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Effect of the Combination of UPFC and TCSC on the Improvement of Transient Stability of Electrical Network.

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SUMMARY:
This research document shows the state of an electrical network following a fault on a busbar (transient overvoltage). Starting from a real network with one source and 21 busbars; FACTS devices are inserted respectively a UPFC, TCSC and the combination of these two devices in order to see the effectiveness of the device in the three cases mentioned above. The study of these three cases is done in two parts, the first is the study of FACTCS (UPFC and TCSC) and the second is the simulation with the Matlab-Simulink software the network mentioned above.

Keywords: power grid, overvoltage, FACTS, UPFC and TCSC

INTRODUCTION

Improving power quality, increasing transited capacity and controlling existing networks can be achieved through the implementation of new technologies. Due to a low need, a cost, a high complexity and a certain mistrust of the operators with regard to their reliability, the power electronics (EP) systems dedicated to the electrical networks have not had so far only limited development. The oldest applications were mainly dedicated to the transport and distribution network for reagent management. The applications, which appeared later, of the FACTS (Flexible AC Transmission System) type, developed a whole range of series and shunt applications. The American research consortium EPRI (Electric Power Resarci Institute) launched the FACTS project (Flexible AC Transmission System) in 1988. The IEEE gives a definition of these systems. It is a power electronics structure or other static system that provides degrees of control over one or more AC network parameters to increase controllability and improve power transfer capability that aims to make networks more " flexible " . This concept brings together a multitude of very efficient devices with very short response times, which allow more flexible and adequate control of the various network parameters (voltage, impedance, phase shift). Thus, the power transits will be better controlled, which will make it possible to increase the stability margins or to tend towards the thermal limits of the lines.In order to study the effect of FACTS devices in a network, it is essential to model them and integrate them into the calculation algorithm to simulate their effects in the whole system.

Modeling and controlling a UPFC

Basic structure and working principle of UPFC

In principle, the UPFC is able to perform the functions of other FACTS devices, namely voltage regulation, power flow distribution, stability improvement and power oscillation attenuation. The UPFC device consists of two three-phase voltage inverters with GTO thyristors, one connected in parallel to the network through a three-phase transformer and the other connected in series with the network through three single-phase transformers whose primaries are connected to each other in a star.

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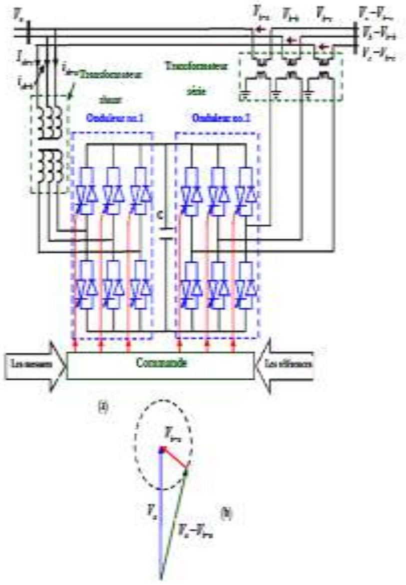

Figure 1 :Simplified diagram of a UPFC connected to the electrical network

The adjustment of the additional voltage in amplitude and in phase makes it possible to obtain three operating modes of the series part:

- Voltage control: if the voltage V_b injected is in phase with the voltage V_2 (Figure 4.16.a).
- Line impedance check: if the additional voltage V_b is in quadrature with the line current i_r (Figure 16.b) . This mode allows the impedance of the line to be varied like a series compensator.
- Phase control: if the amplitude and phase of the injected voltage V_b are calculated in such a way as to obtain the same voltage modulus before and after the UPFC (Figure 2).

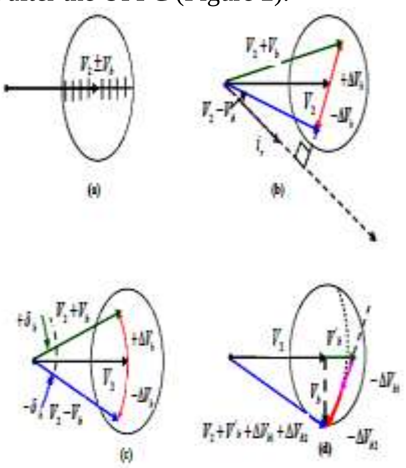

Figure 2:Principle of operation of a UPFC

Modeling of the UP FC

The mathematical model of the UPFC is established in order to study the relations which govern the operation between the electrical network and the UPFC in steady state. The basic one-line diagram in Figure 3 shows a UPFC installed in a transmission line.

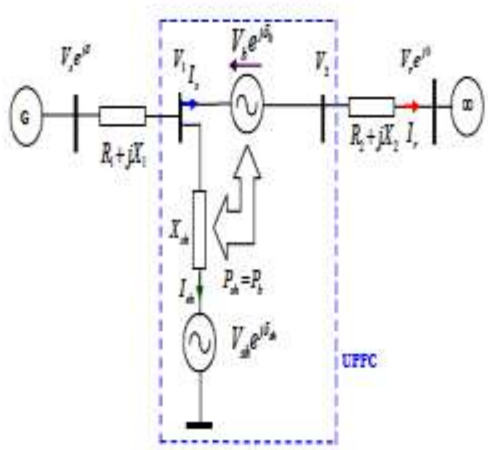

Figure 3: Mathematical model of the UPFC and the transmission system

The elements of the mathematical model of the UPFC and the transmission line are defined as follows

$\bar{Z}_1 = R_1 + jX_1$: The impedance of a phase of the first section of the line.

$\bar{Z}_2 = R_2 + jX_2$: The impedance of a phase of the second section of the line including the reactance

The powers injected by the generator into the network are given by:

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$$P_s = \mathrm{Re}\,al\left(V_s e^{j\delta} \overline{I}_s^*\right)$$

$$Q_s = \mathrm{Im}\,g\left(V_s e^{j\delta} \overline{I}_s^*\right)$$

We consider that the UPFC is installed two hundred kilometers from the generator of the SMIB system. The network parameters in reduced magnitude (pu) are:

$$R_1 = 0.026; R_2 = 0.03;$$

$$X_1 = 0.33; X_2 = 0.304; X_{sh} = 0.62;$$

$$V_{sh} = V_r = V_s = 1; V_b = 0.16; \delta_{sh} = 0$$

In this case the power equations are given by:

$$P_s = \mathrm{Re}\,al\left(V_s e^{j\delta} \overline{I}_s^*\right) = 0.137 + 1.86\sin\delta +$$
$$0.2\sin\left(\delta_b - \delta\right) + 0.02\cos\left(\delta_b - \delta\right) - 0.137\cos\delta$$
$$Q_s = \mathrm{Im}\,g\left(V_s e^{j\delta} \overline{I}_s^*\right) = 0.137 + 1.86\sin\delta +$$
$$0.2\sin\left(\delta_b - \delta\right) + 0.02\cos\left(\delta_b - \delta\right) - 0.137\cos\delta$$

Let us consider a value of the power injected by the generator P_s equal to 0.8 p. u in steady state in the "uncompensated" case (neglecting line resistances)

$$P_s = \frac{1}{X_1 + X_2}\sin\delta = \frac{1}{0.634}\sin 30 = 0.8\,pu$$

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And :

$$V_k(V_k^* - V_m^*) = V_k^2 - V_k V_m e^{j\delta km} \quad \delta_{km} = \delta_k - \delta_m$$

$$P = \frac{V_1.V_2}{X}\sin\delta \quad S_{km} = V_k^2(g_{km} - jb_{km}) - V_k V_m(g_{km} - jb_{km})(\cos\delta_{km} + j\sin\delta_{km})$$

$$P = \frac{V_1.V_2}{X}\sin\delta \quad P_{km} = V_k^2 g_{km} - V_k V_m(g_{km}\cos\delta_{km} + b_{km}\sin\delta_{km})$$

$$P = \frac{V_1.V_2}{X}\sin\delta \quad Q_{km} = -V_k^2 b_{km} - V_k V_m(g_{km}\sin\delta_{km} - b_{km}\cos\delta_{km})$$

From where :

$$P_k = V_k \sum_{\substack{i=1\\ i\neq k\\ i\neq m}}^{N}\left(g_{ki}\cos a_{ki} + b_{ki}\sin a_{ki}\right)V_i -$$
$$V_k^2 \sum_{\substack{j=1\\ j\neq i}}^{N} g_{kj} - P_{km}$$

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$$Q_k = V_k \sum_{\substack{i=1 \\ i \neq k \\ i \neq m}}^{N} \left(g_{ki} \sin a_{ki} - b_{ki} \cos a_{ki} \right) V_i -$$

$$V_k^2 \sum_{\substack{j=1 \\ j \neq i}}^{N} b_{kj} - Q_{km}$$

Modeling and control strategies:
The power transmitted through a transmission line is a function of the values of the voltage amplitudes of the two ends V_1 and V_2, as well as their phase shift θ_{12}.

$$P = \frac{V_1 V_2}{X} \sin \theta_{12}$$

One of the control laws of a TCSC is its modulation reactance, for example for a compensation level equal to 70% is given by:

$$X_{TCSC} = 0.7 X_{ligne}$$

There are several strategies to regulate transit power, namely:

a) Modulation power strategy:

$$P_{TCSC} = P$$

b) Modulation current strategy:

$$I_{ligne} = I$$

c) Modulation transmission angle strategy:

$$\theta_{12} = \theta$$

test network
The test network, shown in Figure 8, comprises an alternator connected to a busbar 1 through power transformers contributing to the supply of ten loads.

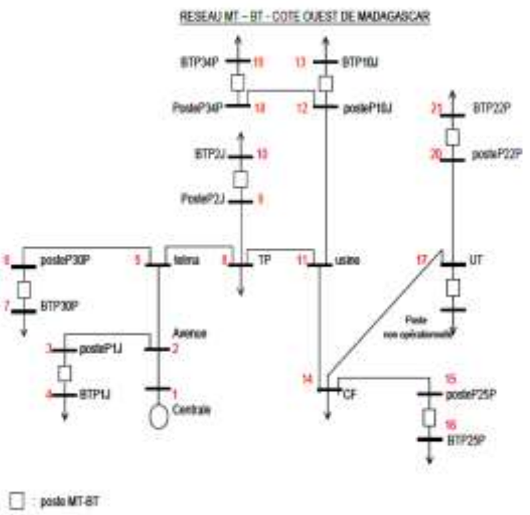

Figure 8:Test network (Morondava network)

The test network with fault is represented by the MATLAB / Simulink software as follows:

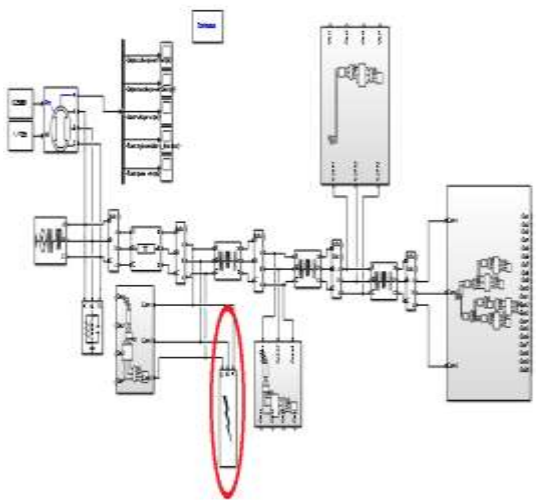

Figure 9: The test network in the presence of a fault

Network simulation results
The execution of the simulation allowed us to obtain the simulation results represented in Figures 10

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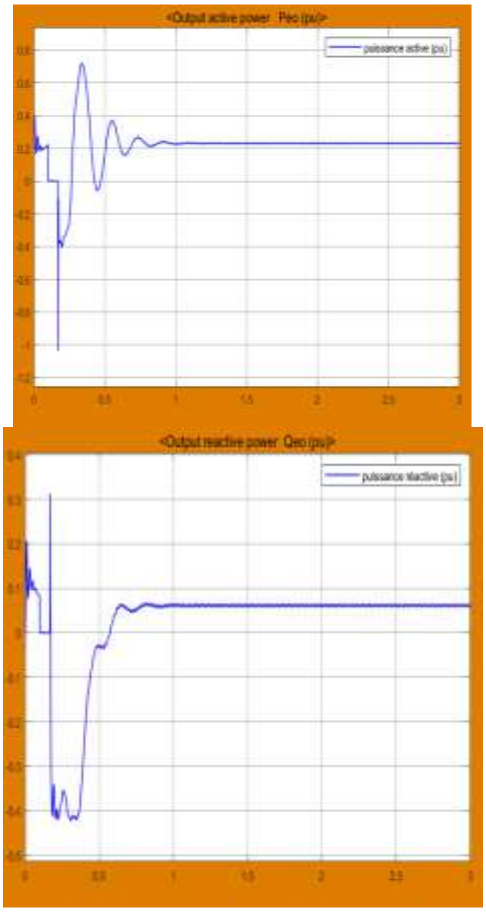
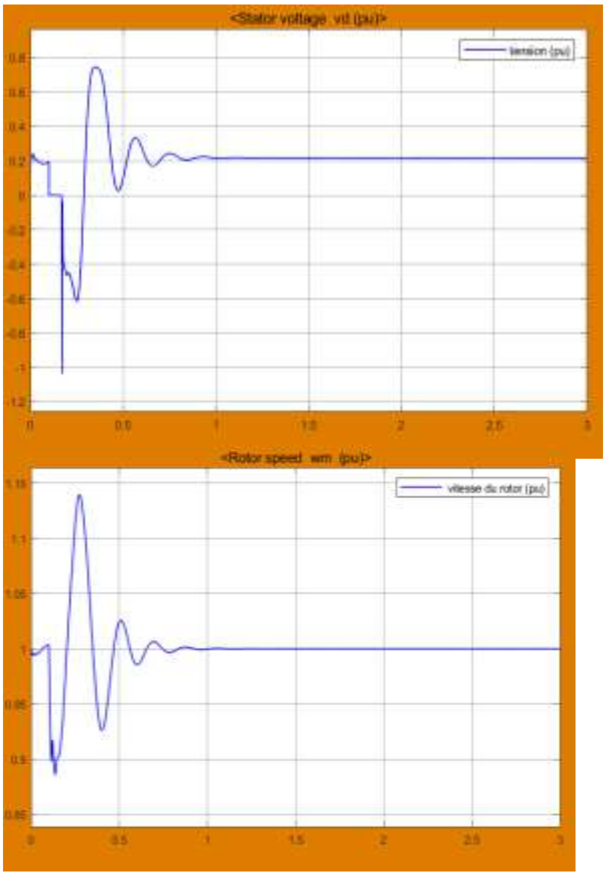
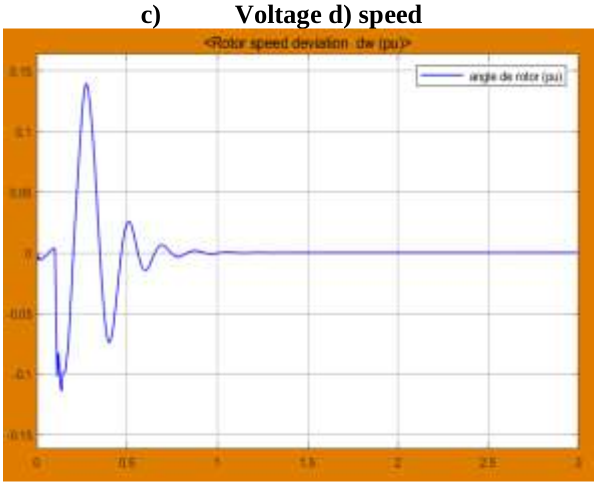
which respectively show the generator rotor angles, its rotational speed and the relative rotor angle for a fault duration Td = 0.01 s.



a) Active power b) reactive power



c) Voltage d) speed



e) Rotor angle

Figure 10: Active and reactive power curves as well as the speed and rotor angle in the presence of a fault

Table 1: CCT during a three-phase short-circuit fault on the Test Network

Lines	3-9		2-7		4-5		8-9	
Faulty busbars	3	9	2	7	4	5	8	9
CCT(s)	0.3	0.25	0.29	0.29	0.32	0.39	0.35	0.25

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Interpretation of the results obtained

The results presented in Table 1 show that for each fault on the network gives a value of CCT. This value is mainly due to the change of the admittance matrix for each case, and therefore the modification of the Y matrix will completely change the power flow and the initial condition and for each time period (before, during and after fault), it is the minimum CCT that shows the network weak point that needs strengthening.

Improved transient stability with FACTS integrationWith the integration of UPFC and TCSC

In this case, a study is made on the combined influence of the two slides UPFC and TCSC on the transient stability. The network with the insertion of UPFC and TCSC is presented by figure 11. The simulation results are presented in the following figure (5.14):

Figures (5.14.a), (5.14.b), (5.14.c), (5.14.d) respectively represent the variation of the generator rotation speed, that active power in the presence of a PSS, a UPFC and a PSS and UPFC, and the active powers at the connection busbars as well as the voltages of the system busbars in the presence of a PSS and UPFC.

The combination between the two FACTS devices in the network is presented by the figure below

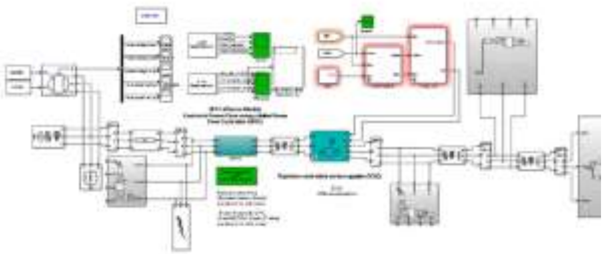
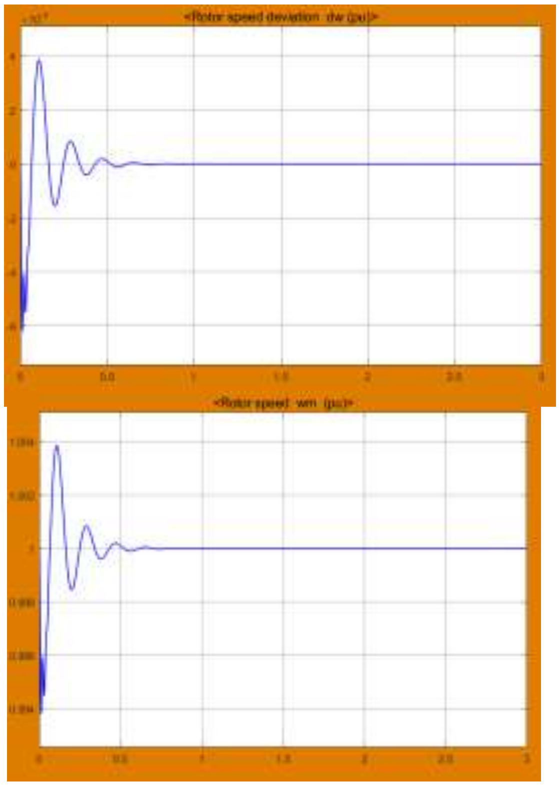
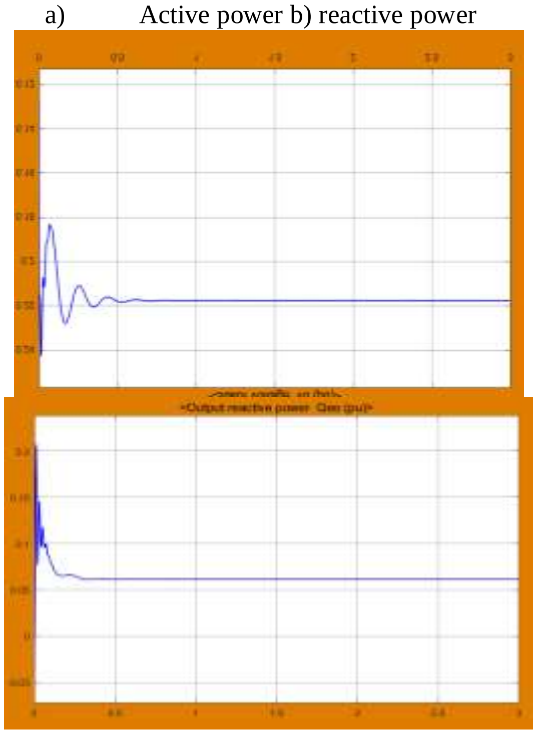


Figure 11: Integration of UPFC and TCSC on the network

After the simulation



a) Active power b) reactive power



c) Voltage d) Speed

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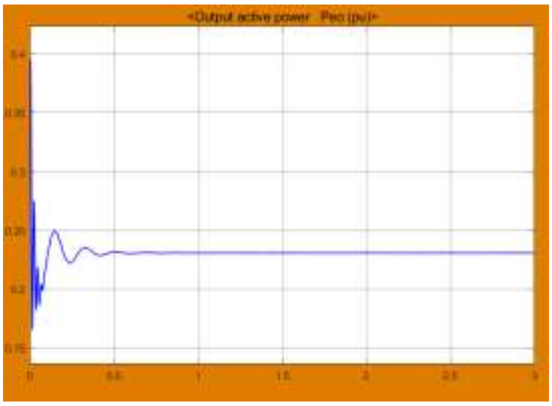

e) Rotor angle

Figure 11: Active and reactive power curves as well as the speed and rotor angle in the presence of the UPFC and TCSC

The curves in Figures 11 respectively represent the rotor angle of the generator, its speed of rotation and the relative rotor angle in the event that the system suffers from a fault and in the presence of the FACTS device and for a fault duration Td = 0.420s.

Figures 5.14(a)-5.14(c) represent respectively the rotor angles of the generators, these rotation speeds and the relative rotor angles in the case where the system is stable for a fault duration Td = 0.420s and for the case where the unstable system for a fault duration Td = 0.393s.

1. 1. 1. 1. Results interpretation

According to the various simulations that we have made and the results obtained, we clearly notice the impact of the use of the TCSC on the transient stability of the electrical networks. The installation of TCSC at the level of the different lines of the networks with degrees of compensation for several cases has made it possible to improve the margin of the transient stability of the electrical networks . The simulation results show that the damping of the oscillations appear in the electrical system due to short-circuit in the presence of UPFC and TCSC and more efficient than that obtained in the event of integration of UPFC or TCSC alone. The combined influence of UPFC and TCSC on transient and achieved stability.

Conclusion

In this chapter, we have shown the effectiveness of UPFC and TCSC devices for improving the transient stability of electrical networks. The choice of particular controllers depends on the application requirements and desired performance. The efficiency of both SVC and TCSC devices is measured by the increase in CCT, however the location must be well optimized taking into account the constraints and criteria related to each device

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