A SOLID STATE STATIC VAR COMPENSATOR BASED POWER NETWORK STABILISER

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Abstract - This paper deals with the study on the application of the Advanced Static Var Compensator (ASVC) for the improvement of the stability margin of the electrical infinite bus.
The ASVC is connected to the bus bar before the main transformer in order to maximise the power transit with large stability margin by compensating the reactive losses. A PI controller is applied to the ASVC to compensate the reactive losses induced by the reactive elements of the electrical network.
Digital simulations studies reveal the technical feasibility of using such ASVC to improve the stability of the system.

I . INTRODUCTION

The requirement to design and operate power systems with highest degree of efficiency, security, and reliability have been central focus for the power system designer, ever since the interconnected networks came into existence. To satisfy these requirements, various advances in technology of ac power transmission have taken place in the context of effective control of reactive power and its compensation. Static VAR Compensators (SVC's) are dynamic reactive power compensation devices. Recent developments in the solid state VAR compensators have opened a very optimistic door towards achieving a very efficient control of reactive power.
In this paper, the ASVC is used to improve the stability margin of the electrical infinite bus. The modelling of the system is based on the d-q transform [1]. The electrical infinite bus has been modelled with the ASVC at the generator terminal. The ASVC considered is a voltage source inverter [2], and equipped with a PI controller that minimise the reactive power losses by injecting a capacitive reactive power to the system.
Time domain simulations using the non linear system model are carried out to demonstrate the effectiveness of the proposed scheme under the condition of the three-phase fault at the infinite bus.

II . MATHEMATICAL MODEL OF THE NETWORK-ASVC

Based on Fig.1 we can establish the following equations [3] :

- Machine side :

$$\begin{cases} V_d = -p\Phi_d - \omega\Phi_q - \Phi_q p\delta' - R_a i_{dA} \\ V_q = -p\Phi_q + \omega\Phi_d + \Phi_d p\delta' - R_a i_{qA} \end{cases} \quad (1)$$

- Network side :

$$\begin{cases} V_{rd} = V_d - R.i_{dL} - Lpi_{dL} - L\omega.i_{qL} - L.i_{qL}p\delta' \\ V_{rq} = V_q - R.i_{qL} - Lpi_{qL} + L\omega.i_{dL} + L.i_{dL}p\delta' \end{cases} \quad (2)$$

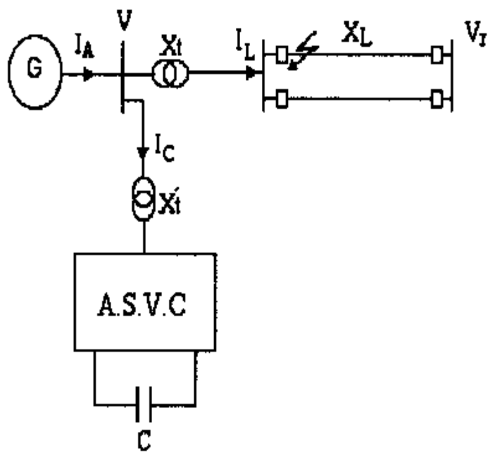

Fig.1 Schematic diagram of the network-ASVC

- ASVC side :

$$\begin{cases} V_{cd} = V_d - R_s.i_{dC} - L_s pi_{dC} - L_s\omega.i_{qC} \\ V_{cq} = V_q - R_s.i_{qC} - L_s pi_{qC} + L_s\omega.i_{dC} \end{cases} \quad (3)$$

$$\begin{cases} pi_{dc} = \dfrac{1}{L_s}\left[V_d - V_{Cd} - R_s.i_{dC} - L_s\omega.i_{qC}\right] \\ pi_{qc} = \dfrac{1}{L_s}\left[V_q - V_{Cq} - R_s.i_{qC} + L_s\omega.i_{dC}\right] \end{cases} \quad (4)$$

With :

$$\begin{aligned} i_{dL} &= i_{dA} - i_{dC} \\ i_{qL} &= i_{qA} - i_{qC} \end{aligned} \quad (5)$$

By putting (5) into (2) we get :

$$\begin{aligned} V_{rd} &= V_d - R(i_{dA} - i_{dC}) - Lp(i_{dA} - i_{dC}) \\ &\quad - L\omega(i_{qA} - i_{qC}) - L(i_{qA} - i_{qC})p\delta' \\ V_{rq} &= V_q - R(.i_{qA} - .i_{qC}) - Lpi_{qA} + Lp.i_{qC} \\ &\quad - L\omega(i_{dA} - i_{dC}) - L(i_{dA} - i_{dC})p\delta' \end{aligned} \quad (6)$$

By developing (6) and replacing by (4) and after a tedious calculation we obtain the complete model of the infinite bus network with ASVC :

$$pi_{dA} = \left[\begin{aligned} &\sqrt{2}v_r\sin\delta' - \left(\xi\left(R_a + \frac{B}{\tau'_{do}} + \frac{D}{\tau''_{do}}\right) + R\right)i_{dA} + \\ &\xi\left(-\omega'\Phi_{q2} + \frac{\Phi_{d2}}{\tau'_{do}} + \frac{\Phi_{d3}}{\tau''_{do}}\right) \\ &-\omega'(L+\xi F)i_{qA} - \xi\left(\frac{C}{\tau'_{do}} + \frac{E}{\tau''_{do}}\right)v_f \\ &+\lambda i_{dC} - \frac{L}{L_s}v_{Cd} \end{aligned}\right] / (L+\xi A) \quad (7)$$

$$pi_{qA} = \left[\begin{aligned} &-\sqrt{2}v_r\cos\delta' - \left(\xi\left(R_a + \frac{G}{\tau''_{qo}}\right) + R\right)i_{qA} \\ &+\xi\left(\omega'\Phi_{d2} + \omega'\Phi_{d3} + \frac{\Phi_{q2}}{\tau''_{qo}}\right) \\ &+\omega'(L+\xi A)i_{dA} + \lambda i_{qC} - \frac{L}{L_s}v_{Cq} \end{aligned}\right] / (L+\xi F) \quad (8)$$

$$p\Phi_{d2} = \left(B\,i_d + C\,v_f - \Phi_{d2}\right)/\tau'_{do} \quad (9)$$

$$p\Phi_{d3} = \left(D\,i_d + E\,v_f - \Phi_{d3}\right)/\tau''_{do} \quad (10)$$

$$p\Phi_{q2} = \left(G\,i_q - \Phi_{q2}\right)/\tau''_{qo} \quad (11)$$

$$p\,\delta' = \omega' - \omega \quad (12)$$

$$p\,\omega' = \left(C_m - C_e\right)/J \quad (13)$$

with :

$$\xi = \left(1 + \frac{L}{L_s}\right) \text{ and } \lambda = \left(R - L\frac{R_s}{L_s}\right)$$

The model of the ASVC is established by taking the voltage of the bus bar as reference hence we get [4], [5]:

$$p\,i_{dC} = \left(-R_s i_{dC} - \omega' L_s i_{qC} - m v_{dC}\sin(\alpha_c) + v_d\right)/L_s \quad (14)$$

$$p\,i_{qC} = \left(-R_s i_{qC} - \omega' L_s i_{dC} - m v_{dC}\cos(\alpha_c) + v_q\right)/L_s \quad (15)$$

$$p\,v_{dC} = m\left(i_{dC}\sin(\alpha_c) + i_{qC}\cos(\alpha_c)\right)/C \quad (16)$$

With : $\alpha_c = \alpha + \delta$, since we have taken the voltage of the bus bar as a reference for the ASVC, i.e on the phasor diagram the voltages of the ASVC are synchronised to those of the bus bar considered.

Hence our model will be made up of ten differential equations, seven for the alternator and three for the ASVC.

III . PROPOSED CONTROL STRATEGY

Fig. 2 shows the main principles of the proposed control of the ASVC, the reactive power demanded is always compensated partly by the capacitive reactive power generated by the ASVC, this method of compensation help ease the alternator and increase the security boundary for the heating of the rotor circuit.

The details of the control block diagram are given by Fig. 3.

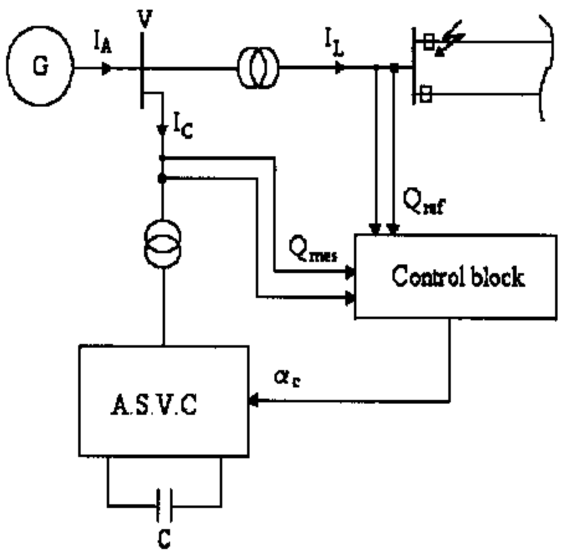

Fig.2 Main circuit of the control strategy

This compensation is controlled by a PI regulator which synthesis the control variable α which is added to the angle δ that is necessary for synchronising with the voltages of the bus bar considered.

This sum being α_c is applied to the ASVC to generate the necessary reactive power, the control variable α being limited by two upper and lower levels will allow to preserve the stability of the compensator.

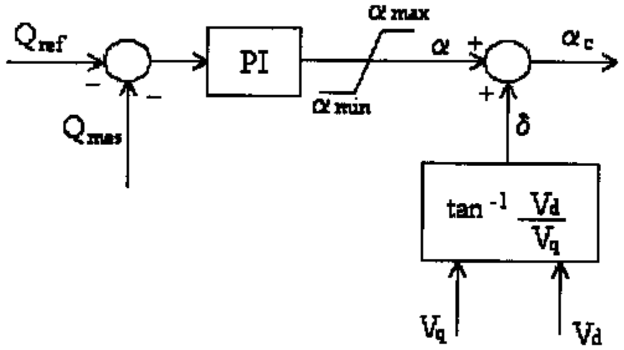

Fig3. Control block diagram

If we suppose that the reference is always the voltage of the bus bar connected to the ASVC, the transfer function relating the reactive power to the control angle α is given by [4], [5], [6]:

$$G(p)=\frac{q(p)}{\alpha(p)}=\frac{\sqrt{2}V^2\left[\frac{p^2}{L_s}+p\frac{R_s}{L_s}+\frac{m^2}{L_s^2C}\right]}{p^3+2p^2\frac{R_s}{L_s}+p\left(\omega^2+\frac{R_s^2}{L_s^2}+\frac{m^2}{L_sC}\right)+m^2\frac{R_s}{L_s^2C}} \quad (17)$$

Hence by using the root locus method, the parameters of the regulator are given as follows :

$K_p = 2.3\,10^{-9}$

$K_I = 7.7\,10^{-7}$

IV . SIMULATION RESULTS

To analyse the performance of the stability of the turbo-alternator with ASVC, a series of simulation tests have been carried out, by taking the compensator parameters as follows:

AC side : $R_s = 1\Omega$, $L_s = 5$ mH

DC side : C = 500 µF.

The results obtained of the turbo-alternator and ASVC are compared with those of the turbo-alternator alone.

Fig. 5 represents the variation of the load angle of the turbo-alternator group with and without compensation after fault clearing time of 0.08 s, we notice that the response with the compensation is more damped and the load angle is smaller than that of the turbo-alternator without compensation.

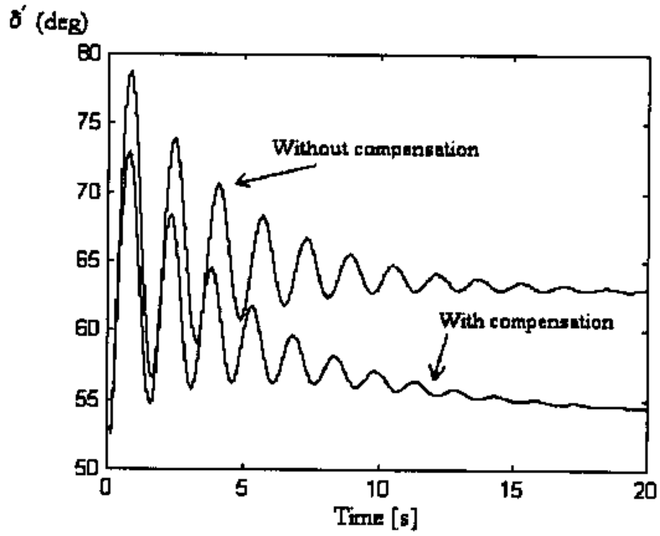

Fig.5 Load angle variation

Fig. 6 represents the variation of the angular speed centred of the turbo-alternator with and without compensation after fault clearing time of 0.08 s, we notice that the response (with compensation) is more damped than without compensation.

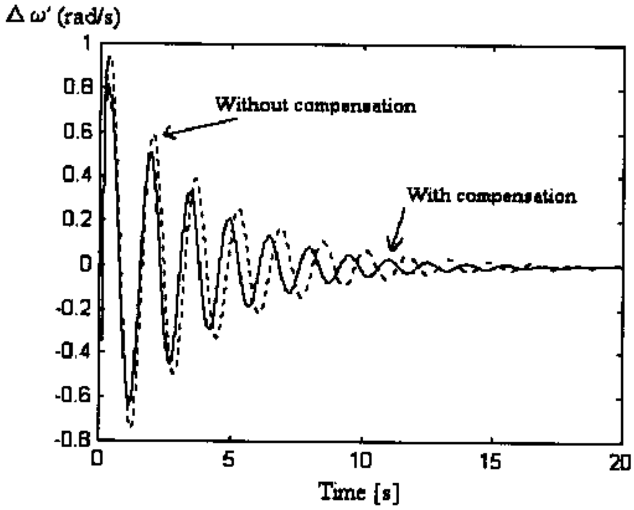

Fig. 6 Variation of the angular speed

Fig. 7 represents the variation of the voltage of the first busbar with and without compensation, the voltage of the system compensated is higher than that without compensation, this is due to the decrease in reactive power losses in the lines by the ASVC which generates a capacitive reactive current which annuls a part of the inductive reactive current absorbed by the line

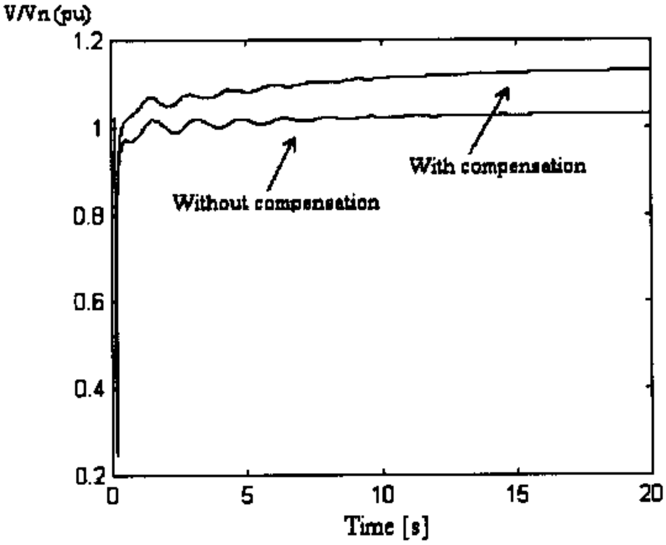

Fig. 7 Variation of the voltage of the first busbar

V. CONCLUSION

In this paper a new approach to improve the stability of a turbo-alternator using a static VAR compensator has been presented. The proposed system has been analysed and a fast current controller been implemented for reactive power applications. The mathematical model derived and the transient simulated results obtained are included to confirm the applicability of the proposed control scheme.

VI. REFERENCES

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