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Influence Analysis of Photovoltaic and Energy Storage Systems in a Distribution System in the Context of Permanent Regime Voltage using the OpenDSS

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I - Introduction

The growing energy demand coupled with the possibility of reducing conventional fuel supply, along with growing concern about environmental preservation, has driven research and development of alternative energy sources less pollutants, renewables and that produce little environmental impact. Among the alternative sources, electricity from photovoltaic panels (PV) is currently considered to be the most useful source of natural energy, since it is free, abundant, non-polluting, distributed along the Earth and participates as a factor of all other processes of obtaining energy on Earth.
In Brazil, the body responsible for the production, transmission and commercialization of electricity is ANEEL – National Electric Energy Agency.
Different solutions to mitigate unwanted voltage levels, or sudden fluctuations of the tension, in low voltage residential networks with photovoltaic systems have recently been proposed and tested, including the use of new devices (e.g., switches, load drifting, battery bank) and topological arrangements (such as ring operation).
In this sense, this article aims to study the influence of the flow of surplus power in a given system for different cases with the aid of OpenDSS software. In addition, the system behavior will also be analyzed when a battery bank is inserted into a given consumer, identifying its influence on the circuit.

II – Methodology

OpenDSS is an open source program that operates in the field of frequency and presents special resources to create models of electricity distribution systems and perform analyses related to distribution planning and energy quality. It also has the ability to perform power flow simulations for both a specific time and a time interval. In addition, it is able to model n-phase lines of arbitrary configurations.
The system present in Figure 1 indicates the base circuit to be simulated in OpenDSS. This represents actual data obtained from [7] and constitute a 30-bus system. In it, the electricity grid is constituted, a transformer with the ratio of 138/13.8 kV at the exit of the substation, and another transformer of 13.8/0.22 kV in consumers, and a set of photovoltaic plates that is not present in the figure, as this is inside the residence.

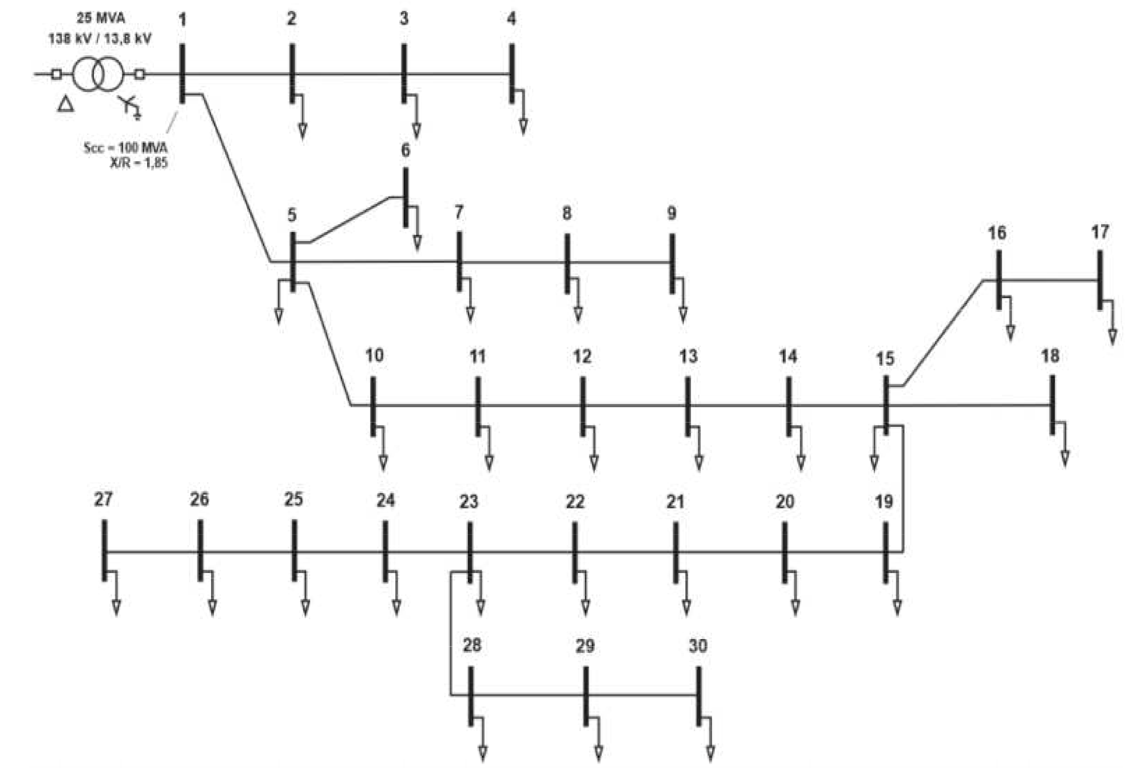

Fig. 1 – Base electrical system.

For the sizing of photovoltaic panels, the demand value of each load was obtained through the active and reactive powers.
The battery bank was sized considering two charging and unloading situations.Charge situations (Pin[t]) and discharge (Pout[t]) can be observed in Figure 2.

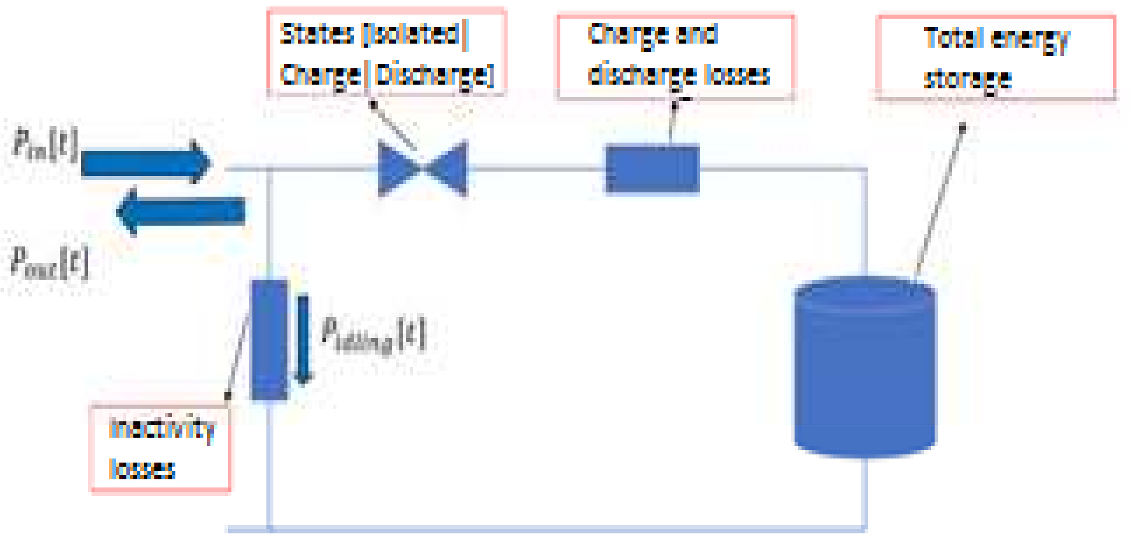

Fig. 2 – Battery storage system scheme.

knowing the losses generated by the battery while charging and unloading, and knowing the value of the power of each charge, considering the efficiency of the charge and discharge of energy is 90%, obtain the total power that the battery banks will have to compensate. Inactivity losses are considered to be 1% of the device's rated power.
The use of batteries in power-compensating systems is intended to control the voltage. It is worth noting that this control can be both for increased tension and to decrease it (this, however, is less usual for this application).
Five cases of analysis were carried out using the Figure 1 system as a reference, which are highlighted below:

- **Case Study 1:** Simulation of the system without DG.
- **Case Study 2:** Simulation with an increase of 30% DG
- **Case Study 3:** Simulation with an increase of 60% DG
- **Case Study 4:** Simulation with an increase of 60% DG adding a battery bank
- **Case Study 5:** Simulation with an increase of 60% DG adding installing 4 sets of battery bank in different consumers.

The representative curves of consumption classes for residential consumers were obtained through measurements on weekdays, provided by energy concessionaires, made in tariff review campaigns requested by ANEEL . For all studies, the tension curve was obtained for two buses: the closest to the substation (bus 2) and another as far away as possible (bus 24).

IV – Results

For the first case, the electrical system without distributed generation was analyzed. Once modeled in the software, the tension curve was obtained for consumers present in buses 2 and 24, as can be seen in Figure 3.

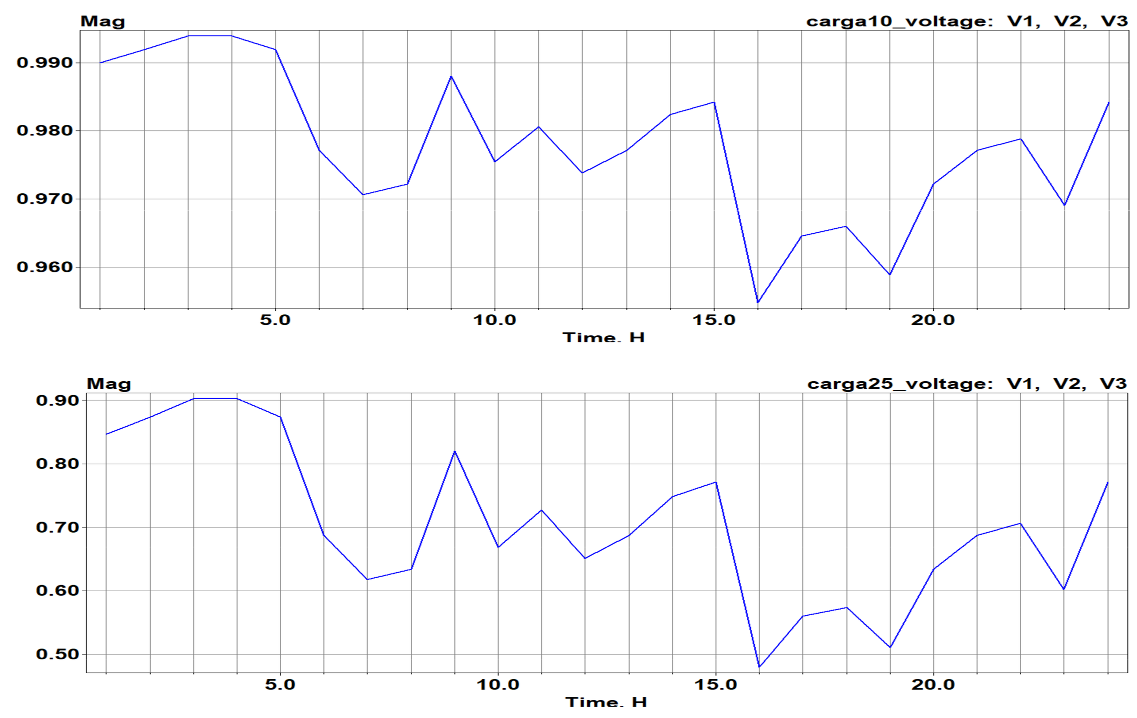

Fig. 3. Voltage on bus 2 (up) and 24 (down) consumers

The second case now consists of the same system, but with 30% distributed generation which tensions are shown in Figure 4.

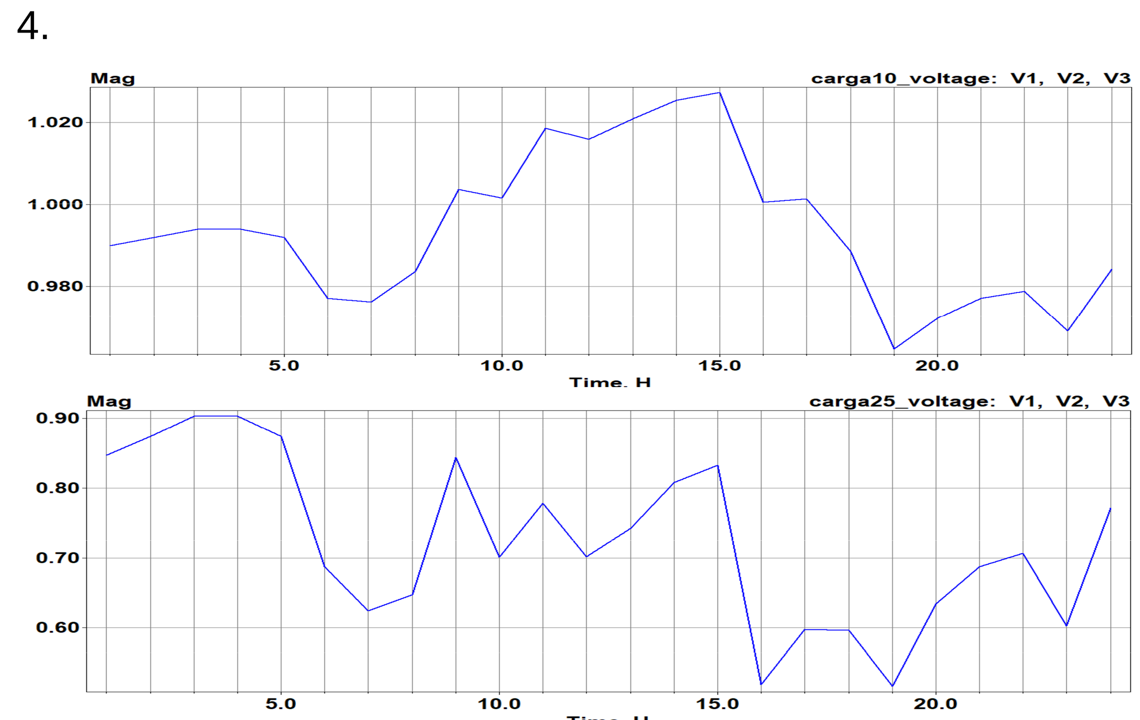

Fig. 4. Voltage on the consumers of bus 2 (up) and 24 (down) for 30% DG

In Case 3 the 60% of DG was inserted into the systems showed in Figures 5 and 6.

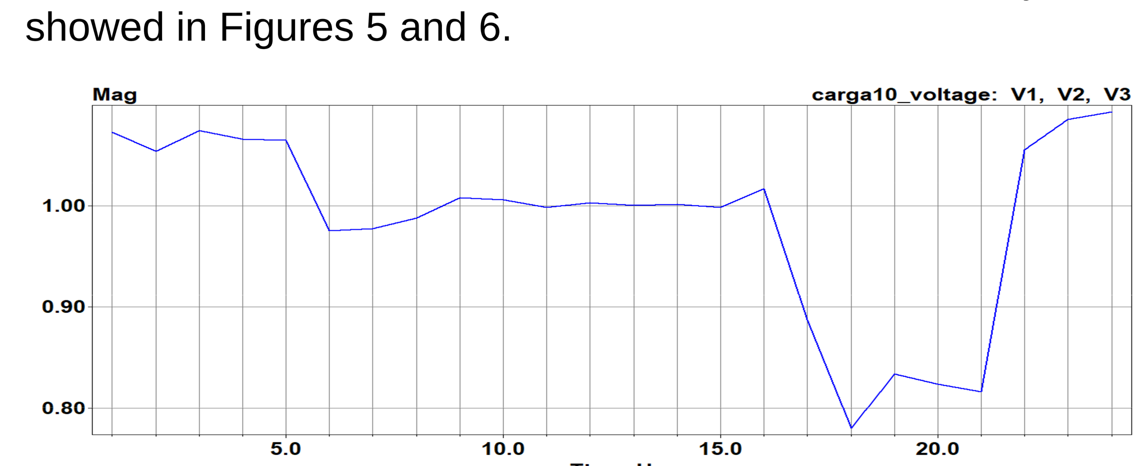

Fig.5. Voltage on the consumer of the bus 2 for 60% DG

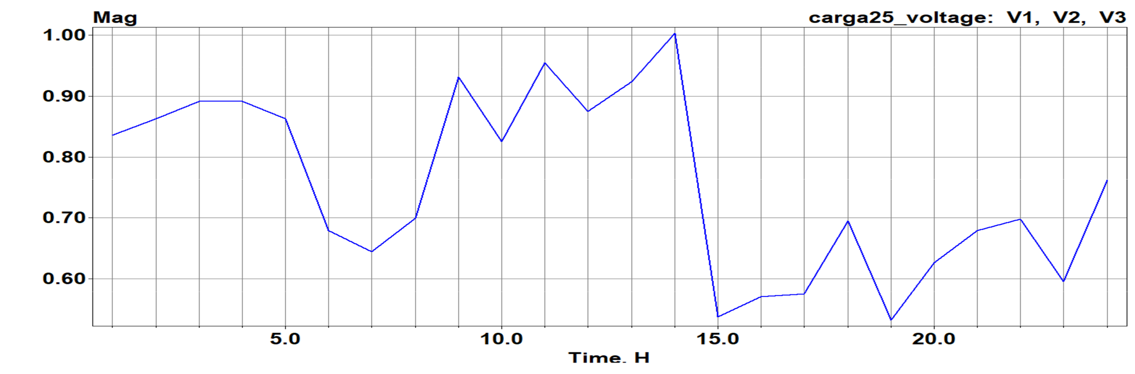

Fig.6. Voltage on the consumer of the bus 24 for 60% DG

Figure 7 exhibit the results for case 4.

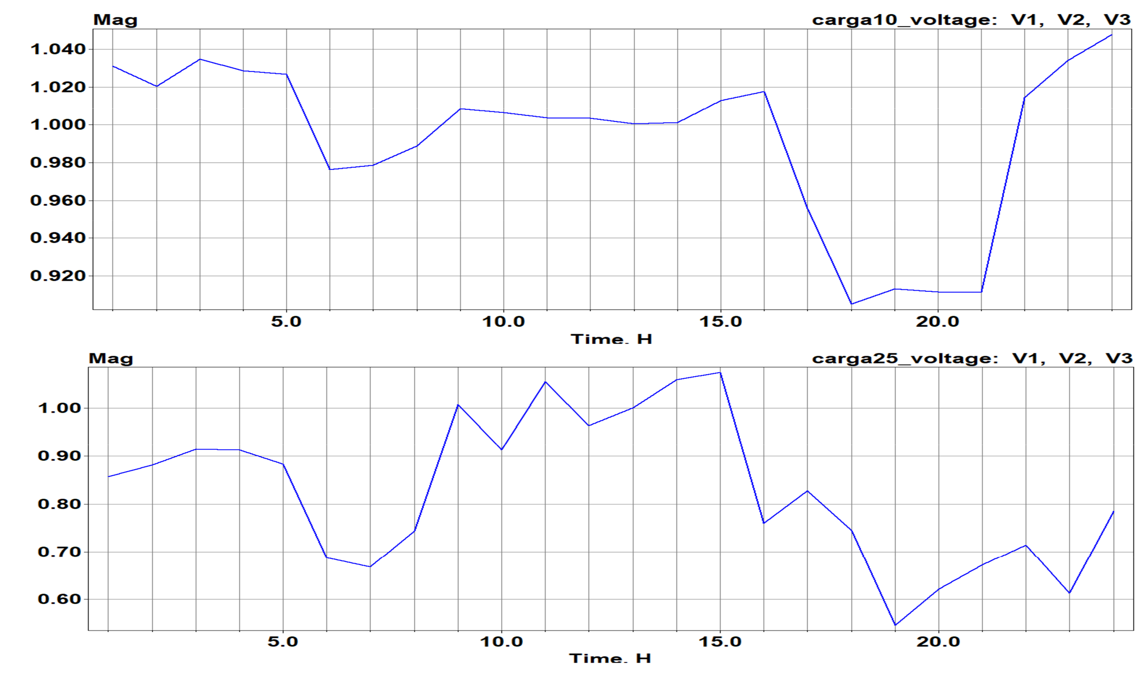

Fig.7. Voltage on buses 2 and 24 consumers with battery.

The results for Case 5 was shown in Figure 8 for both buses. The table I presents results for maximum and minimum voltage for all cases.

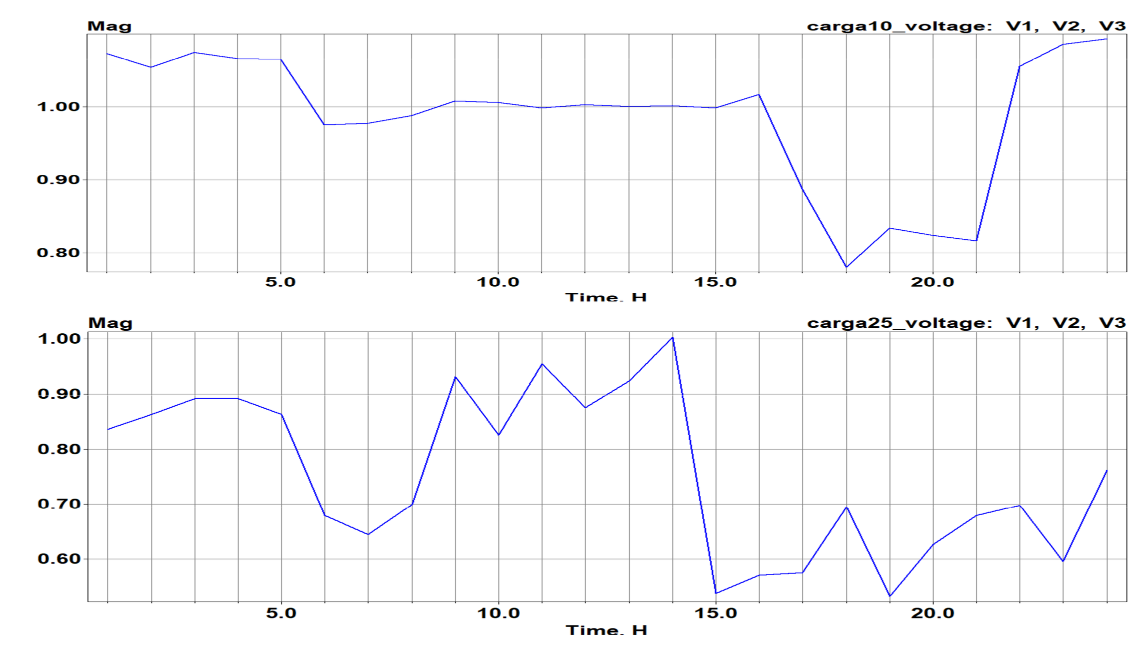

Fig.8. Voltage on buses 2 and 24 consumers with 4 batteries

Table I. Result of each simulation on buses 2 and 24.

Case	Maximum voltage [V] (Bus 2)	Minimum voltage [V] (Bus 2)	Maximum voltage [V] (Bus 24)	Minimum voltage [V] (Bus 24)
1	0,99	0,96	0,9	0,5
2	1,02	0,97	0,9	0,53
3	1,01	0,97	1,05	0,53
4	1,04	0,92	1	0,6
5	1,01	0,8	1	0,6

VI - Conclusions

In this work, a study of reverse power flow and the application of battery banks in the network were presented. Five case studies were conducted in which tension increased strain was proven in loads that there were no photovoltaic panels through the system's power flow. The use of DG improves the stability of tension in the system when it is decentralized in the network, as observed in case 3, which consisted of the insertion of 60% of generation distributed in the system.
In other time, a set of batteries was inserted to present increased average voltage, and the possible problem that may occur from voltage sinking.
Moreover, there was a drop in compensation provided by the battery bank with the increase in it in the network, with tension sinking on bus 2, as noted in the case study 5.

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