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RESEARCH ARTICLE

TRANSIENT STABILITY ENHANCEMENT OF REAL TIME SYSTEM USING ETAP

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ABSTRACT

The modeling of the real time system with Static VAR Compensator (SVC) using ETAP software is presented in this paper. The system is analyzed under severe disturbance to study the transient behavior by simulating three phase to ground fault at particular bus. To enhance the transient stability of the system, SVC is inserted and tested to show the effect of the same on the transient stability under severe disturbance. The potential application of SVC on the improvement of voltage profile of the various buses and reduction in rotor angle oscillation of the generator is evaluated from the implementation results.

INTRODUCTION

Transient stability evaluation focuses on the reactive power flow of the power system in response to a fault. In transient stability prediction, the progress of the power system transient due to occurrence of disturbance is to be monitored. The key factor in transient stability prediction is based on the convergence and divergence of transient swings. The problem is formulated as the insertion of SVC in real time system that is to be analyzed using ETAP simulation software for enhancing the transient stability. SVCs, with an auxiliary injection of a suitable signal, can significantly improve the dynamic stability performance of a power system (Byerly *et al.*, 1982; Hammad 1986) presented a fundamental analysis of the application of SVC for enhancing the power system stability. Also, the enhancement of low frequency oscillation damping via SVC has been analyzed (Padiyar and Varma 1991; Zhou 1993; De Oliveira 1994; Messina *et al.*, 1999). The SVC enhances the system damping of local as well as inter-area oscillation modes. Ref (Messina and Barocio 2003) studied the nonlinear model interaction in stressed power systems with multiple SVC voltage support. It is observed that SVC controller can significantly influence nonlinear system behavior especially under high-stress operating conditions and increased SVC gains (8).The general representation of SVC is represented in the Fig.1.1

MODELING OF SVC

SVCs, with an auxiliary injection of a suitable signal, can significantly improve the dynamic stability performance of a power system (Byerly *et al.*, 1982; Hammad 1986) presented a fundamental analysis of the application of SVC for enhancing the power system stability. Also, the improvement of low frequency oscillation damping via SVC has been analyzed (Padiyar and Varma 1991). The SVC improve the system damping of local as well as inter-area oscillation modes.SVC model shown in Figure 2.1, used to improve the transient stability of the real time system considered, has been modeled in ETAP 12.5

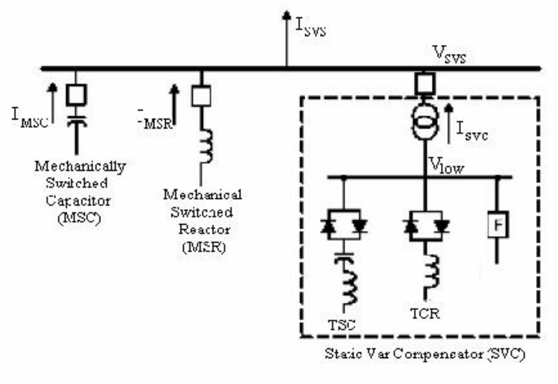

Figure 1.1. SVC employing TSC and TCR

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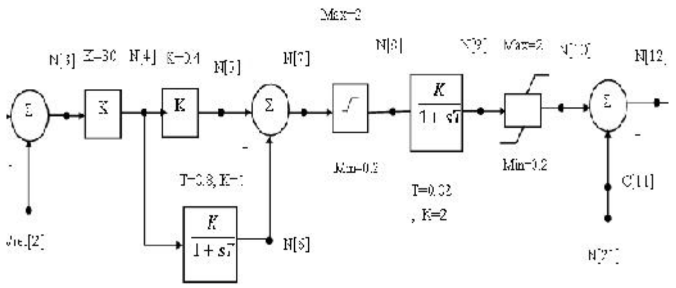

Figure 2.1 Modeling of SVC

MODELING OF REAL TIME SYSTEM

Test system having a peak demand of 50 MW with a cogeneration plant of 35 MW is considered. Considering the peak load of 50 MW, the test system receives the power supply at 220 kV. Further it is stepped down to 110 kV through two 100 MVA, 220 / 110 kV transformers. 35 MW generator is modeled using ETAP with the technical parameters shown in Table 3.1.

Table 3.1. 35 Mw Generator Parameters

Variable	Description	Data
	MVA rating	43.75
	MW rating	35
	Rated voltage in kV	11
R_a	Armature resistance in p.u.	0.004593
X_2	Negative sequence reactance in p.u.	0.149
X_0	Zero sequence reactance in p.u.	0.066
X_d	Direct axis reactance in p.u.	2.036
X_d'	Direct axis transient reactance in p.u.	0.237
X_d''	Direct axis sub - transient reactance in p.u.	0.185
X_q	Quadrature axis reactance in p.u.	1.8
X_q'	Quadrature axis transient reactance in p.u.	0.33
X_q''	Quadrature axis sub – transient reactance in p.u.	0.1678
T_{do}'	Direct axis open circuit transient time constant in p.u.	4.902
T_{do}''	Direct axis open circuit sub – transient time constant in p.u.	0.017
T_{qo}'	Quadrature axis open circuit transient time constant in p.u.	0.533
T_{qo}''	Quadrature axis open circuit sub – transient time constant in p.u.	0.1
H	Inertia constant (Generator + Exciter)	3
	Winding connection	Y grounded through NGT

The generator is connected to the transformer of 40/45 MVA, 110/11 kV, ONAN / ONAF with 12.5% impedance on its own base. This transformer has an OCTC with 17 taps (-15% to 7.5%). Major loads like Electric Arc Furnace (EAF), Ladle Refining Furnace (LRF) and Rolling mill are highly fluctuating in nature and hence considered with one dedicated transformer of 35/40 MVA, 110/33 kV, ONAN/ONAF with 10% impedance on 40 MVA base. This transformer has an OCTC with 9 taps (-15% to 5%). Other additional auxiliary supply for process, power plant, lighting loads and small power loads are grouped together and fed from 11 kV via 15 MVA, 110/11 kV, ONAN with 10% impedance on its own base. This transformer also has an OCTC with 9 taps (-15% to 5%). The system uses 220 kV, 110 kV, 33 kV, 11 kV, 6.6 kV and 415 V systems for the efficient operation.

Transformer data (rated MVA, rated HV/LV voltage, % impedance) considered is given in Table 3.2.

Table 3.2. Transformer Data

Rated MVA	Rated HV/LV	% impedance
100	220/110	10
40	110/33	10
45	11/110	12.5
6.3	11/6.6	7.15
15	110/11	10
1.25	11/0.433	6
3	11/0.433	6
0.5	11/0.433	6
6.3	11/6.9	6
0.315	11/0.433	6

Detailed system modeling is of prime importance for carrying out any system study. The block diagrams of automatic voltage regulator (AVR) and turbine governor (TG), shown in Figures 3.1 and 3.2 respectively, have been modeled using ETAP for 35 MW generator. The parameter related to the AVR and TG are listed in Tables 3.3 and 3.4 respectively.

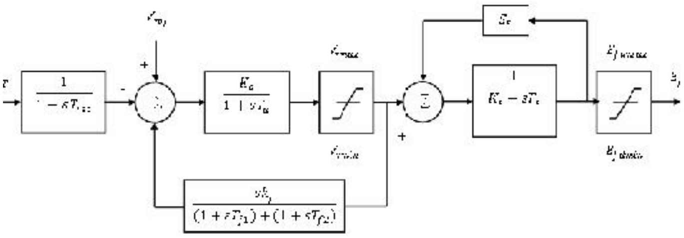

Figure 3.1. Block diagram of AVR for 35 MW Generator

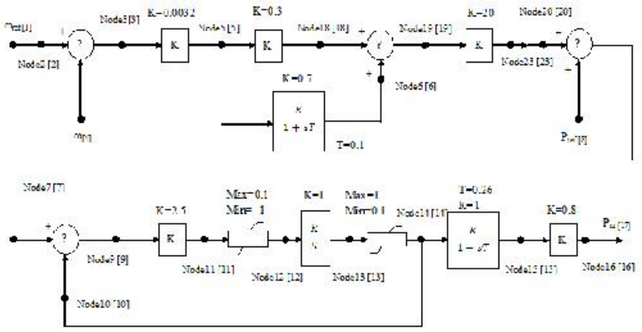

Figure 3.2. Block diagram of TG for 35 MW generator

Table 3.3. Avr Data for 35 Mw Generator

Variable	Description	Data
T_{rec}	Input rectifier time constant in s	0.02
T_a	Amplifier time constant in s	0.02
T_e	Exciter time constant in s	0.6
T_{f1}	Regulator stabilizing circuit time constant1in s	1.0
T_{f2}	Regulator stabilizing circuit time constant2 in s	0.1
k_a	Amplifier gain	100
k_e	Exciter gain	1.0
K_f	Regulator stabilizing circuit gain	0.01
V_{se1}	Saturation function at 0.75 times maximum field voltage	0.4
V_{se2}	Saturation function at maximum field voltage	0.7
V_{rmax}	Maximum amplifier voltage	4.3
V_{rmin}	Minimum amplifier voltage	-4.3
Ef_{dmax}	Maximum field voltage	4.3
Ef_{dmin}	Minimum field voltage	0

This real time system is modeled using ETAP simulation software and the corresponding single line diagram is shown in Figure 3.3.

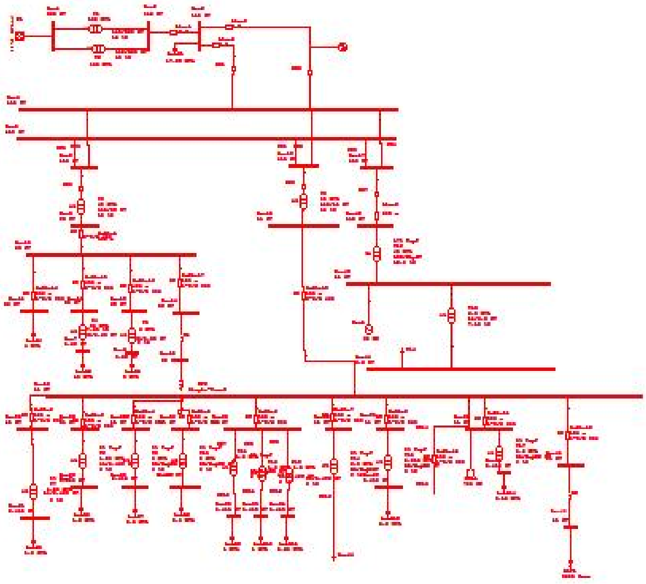

Figure 3.3. Single line diagram of real time system

Table 3.4. Turbine Governor Data For 35 Mw Generator

Variable	Description	Data
σ	Droop	0.05
Pmax	Maximum power limit	1.0
Pmin	Minimum power limit	0.1
Cmax	Rate of valve opening	0.1
Cmin	Rate of valve closing	-1.0
T1	Phase compensation 1	0.1
T2	Phase compensation 2	0.3
T3	Servo time constant	0.4
Thp	HP section time constant	0.26

SIMULATION RESULTS

The ETAP software is used to simulate the real time system yield validated results. To simulate the real time system ,models have been developed for each element and implemented in the dedicated power system simulation tool ETAP which provides the ability to simulate load flow study, short circuit study and Transient events in the same software environment. The ETAP simulation tool therefore has a dedicated model for generators which take into account the current displacement in the rotor, slip and short circuit analysis curves. Also models of synchronous machines, transformers, bus bars, grid models, Transmission lines etc are provided.

TRANSIENT ANALYSIS

a. With out disturbances

The real time system was kept as ideal and the simulation results are presented here. The power generated by the generator remains constant even if the loads of the system can vary is represented in the 4.1

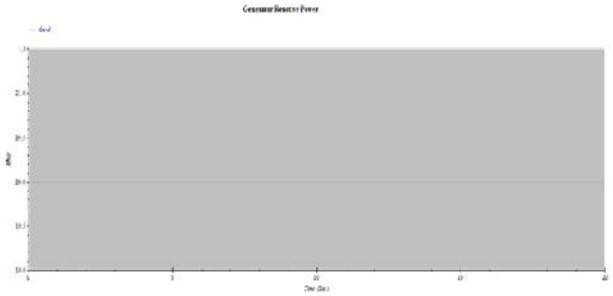

Figure 4.1 Real power P of the Generator

The given loads,the generator has to generate 20 MVAr to maintain its terminal voltage is depicted in the Figure 4.2.

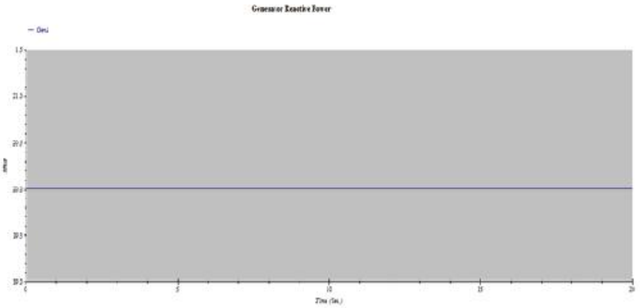

Figure 4.2 Reactive power Q of the Generator

The generator has the capability to adjust the reactive power and to maintain the voltage is represented in the Figure 4.3

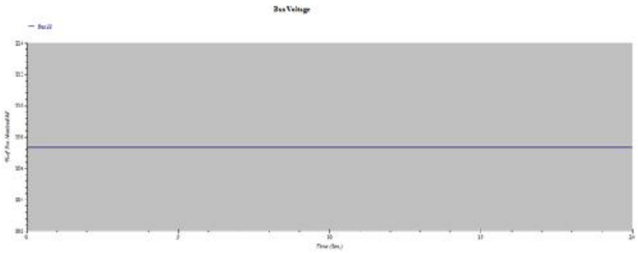

Figure 4.3 Generator bus (22) voltage

Since the 110 k V bus is considered as slack bus for the load flow study,the voltage and angle of the bus remains constant is represented in the Figure 4.4.

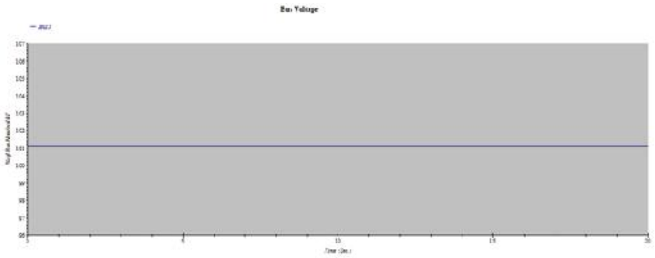

Figure 4.4 110 kV Bus (5) voltage

The 33 k V bus receives power from 110 kV grid through two winding transformer. Due to the leakage reactance of the transformer the voltage at the 33 kV bus starts falling is depicted in the Fig.4.5.

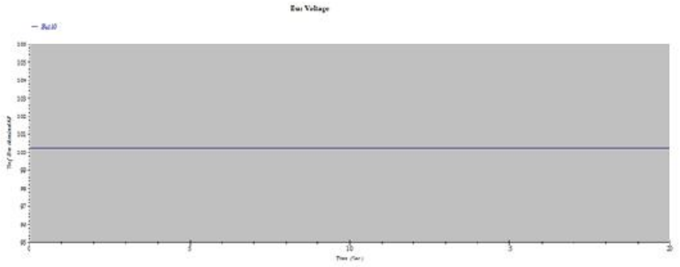

Figure 4.5. 33 kV Bus(10) voltage

11 kV bus receives the power from 110 k V grid through two winding transformer.In that real time system the generator auxiliary,EAF auxiliary,Oxygen plant loads are fed by the given transformer.The terminal voltage is 106.44 % is depicted in the Figure 4.6.

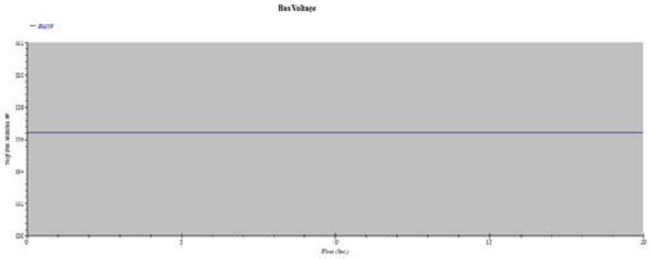

Figure 4.6. 11 kV Bus(29) voltage

b. With disturbances

Here the real time system was tested by creating the three phase to ground fault at the 11 kV bus(29) and the simulation results were produced. Figure 4.7 describes the generator will oscillate whenever there is a fault in network. The oscillation of generators is basically measured with respect to infinite bus(grid) which is represented as slack bus. The oscillation level of the generator depends on the disturbances severity and its time duration. A 100 ms duration of the three phase fault at 11 kV bus leads the generator to oscillate from 2.4 to 6 degree, whereas at the steady state condition it is 2.3 degrees with respect to grid.

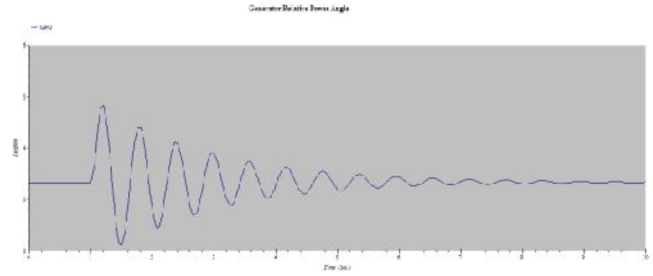

Figure 4.7. Swing curve of the generator at fault condition

Figure 4.8 describes the real power generation and reactive power generation of the generator when there is a fault at 11 kV bus. It indicates the oscillation of real power of the generator that varies from 27 MW to 43 MW.

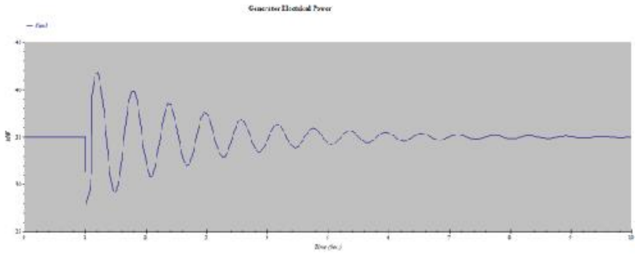

Figure 4.8 Real power P of the Generator

The reactive power of the generator drastically increases from 22 MVAr to 76 MVAr during the fault without any time delay because the exciter characteristics are fast in nature is represented in the Figure 4.9.

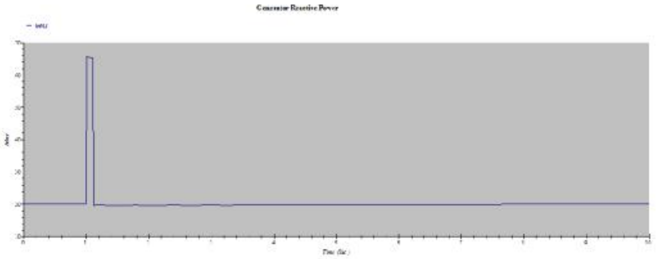

Figure 4.9 Reactive power Q of the Generator

The severity of the dip in the voltage at any bus is directly related to the distance from the fault location.Since,110 k V grid bus is far away from the fault location, hence the voltage reduced from 100 % during fault and recovers back to normal after the clearance of the fault is described in the Figure.4.10

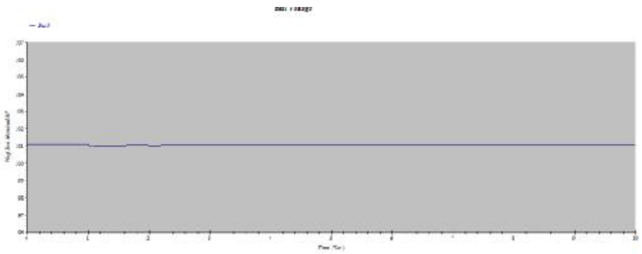

Figure 4.10. 110 kV Bus (5)voltage

The 33 kV bus is far away from the faulty 11 kV bus and two winding transformer impedances exist between the two buses, the voltage reduction is severe during fault and recovers back to normal after clearance of the fault is represented in the Figure 4.11

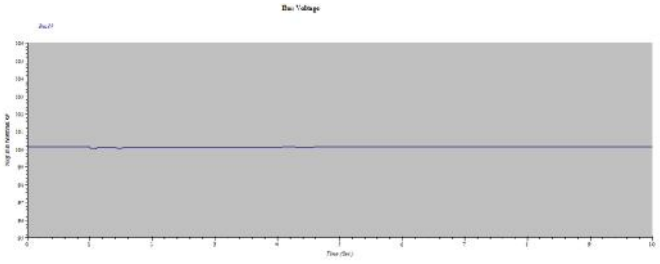

Figure 4.11. 33 kV Bus (10)voltage

Since the fault is at this bus,the voltage is zero during fault and recovers back to the normal after clearance of the fault is represented in the Figure 4.12

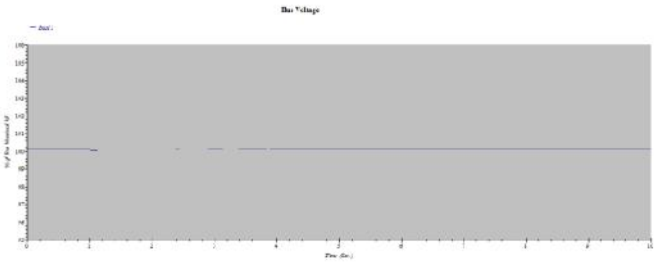

Figure 4.12 11 kV Bus (29)voltage

c. WITH SVC

The SVC is placed at 33 kV bus and fault is created at the 11 kV bus and the simulation results were produced here.SVC at 33 kV bus slightly improves the transient stability by reducing the oscillation represents the figure 4.13. The ability of the SVC at 33 kV bus significantly contributes the reactive power and improve the voltage profile of the 110 kV ,33 kV , and 11 kV bus respectively, which prevents the large motors connected to these buses to stall were represented the figure.

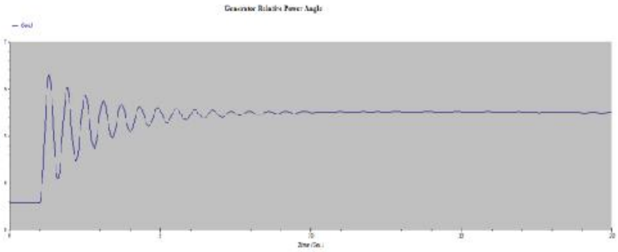

Figure 4.13 Swing curve of the generator

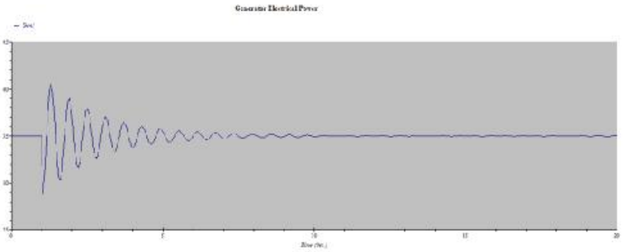

Figure 4.14 Real power P of the Generator

Conclusion

The fluctuating /non-linear nature of the load present in the real time system, SVC is considered to maintain the voltage profile and to enhance the transient stability of the system. Various cases are simulated and the response of the system are presented. Modeling of real time system with SVC is presented .SVC is modeled using ETAP for enhancing the transient stability of the system. From the transient stability analysis, SVC at 33 kV Bus improves the voltage profile of the real time system for the three phase to ground fault. However the impact of SVC on damping the rotor angle oscillation of the generator is not so effective for the system considered.

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