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SYNCHRONOUS MACHINE DYNAMIC ANALYSIS BEHAVIOR USING SCADA

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Abstract: The study of the V-curve characteristics of synchronous machine was made to prove that the operation of the synchronous generator in underexcited or overexcited mode can be monitored for different values of the reactive power. If the generator operates in overexcited mode, it delivers reactive power to the network, and if operates in under-excited mode, absorbs reactive power from the network. The V-curve of a synchronous machine shows its performance in terms of variation of the armature current with the field current when the load and the input voltage to the machine are constant. When a synchronous machine is connected to an infinite bus, the current input to the stator depends on the shaft-load and on the excitation (field current).

Keywords: SCADA, real data measurement, synchronization, synchronous generator, synchronization relay.

1. INTRODUCTION

This paper provides the fundamental knowledge regarding the effect of changing in excitation of the synchronous generator [7]. The same synchronous machine can be used as a generator or as a motor. When it converts mechanical power or energy into electric power or energy, it is called a synchronous generator. On the other hand, when it converts electric power or energy into mechanical power or energy, it is called a synchronous motor.

The V curve is the graph showing the relation of the armature current as a function of the field current in synchronous machines. The purpose of the curve is to show the variation in magnitude of the armature current as the excitation voltage of the machine is varied.

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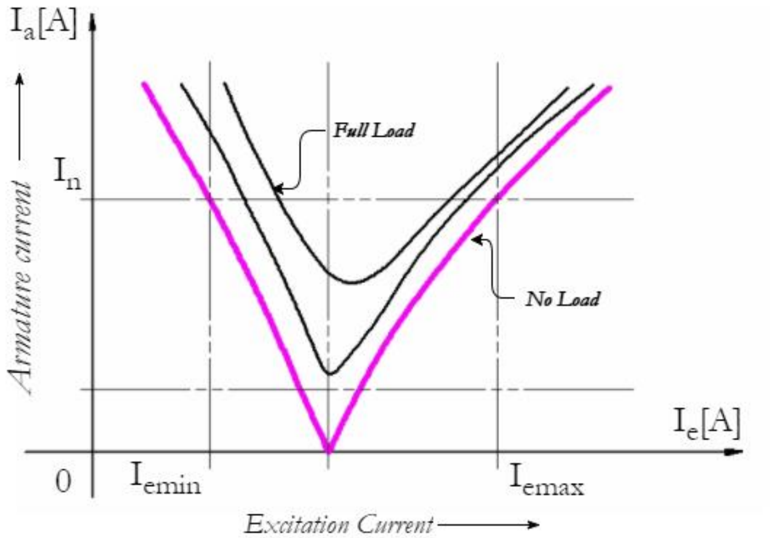


Fig. 1. V curves of the synchronous machine

For a given level of real power transmission, the position on the V-curve is controlled by the magnitude of the field current.

2. PARALLEL OPERATION OF ALTERNATORS

The V-curve characteristics are made based on the single line diagram shown in figure 1. The double voltmeter/frequency meter measures the voltage (UB-main voltage and UG-generator voltage) in order to give you information when both are matched.

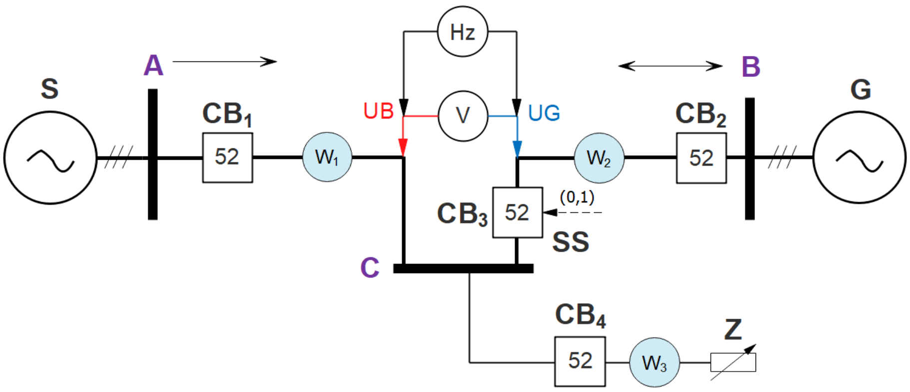


Fig. 1. Single line diagram of the synchronous generator parallel manual operation (The voltmeter (V) and the frequency meter (Hz) measures the input voltage L1-L2 – UB with the input voltage L1-L2 of the generator – UG. The synchronization circuit breaker 52 – CB3 is controlled by SCADA. The phase sequence is 123 related with the phases L1, L2 and L3)

The prime mover speed or the frequency was controlled from the SCADA software co establish the set point (of the motor-driven power supply) to match the generator frequency to the main system frequency. By keeping the load constant, the curve will be plotted between field current Ia and armature or load current Ie. Using SCADA, the excitation level of a three-phase synchronous motor will be controlled. An automatic synchronization can be performed using an automatic relay (ANSI Code 25). This relay is a device that can perform all the functions required to synchronize a generator. It can measure the parameters needed for synchronization and it can close the breaker.

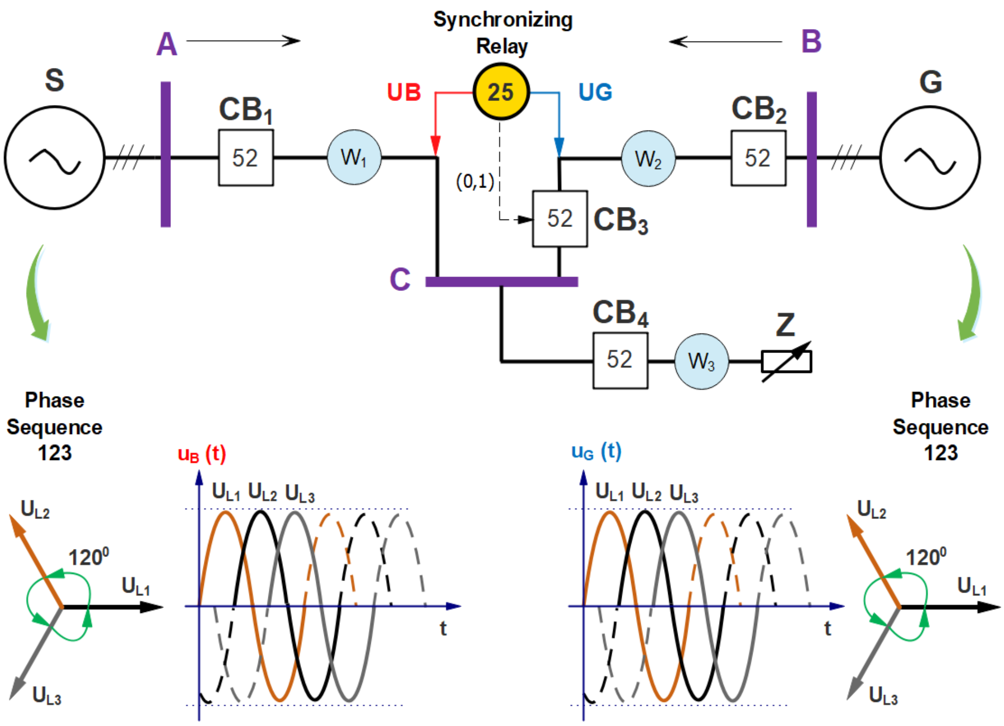


Fig. 2. Single line diagram of the synchronous generator parallel automatic operation (The numerical synchronizing relay measures voltage and frequency of two inputs. The voltage, frequency and phase angle of the Generator Input (UG) are individually compared with those of the Bus Input (UB) considered as reference. The synchronization circuit breaker CB3 is controlled by the numeric relay. The phase sequence is related with the phases L1, L2 and L3)

The generator G (the generator to be put in parallel with the mains) has a prime mover. Once the prime mover is up to its rated speed and the generator is producing voltage at the nominal frequency, the relay (24) will make decisions in the synchronization process and will give the "switch on" command to the proper circuit breaker CB3 (52).

The control is made from SCADA software via a dedicated communication HUB, as shown in figure 3.

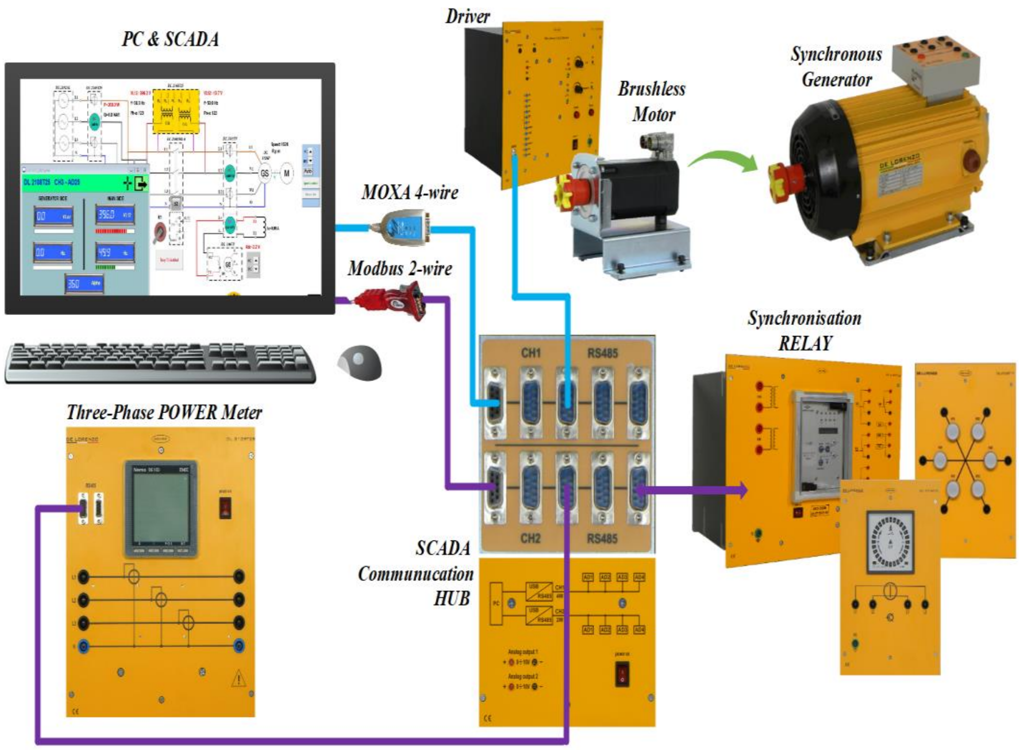


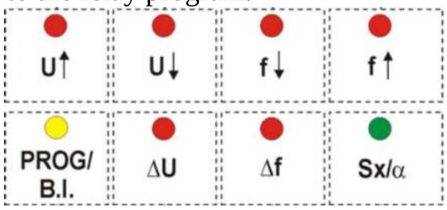
Fig. 3. MODBUS communication diagram for dynamic analysis

3. DINAMIC ANALISIS OF THE SYNCHRONOUS MACHINE

Figure 4 shows the schematic diagram related to the experiment, where the prime mover (M - brushless motor) will be controlled using SCADA. The generator stator configuration can be in star/delta, but for this experiment we have selected the star connection (the parallel coupling will be with the power network). The electrical parameters of the synchronous generator will be measured with the three phase measuring devices. The generator excitation will be provided from a DC power supply.

For the live bus synchronization, the synchronization relay will supervise the closing to operate the breaker at a point when the waveforms are in sync. The busbar is then directly connected to the load, the local grid for example. For the automatic synchronization, as shown in figure 4, using the three-phase power meter the user will measure the BUS parameters and using the will measure the GENERATOR parameters. The generator field excitation will be measured with the DC part of the three-phase measurement module.

The front panel relay has LEDs that are Flashing, that means that the associated parameter is not yet matched (ΔU, Δf or the displacement angle from the relay display). The LEDs will turn OFF one by one when the synchronization conditions are according to the relay program.



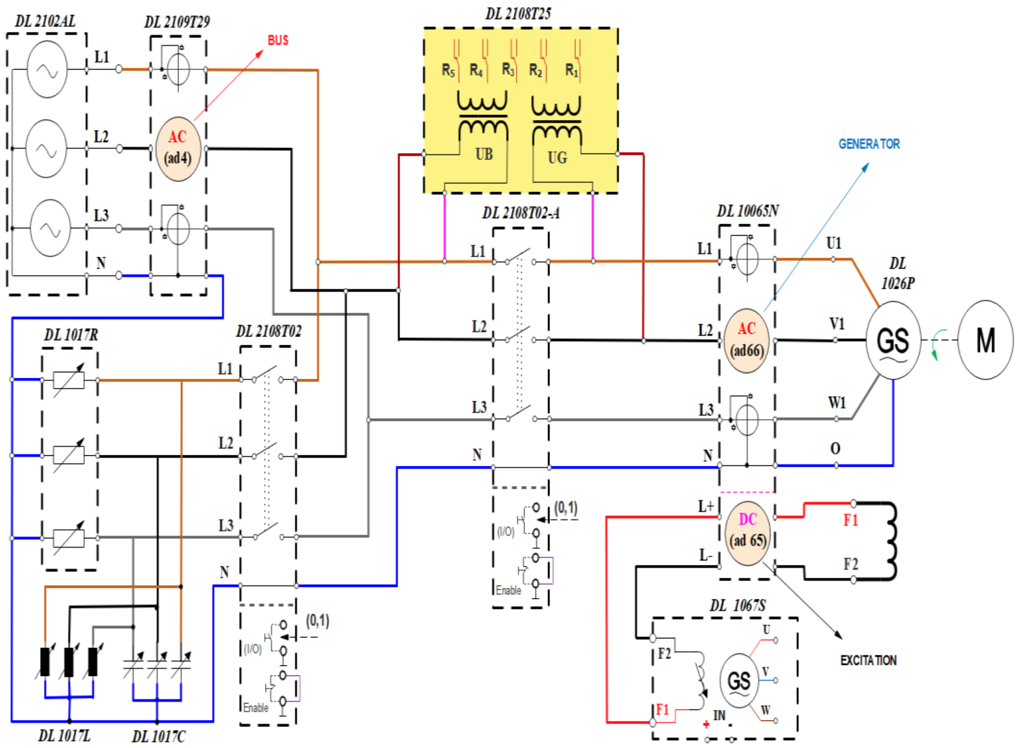


Fig. 4. Schematic diagram of the automatic synchronization (generator with the mains).

The measured values of the armature voltage (UG) and main grid voltage (UB) can be seen in the SCADA software (2). The voltages values are indicated on every line from the schematic diagram. By pressing INC/DEC (1) from SCADA will increase (decrease) the excitation current, until the generator amplitude voltage (UG) is as close as possible with the mains amplitude voltage (UB).

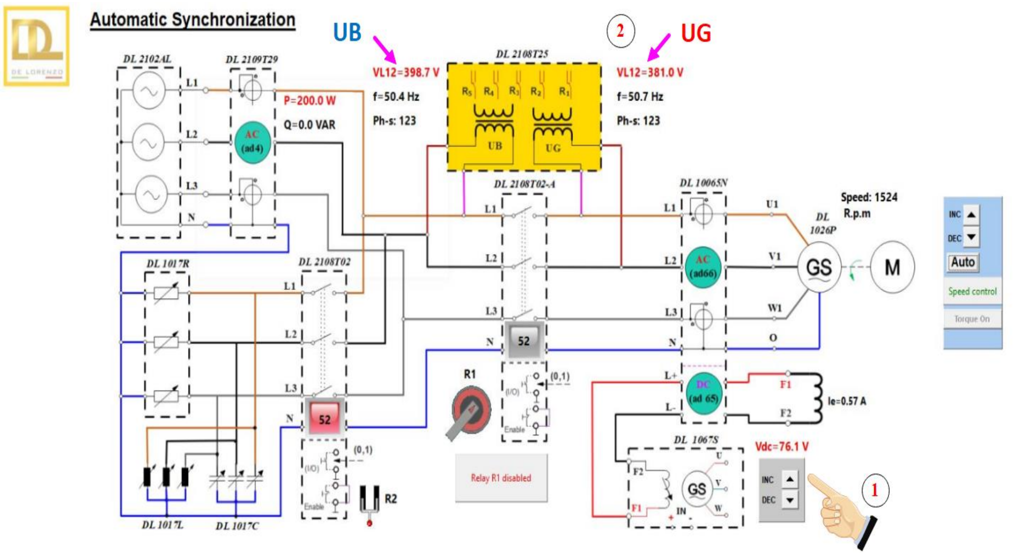


Fig. 5. Dynamic analysis using SCADA

The automatic synchronization relay (25) can be programmed to operate in different systems conditions (programmed using a dedicated software). The angle where the circuit breaker closing command is issued (energization of the output relay) can be different according to the programming of the parameter [tCB = 0,05 - 0,50 / Dis.] which represents the closing time of the circuit breaker for automatic selection of the closing angle.

If the closing time of the circuit breaker is disable → tCB = DIS, then the closing command is issued as soon as phase difference α between the generator voltage (UG) and bus voltage (UB), while decreasing, is below the set value [α], as shown in figure 2a.

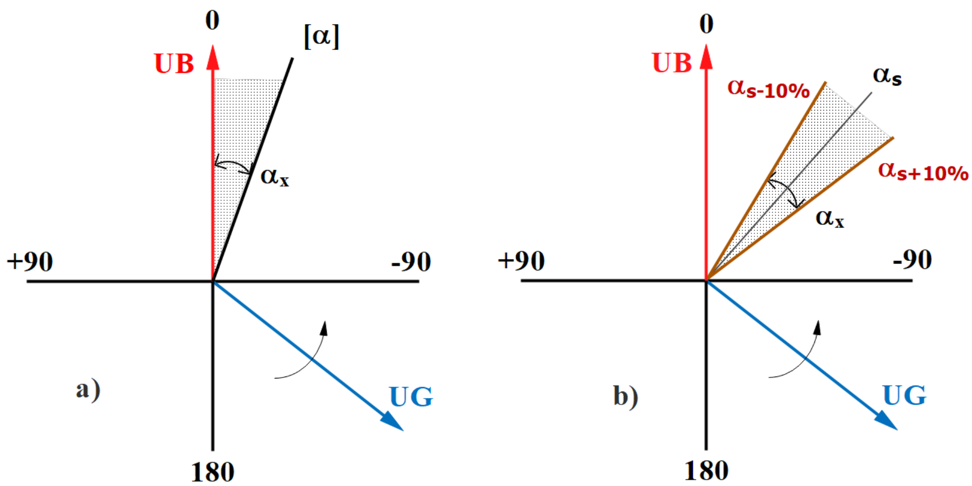


Fig.6. Phase angle characteristic for closing the synchronizing relay

When the power P = 0, i.e. in no-load operation, the "V" curve touches the abscissa axis and it is particularly interesting when the synchronous motor is used as rotating capacitor to improve the power factor in the installations. With a suitable over excitation, the motor absorbs current suitable to offset the lag current due to the presence of inductive loads.

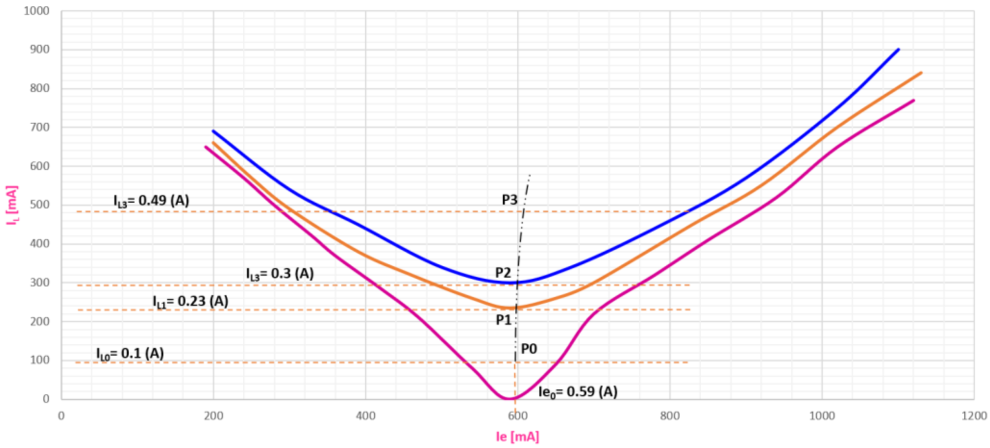


Fig. 7. Dynamic V curves of the analyzed synchronous machine

The experimental results can be integrated with a simplified synchronous generator to provide an acceptable level of power quality to the load [5], [6]. Performing the tests was considered that the safety is dependent on the awareness, concern and prudence of all those who operate and service machines and the numerical relay [2], [4].

In [1], [3] was performed in depth detailed analysis regarding the control of synchronous machines and the synchronization issues.

4. CONCLUSIONS

Parallel operation of generators is realized automatically when all parallel connection conditions are fulfilled. The system doesn't require additional measuring tools for monitoring and control processes. The developed automatic synchronization relay is fast, cost effective, reliable and precise to be used for monitoring, measurement and parallel operation of the synchronous generators. The knowledge used in the paper are very useful in understanding the smart grid concept. The synchronization of generators in parallel allows a greater efficiency of the equipment, since in this type of installation it is possible to connect and disconnect one or more of the synchronized generators according to the demand of the electric network.

When the reactive power is zero, the machine is operating with unity power factor and the armature current drawn from the source is minimum. The armature current is plotted versus the field current to obtain the classical "V-curves".

REFERENCES

[1]. Betz, Robert E., et al. *Control of synchronous reluctance machines*, IEEE Transactions on Industry Applications 29.6 (1993): 1110-1122.

[2]. Dobra R., Buica G., Pasculescu D., Leba M., *Safety Management Diagnostic Method Regarding Work Cost Accidents from Electrical Power Installations*, Recent Advances In Industrial And Manufacturing Technologies, Proceedings of the 1st International Conference on Industrial and Manufacturing Technologies (INMAT '13), Vouliagmeni, Athens, Greece, May 14-16, pp. 58-63, 2013.

[3]. Guo, Yi, et al. *Time and frequency synchronization scheme for orthogonal frequency division multiplexing-based cooperative systems,* IET Communications 7.16 (2013): 1836-1843, 2013.

[4]. Niculescu T., Pasculescu D., *Use of numerical simulation to study capacitive loads which is connecting to an AC power source*, 15th International Multidisciplinary Scientific GeoConference SGEM 2015, Conference Proceedings, June 18-24, 2015, Book2 Vol. 1, pp. 391-398, 2015.

[5]. Pana L., Grabara J., Păsculescu D. , Pasculescu V. M., Moraru R. I., *Optimal quality management algorithm for assesing the usage capacity level of mining tranformers*, Polish Journal of Management Studies, Vol.18, No.2, pag.233-245, (2018), DOI: 10.17512/pjms.2018.18.2.1 9.

[6]. Utu I., Pasculescu D., *Power quality study in order to comply with European Norms*, Supplement of Quality-Access to Success, Vol. 18, S1, January 2017, pp. 366-371, 2017.

[7]. *** *Generator transmission and utilization*, www.deloreonzoglobal.com, last visited in October 2020.