Stability Improvement of Captive Generator Sets Utilizing FACTS Device

Utpal Goswami, Madhuria Chanda, Arijit Ganguly, P.K. Sadhu and Suprava Chakraborty

Abstract Power demand in last two decades has increased substantially increasing the complexity in power system network. Therefore to maintain the transient stability of captive power plant (CPP) during any grid fault or disturbance presents a new challenge to researchers. In case of grid fault, captive power plant immediately isolates its captive generator sets from grid to ensure safety. In this paper, an attempt has been made to improve transient stability of captive generator sets during grid fault using FACTS (Flexible AC Transmission System) controller. The performance of FACTS controllers likes Static Var Compensator (SVC) is observed during grid fault condition. The simulation analysis was performed using MATLAB/Simulink software.

1 Introduction

The modern power system network consists of several complex electrical components such as generator, automatic voltage regulator (AVR), exciter, power transformer, distribution transformer, transmission line, electrical motors and combination of variety of linear and nonlinear loads etc. Combination of these components makes the power system network more complex [1]. De-regularization in power industry emphasizes the liberal provision with respect to build up of captive power plant with a view of not only providing dependable power but also to provide high quality and economic power as well. Current industry practice suggests that after any grid fault captive power plant needs to be disconnected from the

U. Goswami (✉) · M. Chanda · A. Ganguly
Department of Electrical Engineering, University of Engineering & Management, Kolkata, West Bengal 700160, India
e-mail: utpal.goswami@uem.edu.in

P.K. Sadhu
Indian School of Mines, Dhanbad, India

S. Chakraborty
National Institute of Solar Energy, Gurugram, India

I. Bhattacharya et al. (eds.), *Advances in Optical Science and Engineering*, Springer Proceedings in Physics 194, DOI 10.1007/978-981-10-3908-9_84

grid within 200–300 ms [2], if the system has not regained its stability. Stabilization of CPP, under grid disturbance condition, can be done implementing load shedding and anti-islanding scheme [3]. Active and passive filter array system is one of the useful system to manage CPP [4, 5].

Recent power electronics research suggests that FACTS device is a useful tool to enhance the transient performance index during any major grid disturbance [6]. First operational feature of FACTS device is to help the network to regain its transient stability. Static Var Controller (SVC) is one of the reliable FACTS controller which control the voltage of power network using reactive power compensation technique. SVC also acts as a shunt compensator to control the transient voltage and damp out oscillation during any grid fault [10, 11]. FACTS controller is considered to be the most versatile one and used for improving the dynamic stability of power system network. FACTS devices consist of Static Synchronous Compensator (STATCOM), Series Synchronous Compensator (SSSC), Unified Power Flow Controller (UPFC) and SVC to control many electrical parameters simultaneously. This paper presents a novel approach to improve transient stability by connecting SVC inside the process plant network system [7–11]. Result shows that the transient stability index of CPP generator improve significantly in terms of time duration to reduce generator output voltage oscillation as well as rotor angle variation of CPP.

2 Methodology

To study the transient performance of proposed network model a detailed network diagram is prepared using MATLAB/Simulink software. The network block diagram is depicted in Fig. 1.

In the network shown below, the alternator rated 30 MVA, 11 kV is connected to the grid. A part of the generated power is used to supply the plant itself to sustain the process of generation. After supplying the internal plant load of 5 MW, the

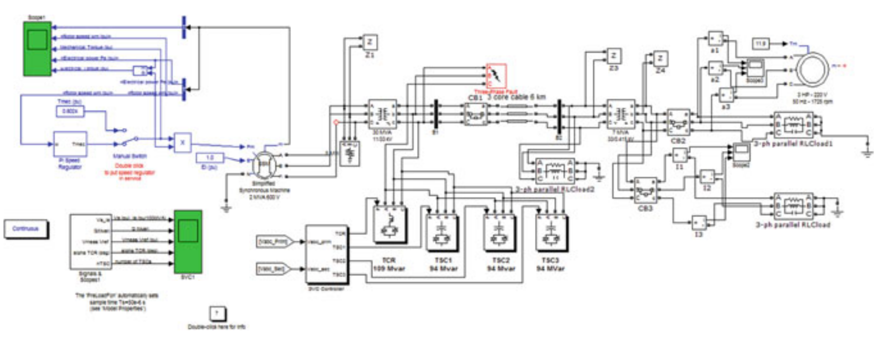

Fig. 1 Network diagram consider for analysis with SVC

generated voltage is stepped up to 33 kV. The rating of the transformer considered as 30 MVA and the primary side voltage of the transformer is 11 kV and secondary side voltage is considered as 33 kV. The power is transmitted through a line of considerable length to supply the grid. The power transmitted at this voltage is ultimately stepped down to supply the load at the distribution end.

Now the interesting area is to deal with a sudden three phase fault occurs in 33 kV bus as shown in the Fig. 1. The voltage profile of the grid shows abnormality. To maintain the safety rule as mention in IEC standard the generator immediately needs to be isolated from the grid within critical fault clearing time. The system behavior is analyzed in two domains one incorporates FACTS devices in the network and other without it. SVC and UPFC is considered as FACTS device to improve stability.

Basic points that are considered for the study:

(a) Loads as shown in various buses are motor load; static load, etc.
(b) Short circuit fault level of existing 11 kV system considered as 30 kA.
(c) Tolerance of impedances not considered except generator transformer.
(d) Tolerance of impedances for 30 MVA GT is considered as per IEC standards.
(e) Overhead 33 kV line fault level consider as 50 kA.

3 Results

The Transient stability study of the proposed network is performed in the following conditions.

(a) For a fault in 33 kV grid side without connection of SVC at generator bus.
(b) For a fault in 33 kV grid side and SVC is connected at generator bus.

Event of operations performed for the transient stability study is indicated in Table 1.

The simulation results of Transient stability study for case-1, case-2

Table 1 Event of operation performed for transient stability study

Event	Time (s)	Action	Status of SVC
Case-1	0.5	3Ph fault on grid bus	Without SVC
Case-2	0.5	3 Ph fault on grid bus	With SVC

4 Discussion

From the simulation result Figs. 2, 3, 4, 5 and 6, the summary output is depicted in Table 2.

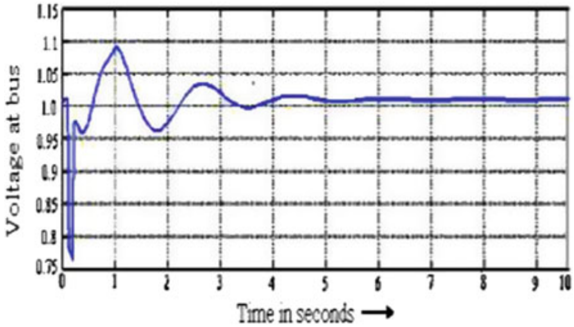

Fig. 2 Voltage profile at generator bus without SVC

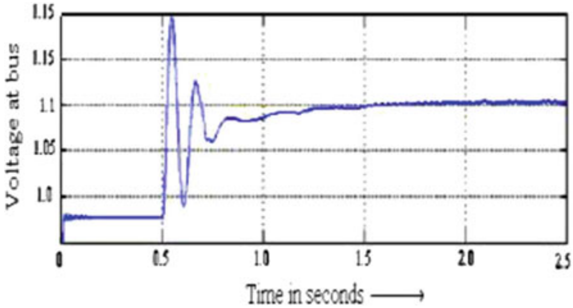

Fig. 3 Voltage profile at generator bus with SVC

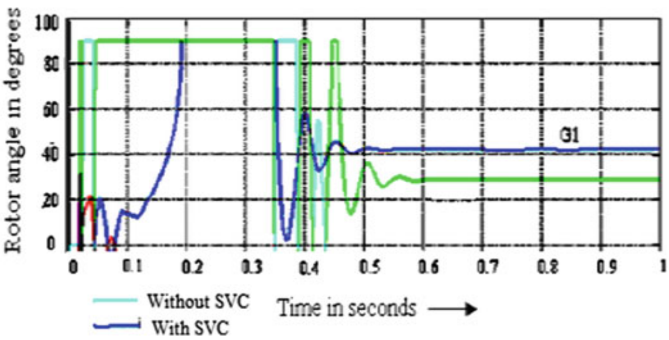

Fig. 4 Variation of rotor angle during fault with and without SVC

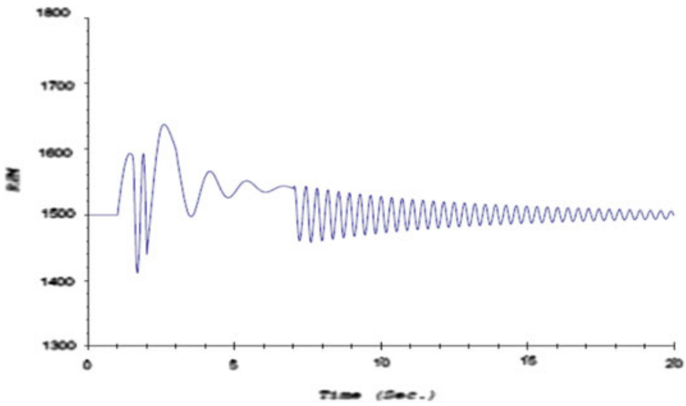

Fig. 5 Speed variation of captive generator during grid fault without SVC

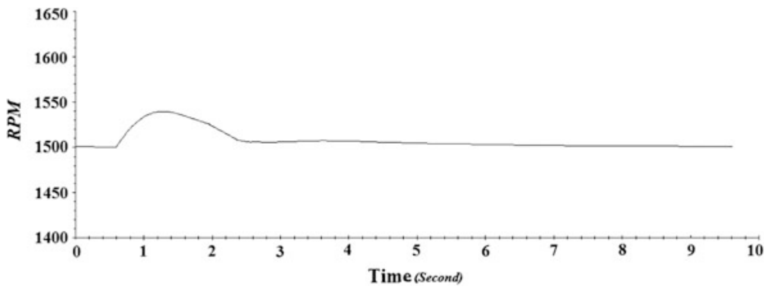

Fig. 6 Speed variation of captive generator during grid fault with SVC

Table 2 Summary of event of operation performed for transient stability study

S. No.	Status of SVC	Rotor angel stabilization time (s)	Final speed attended (rpm)	Time for stabilization (s)
1.	Without SVC	0.6	Oscillates 1550–1520	5
2.	With SVC	0.5	1500	2

5 Conclusion

As per the analysis it is observed that, during grid disturbance and after removal of fault, first acting turbine governor system along with exciter and SVC plays an important role to maintain the transient stability of the system. From the transient stability study it is very clear that turbine governor model with SVC performs better in terms of improving transient stability index i.e. voltage variation, damping oscillation and generator speed variation during a grid fault condition. With the use of SVC, time duration of voltage oscillation reduced from 5–2 s during 33 kV grid bus fault. With the use of SVC, reduction in generator speed oscillation results in reduction of thermal stress in turbine system and improvement of plant reliability significantly. Improvement of reliability also helps plant operator to perform safe islanding operation of captive generator.

References

1. Mukhopadhyay. S and Singh. B, "Distributed Generation - Basic Policy, Perspective Planning, and Achievement", India Power & Energy Society General Meeting, 2009. PES '09. IEEE.
2. Utpal Goswami, Tapas Kumar Sengupta, Arabinda Das, "Improvement of Transient Stability Performance of Captive Power Plant during Islanding Condition", TELKOMNIKA Indonesian Journal of Electrical Engineering, Vol. 12, No. 12, 2014, pp. 8001–8007. DOI: 10.11591/telkomnika.v12i12.6730.
3. Rajamani. K, Hambarde. U.K, "Islanding and Loadshedding Scheme for Captive Power Plant Power Delivery", IEEE Transactions, Vol. 14, Jul 1999.
4. NEMA Standards Publication ICs 1-1988, General Standards for Industrial Control and Systems; ICs 2-1988, Industrial Control Devices, Controllers and Assemblies; ICs 3-1988.
5. Bindon. R.E, "Emergency operation of large steam turbine generator", presented at South Eastern Electric Exchange, Atlanta, Georgia, October 13–14, 1966.
6. IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (ANSI).
7. IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (ANSI). 19458.
8. Sengupta T.K., "Studies on Assessment of Power Frequency in Interconnected Grid – Its Computer based Control and Protection", Research Paper, The Faculty of Engineering and Technology, Department of Electrical Engineering, Jadavpur University, 2008.
9. Krishnamurti. P, "Captive Power Plant Quality Journal" of TCE Limited, Vol.4-I-pp. 10, April 2006.
10. Fishow, A.G, "Transient ans Steady State Stability margin to state a power system stability standardization", published in UPS of Russia.
11. Canizarea. C. A, Bhattacharrya. K, Haghighat. H, Pan. J, Tang. C and Samahy. E. I, "Reactive Power Despatch Problem in the context of Captive Electricity Market Generation, Transmission and Distribution", Vol. 4, IET issue, February 2010.