI indicators, it is necessary to have technological advances in infrastructure, such as enhancing smart grid functionalities.

This paper presents recent studies conducted by the author in the company to provide technological alternatives to continue decreasing the Equivalent Duration of Interruptions per Consumer Unit. Although, the most part of interruptions are due to faults in the medium voltage distribution system, in AES Eletropaulo, around 70% of CAIDI, the proposed approach requires relatively minor investments (changes in the SCADA algorithm for each substation), and it will positively increase the quality of service, this kind of improvement are continuously encouraged in the company.

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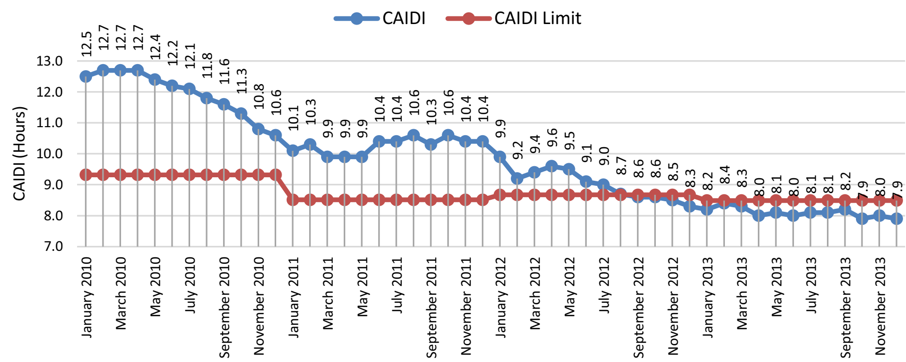


**Fig. 1.** CAIDI evolution over the last four years in AES Eletropaulo utility.

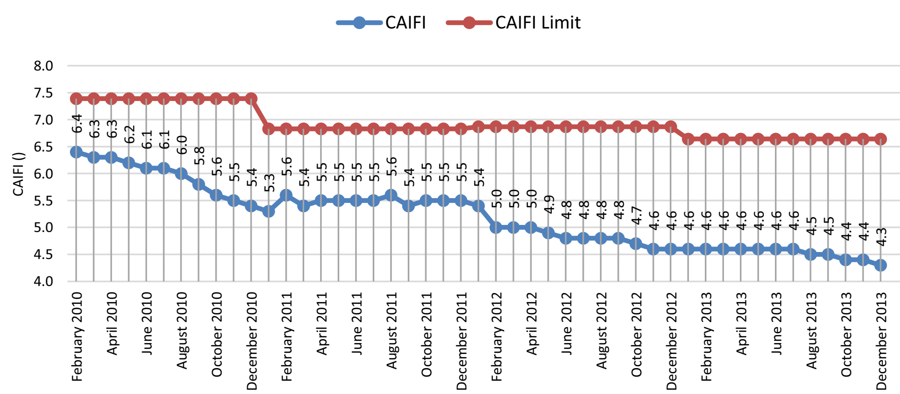


**Fig. 2.** CAIFI evolution over the last four years in AES Eletropaulo utility.

AES Eletropaulo receives connection inquiries from industrial plants to enable power export by them. These inquiries are often issued by industries connected in the medium voltage level of 13.8 kV. The impacts of distributed generation are well known and approached by available literature [2].

When an outage is detected in a specific feeder of AES Eletropaulo distribution network, where it is connected to an industrial plant with distributed generation (DG), this plant receives a transfer trip signal to disconnect the plant from the grid and interrupt the power export. The industrial plant operates only in island mode until the power supply from the utility company is restored [3]. This procedure is required considering the risks in letting customers around the distributed generator to be supplied exclusively by the DG and not to a regular supply. However, as described previously, the longer the outage, the higher will be the CAIDI, which makes it harder for the utility company to achieve its targets set by the regulatory agency. Therefore, this paper presents an alternative to the transfer trip in order to keep the DG exporting to its neighborhood during a loss of power supply in the substation. This functionality enables a microgrid configured by an autonomous system based on genetic algorithms, enhancing the continuity indicators of the utility company.

This paper also approaches the development of a simulation model for a synchronous generator connected to the medium voltage grid, namely, the primary feeders. The SCADA (Supervisory Control and Data Acquisition) system interfaces with the simulation model to suggest operational screens for both the generator and the distribution company, which allows training the operations personnel in dealing with critical situations in distributed generation. Based on this proposed simulation model, this paper presents the control modes and limiters proposed for synchronous machines of typical distributed generation plants.

## 2. Literature review

### 2.1. The generation unit

This study focuses on synchronous generation units, typically represented by Fig. 3. Either a turbine or an engine drives the synchronous generator in majority of critical power export for distributed generation. The speed regulator is responsible for speed and power control that the turbine produces. Typically, this element has its feedback with speed sensors in the turbine shaft. Via active power transducers in the generator terminals, it might use more signals to improve control performance such as valve position feedback, but it is not usual for speed regulators used in distributed generation. Then, it actuates the admission valves of fuel, steam or water, depending on the type of turbine or engine. Fig. 3 indicates a power transformer that might be used for generators of 4.16 kV, for example, but it can be neglected when the machine is suited to the voltage level of the distribution grid.

The second major control element in the generation unit is the Automatic Voltage Regulator (AVR). This device has three key control modes: voltage, reactive power and power factor control. The voltage regulator sets the current that supplies the excitation system, which may be static or brushless. If it is static, the AVR usually controls the trigger angle of a controlled rectifier bridge that supplies the generator field directly. Thus this field current is relatively high, and requires suitable rated semiconductors. In brushless case, the AVR produces a certain current level by a dc–dc converter; this current will supply the exciter machine that produces the proportional field current suitable to magnetize the generator rotor.

The simulation model built in this study has been developed based on the control modes available. Specifically, speed regulation has two key aspects: to keep the turbine operating at its rated speed, without excessive efforts, which the shaft material can handle, and