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Analysis of Synthetic Inertia Applied to Wind Farms

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I - Introduction

In order to meet carbon emission reduction targets, in addition to meeting the sustainable part aimed at improving the environment, many countries have begun to look more carefully at renewable energy sources, such as hydroelectric, photovoltaic, biomass and wind [1] . In recent years, wind energy has shown an accelerated growth rate over renewable energy sources, largely due to government incentives, the need to diversify the energy matrix, reliability, among other factors [2]. However, some problems, such as its low inertial response, will be felt in the near future, given this rapid insertion of renewable energies, thus inducing instability to the system [3]. This work aims to understand and analyze how synthetic inertia influences in the Brazilian electrical system. With the increase of renewable sources, mainly with the increasing advancement in distributed generation, largely due to the increase in photovoltaic energy and also by wind power plants, both being controlled by electronic converters, the kinetic energy has decreased, thus causing instability in the system, when there is a failure of some bar, for example. For this reason, the study aims to study the synthetic inertia extracted through the blades of wind generators, analyzing the influence caused on the 14 bus system, applied to the SIN.

II – Methodology

In this aspect, a feasible methodology consists of emulating the inertial response through the control of the converters. This technique is commonly called "synthetic inertia". Based on the balance equation, given by equation (1), the rate of change of frequency (ROCOF) will be inversely proportional to the total inertia of the system. For this reason, what is called "synthetic inertia" [3][10] is executed. The concept of synthetic inertia consists of temporarily extracting the rotational energy stored in the turbine and transforming it into active power, during underfrequency events, by additional control functions in the wind turbine converter controller. It is expected that, in this way, it will achieve a greater expansion of the sector, contributing with a greater participation along with hydroelectric and nuclear [10].

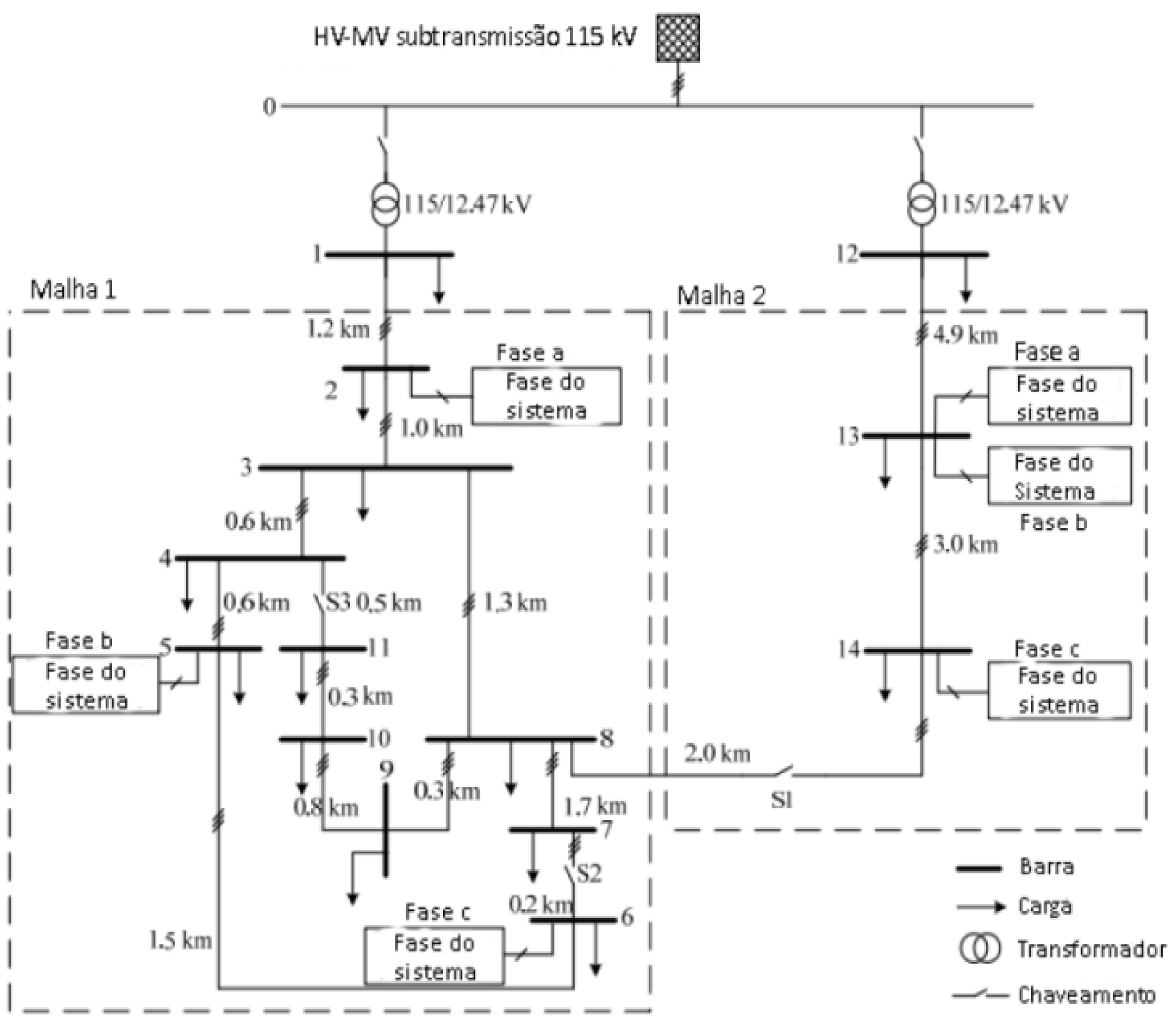

Fig 1. topology of the test system.

The change in kinetic energy is similar to the changing state of the rotation mass of motion, causing the frequency to change according to the angular velocity and how much the generating unit has influence on the system [20].
Wind turbine generators cannot respond instantaneously to imbalances, as with the mechanical power extracted from the rotating mass. Controllers are used to complement this missing phenomenon that emulates the inertial response of synchronous generators [20].
With this, it is concluded that the contribution of the synthetic inertia is not enough to avoid high frequency dips in the case of failures of several generation units. With this control, there is the disadvantage of delaying frequency restoration and imposing a greater demand on the primary control, but as an advantage, it reduces the frequency drop in the system in the cited cases [20] [21].

The computational simulation of the study was performed on the MATLAB computational platform, within the module specialized in block diagrams and simulation of engineering systems, Simulink. The base system used to carry out the simulation, for testing the studied theory, was the CIGRÈ with 14 buses, based on the configuration of North America [21]. This system was implemented with some changes in values, since components were added to some bars of the system.

A. Case 1: North America Cigre Configuration

The distribution feeders are all three-phase, thus allowing a degree of flexibility in structuring the system grids. The system has 14 buses, with nominal voltage in the three-phase sections of 12.47 kV, with a frequency of 60Hz. It contains voltage drops represented by resistors [21]. Meters were placed on all the bars so that, in this way, it was possible to visualize the resulting voltages and currents in the same. The total power demanded by the system is 12.7307 MW.
The original wind farm of the studied model consists of 9MW of power, using six turbines connected to a 25 kV distribution system that exports energy to the 120 kV grid through a 30 km and 25 kV feeder [22]. The number of turbines was changed to 5 turbines of 1.5 MW, totaling a power of 7.5 MW.

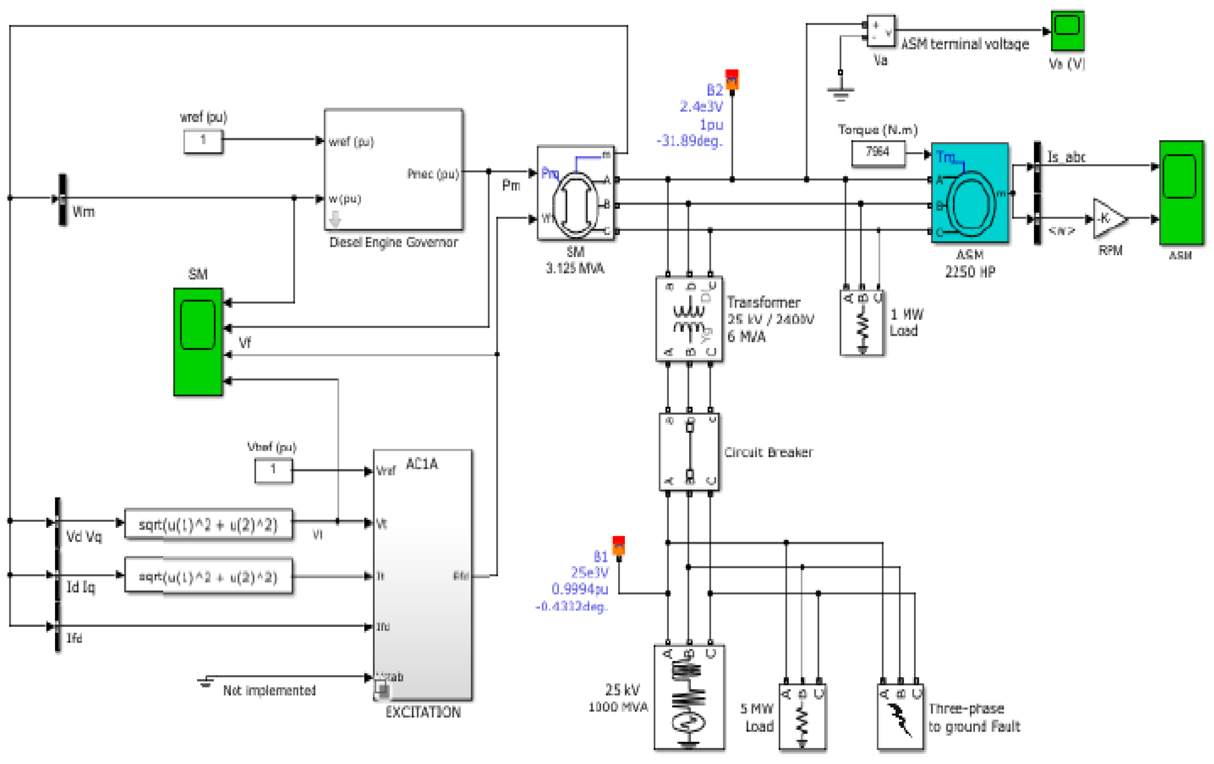

Figure 2 : - Synchronous diesel generator

III – Simulation Results

After simulating the circuit explained in the previous items, the result obtained in the system buses was first observed – in order to observe all the voltage drops that were being imposed on the system as a whole, in addition to evaluating their coherence.

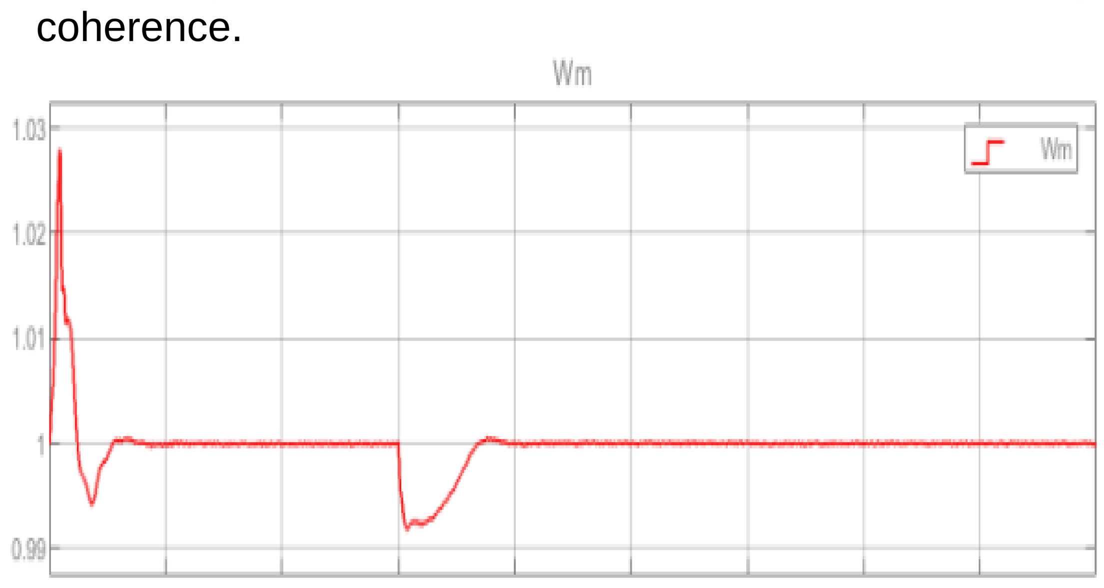

Fig. 3: Wm (speed)
DG

It is also noted that there are losses when advancing the bars, this is due to the existing lines between them. Then, the outputs of the synchronous generator are verified and the influence that the load upon entering had on the system as a whole Figures 3 to 8are the results displayed by the synchronous generator.

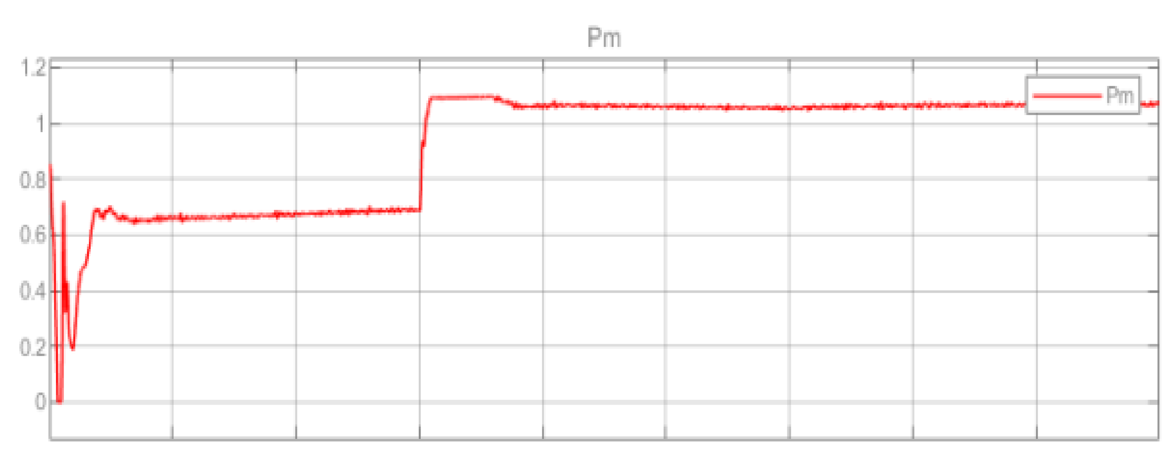

Fig. 4: – Pm (power)

Figures 3 and 4 show that the synchronous machine has an initial period of a few seconds to stabilize. When the load enters, at 15 seconds, there is a drop in speed, which is returned close to 18 seconds. With regard to power, it appears that it increases with the entry of the load and is maintained, jumping from 0.7 to 1.06

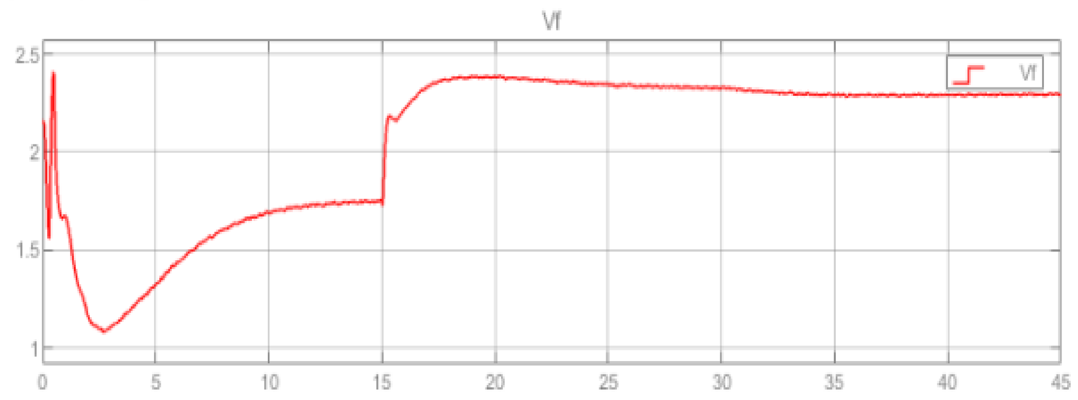

Fig 5 : Vf

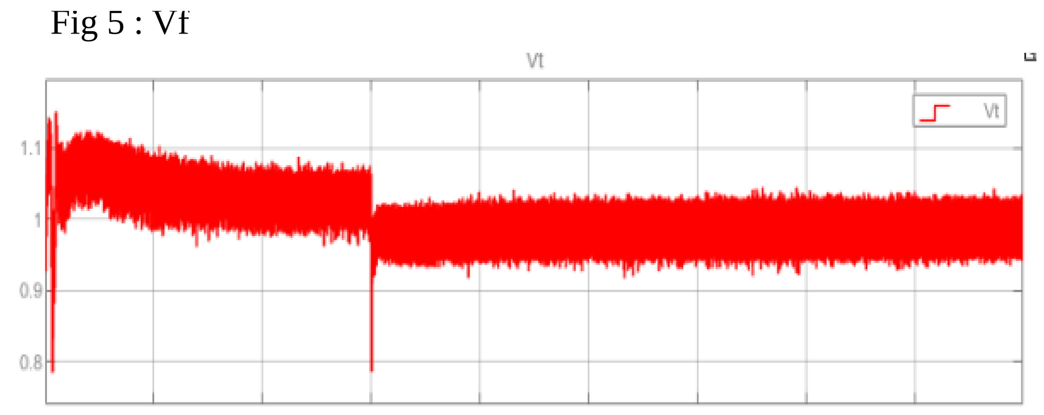

Fig. 6 : Vt

In figure 5 it can be seen that after machine stabilization, there is an increase and when the load enters the system, it stabilizes at 2.3. In figure 6 it can be seen that it was remaining close to 1 pu, when the load entered, it had a sudden drop and stabilized again at 0.97, In figure 7, it is possible to better observe the load entry period.

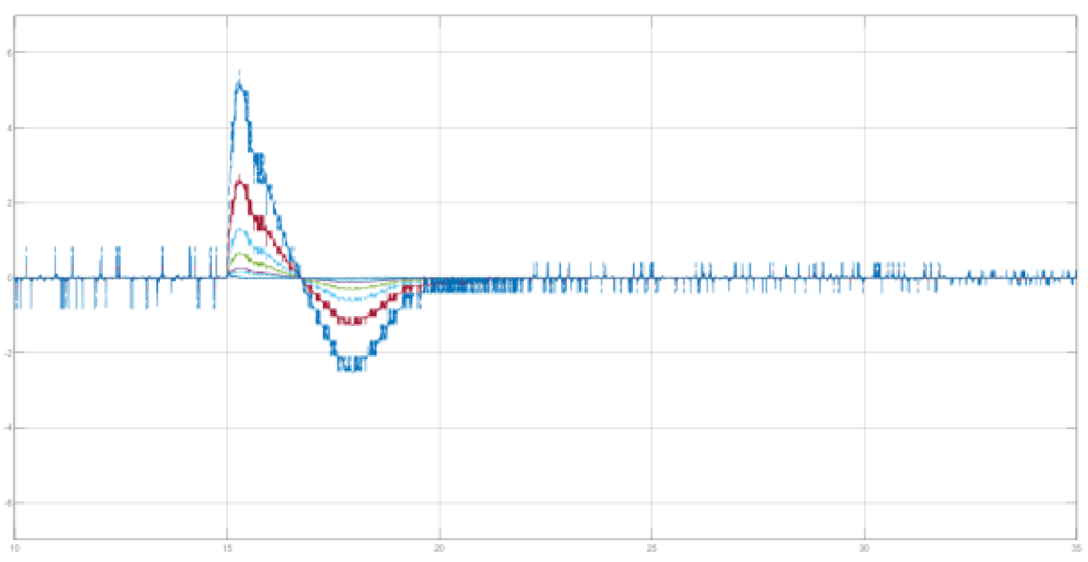

Fig 7: Delta P

It is observed that the greater the Hsys value, the greater the amplitude reached during the instability period. Table 2 displays the peak, trough and time to stabilize again values of the simulated Hsys values. Analyzing Table 2, there is evidence that the higher Hsys, the greater the amplitude of oscillations, however the system manages to stabilize with similar times, showing that the control performed is correct.

Table I. Variation Values of Hsys

Hsys	Peak value	Valley Value	period
1	0.2402	-0.04785	2.885
5	0.0729	-0.03138	2.906
9	0.1313	-0.05649	2.906
13	0.1896	-0.0816	2.906
20	0.2917	-0.01255	2.906
50	0.7292	-0.3138	2.906
100	1.458	-0.6277	2.906
200	2.917	-1.255	2.906
400	5.833	-2.511	2.906

VI - Conclusions

The increase in the share of renewable energy sources, with a greater emphasis on those interfaced by converter, in the global energy matrix has been presenting major challenges. In this work, the problem of effective inertia in the electrical system was exposed, which can cause large oscillations and instabilities to the system. . After parameterizing the blocks used, the results obtained by making changes to the Hsys are compared and seeing that the larger it is, the greater the peak will be, but the response time is similar for all. In this work, basic concepts were also presented for understanding the presented problem, such as the nature of wind generation, methods of controlling wind turbines, influence of wind energy on the Brazilian system, being the second largest source of energy in the country.