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Improvement of Transient Stability Performance of Captive Power Plant during Islanding Condition

Utpal Goswami[1]*, Tapas Kumar Sengupta[2], Arabinda Das[3]
[1]Development Consultants Private Limited, Kolkata – 700 091, India
[2]Supreme Knowledge Foundation Group of Institutions, Mankundu, Hooghly, India
[3]Electrical Engineering Department, Jadavpur University, Kolkata – 700 032, India
*Corresponding author, e-mail: utpal.goswami@in.dclgroup.com

Abstract

This paper deals with an idea to improve the transient stability of captive generator sets during islanding condition. But doing so, the transient stability of the generator sets and the power system is severely disturbed in case of a fault in the utility side. In case of fault, the own generation is isolated, synchronization is lost and finally the sets go in islanding mode of operation. As such sets are of small size (5-50 MWs), total load throw-off in utility side causes disturbance in the transient form. If disturbances are not recovered immediately in terms of turbine speed, voltage variation etc., the power supply will be unstable and process suffers. A remedial measure, for the case concerned, can be taken with the aid of a SVC during the tripping of the utility load, at the generator bus before the frequency and voltage stabilization. The analysis was done using ETAP software.

Keywords*: islanding, transient stability, SVC, utility load*

1. Introduction

Power reforms have become a globalised issue in modern industrial as well as corporate power sectors. This also can be termed as de-regularization [2] in power system. The era of deregulated electric industry, companies are permitted to produce and sell electrical power to power grid and the industry type need not necessarily be a generation company.

Deregulated electrical industry emphasizes the liberal provision in the Act with respect to setting up of captive power plant with a view to not only securing reliable, quality and cost effective power but also to facilitate opportunities for speedy and efficient growth of Industry. Current industry practice is to disconnect all distributed generators immediately after an islanding occurrence typically after 200 ms and 300 ms after the loss of main supply [7] if the system has not regained its stability. Various schemes have been utilized for stabilization of captive power plant under grid disturbance condition in terms of islanding and load shading. Such scheme involves the utilization rate of change of frequency along with under frequency relay [1]. Real time digital control based on Fuzzy logic on a filtered programmable gate array chip [10] is suitable for management of captive power plant in automatic decision making for load shedding during grid disturbance for stabilizing the system. Predetermination of islanding can be done with an aid of vector surge relay, which is applicable for isolating the system, well before occurrence of the severe disturbance to retain stability [7, 8]. When a grid failure occurs in captive generator systems, they are usually isolated from the grid accompanying a sudden load throw off, resulting in added thermal stresses on turbine blades and boilers connected therewith. The consequence of thermal stress is reduction of life span of equipments used for system operation [9]. SVC is suitable for improving the system performance when a generator bus is connected to grid.

As grid disturbance is a major issue nowadays, therefore improvement of the transient stability performance, during and after islanding, in much faster way, is a real challenge for power industry. Improvement of the transient stability of a system after islanding was done, by controlling the governor speed along with controlling the AVR of alternator [9]. Still the requirement of reducing the time span of oscillation of speed, of alternators, is a major concern of recent times.

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This paper presents a unique approach for improving the transient stability of a captive power plant after islanding by connecting a SVC in generator cum load bus which reduces the time duration of oscillation of generator speed much faster, thus improving the stability of power system.

2. Profile of the Power System

2.1. Description

The power system considered in this paper is a process industry having the co-generation facility. Tail gases produced as a part of the process is used to generate power for captive power plant. The plant has two independent process lines. Electric power supply for line1 supplies power with the help of 11 kV/415 V distribution transformer to following 415 V power and motor control centre denoted as 4G11BuA, 4G11BuB, 4G13BUA, 4G13BUB, 4G12 and 4G13BUErm. 11 kV/415 V transformer is supplied by 11 kV switchgear denoted as 11G1. 11 kV switchgear is taking supply from 17 MW generator 1. Line 2 supplies power with the help of 11 kV/415 V distribution transformer for supplying power to following power and motor control centre denoted as 4G21BuA, 4G21BuB, 4G22BUA, 4G22BUB, 4G22Bu and 4G23BUErm. Line 2 is taking supply from 11 kV switchgear denoted as 11G2. 11 kV switchgear is connected with 17 MW generator G2. One 415 V DG set (DG1) and one HT diesel generator is installed as standby for emergency condition during total black out of the process plant [3]. Start-up power of any of the generators is generally available from the electric grid. Alternatively, 11 kV diesel generator (DG2) is available to provide start-up power also. Second turbine generator (G2) also can manage the start-up power from the first turbine generator (G1), if already started or vice-versa. Basic power system arrangement [3] of all generators along with interconnection is shown in key single line diagram showing all circuit breakers prepared for the study. As per the system philosophy for feeding the process lines G1 and G2 are generally run in parallel continuously. However, in case one generator is out of service another generator is capable of taking the entire plant load for longer period of time. The 11 kV, 17 MW generating unit will be connected to 11 kV switchboard. Auxiliaries of this unit will be fed from a new 2.5 MVA distribution transformer connected to the said 11 kV switchboard. 20 MVA generator transformer will be connected to 132 kV switchyard. The 132 kV switchyard will be connected by a single circuit overhead transmission line for evacuating power to grid. Upon an emergency situation such as failure of generators the DG2 will also be used to supply the emergency load in the plant in order to keep the plant in operation. The above power system arrangement is shown in the key single line diagram meant for study. 132 kV buses and the plant 11 kV buses, generators, LT transformers and LT buses with lump loads and tie inter connection required for the study is shown in the said diagram. Purpose of this key single line diagram is to identify various equipment and buses with respective IDs used in the study.

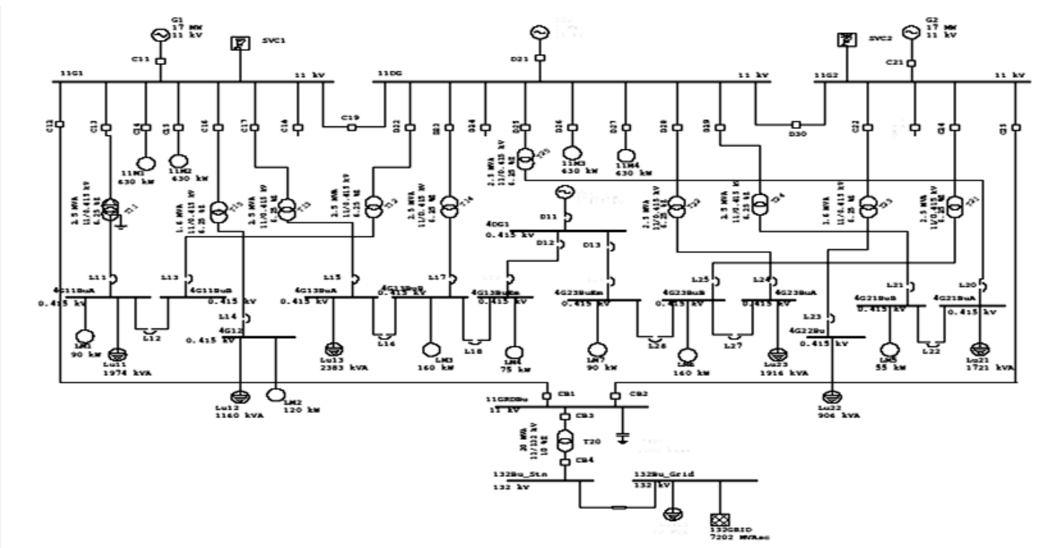

Figure 1. Network Diagram for System Study

2.2. Detailed Single Line Diagram for Simulation

Block Diagram of the power system is modelled in ETAP 11 and hereby attached with this scope of work as Network Diagram for system study (Figure 1). This has been studied to simulate the different cases to meet our objectives.

2.3. Network Parameter Considered for System Study

Power system study through ETAP software requires considerable numbers of accurate system data and equipment data and their related information. Such data were listed, discussed with plant engineers and collected as far as possible from the available document [5]. There are number of required data which were not available but were assumed from references [3-6]. Following basic points were considered for reviewing and finalizing the input data required for the study:

1) Lump loads as shown in various buses are average load consisting of motor load; static load etc. fed from respective PMCCs connected to corresponding switch boards
2) Fault level of existing 415 V switch boards is considered as 50 kA.
3) Except generator transformer, no tolerance of impedances of generators and existing transformers are considered.
4) Tolerance of impedances for 20 MVA GT is considered as per IEC standards.
5) Overhead 132 kV line is considered from Station switchyard end to the Power grid end.

2.4. Data Considered for Models used in ETAP Software

Model used	Specifications
Synchronous generator	***Impedance model*** X_d'' = 12, X''/R_a = 48, R_a% = 0.25 R_a= 0.014235 Ω X_2 = 12, X_2/R_2 = 48, R_2% = 0.25 R_2 = 0.014235 Ω X_0 = 12, X_0/R_2 = 48, R_0% = 0.25 R_0=0.014235 Ω ***Subtransient model*** X_d% = 110, X_q% = 108, $T_{d0'}$ = 56, S_{break} = 0.8 X_{d4}% = 116.93, X_{q4}% =114.79, $T_{d0''}$ = 0.002 S_{100}=1.07 X_d'% = 23, X_q'% = 15, $T_{q0'}$ = 3.7, S_{120} = 1.18 X_L%=11, X_q'%=12, $T_{q0''}$=0.02 Damping = 5, H = 1.7 ***Machine model*** Generator type = Turbo Rotor type = Round rotor IEC Exciter type = 130% Turbine ***Exciter model*** Exciter type : UDM - IEEE1, Exciter model type : ST1 Nominal voltage = 132 kV
Grid model	Fault level of 132 kV switchyard Bus = 7201 MVA X/R ratio (3 ph) =60, X/R ratio (1ph) = 60 Capacity = 20 MVA
Generator transformer	Primary voltage = 11 kV Secondary voltage = 138 kV Vector group = Ynd 11 Neutral grounding = Solid Impedance (+ Seq)= 10% Impedance (- Seq) = 10%, X/ R=18.6

2.5. Considerations in Export Conditions for the Analysis

Case - 1: For a fault in 132 kV grid side, the utility breaker tripped after 180 ms (including relay and circuit breaker operating time plus 20 ms time delay), thereafter transformer upstream breaker opened with 30 ms time delay.

Case - 2: For a fault in 132 kV grid side, the utility breaker tripped immediately within the critical clearing time of 160 ms (including relay and circuit breaker operating time), thereafter transformer upstream breaker opened with 30 ms time delay.

Case - 3: For a fault in 132 kV grid side, the utility breaker tripped immediately within the critical clearing time of 160 ms (including relay and circuit breaker operating time), thereafter immediately SVC is connected with 11 kV generator bus 11G1 and 11G2.Then generator transformer upstream breaker is opened with 30 ms time delay.

2.6. Event of Operations Considered for the Analysis

Event	Time	Device Type	Device ID Action
Case 1			
T1	2.0s	3Ph	Fault on 132 kV bus
T2	2.18s	CB4	Open
T3	2.48s	CB9	Open
T4	2.78s	CB1	Open
Case 2			
T1	2.0s	3Ph	Fault on 132 k V bus
T2	2.16s	CB4	Open
T3	2.46s	CB9	Open
T4	2.76s	CB1	Open
Case 3			
T1	2.0s	3Ph	Fault on 132 kV bus
T2	2.16s	CB4	Open
T3	2.46s	SVC	Connected
T4	2.76s	CB9	Open
T5	3.06s	CB1	Open

2.7. Graphs for Transient Analysis

Case 1

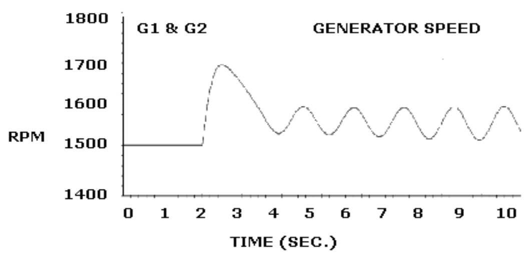

Figure 2. Generator speed (RPM) vs. Time (sec.)

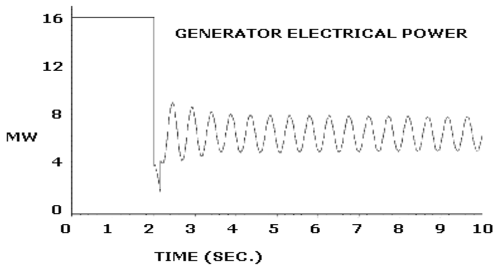

Figure 3. Generator active power (MW) vs. Time (sec.)

Case 2

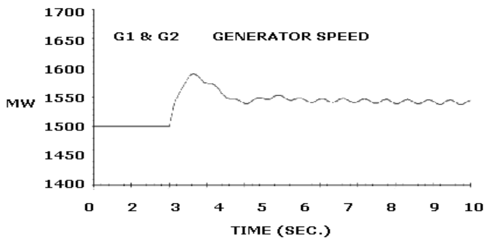

Figure 4. Generator speed (RPM) vs. Time (sec.)

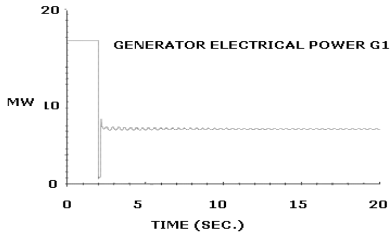

Figure 5. Generator active power (MW) vs. Time (sec.)

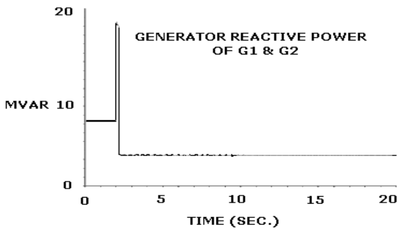

Figure 6. Generator reactive power (MVAR) vs. Time (sec.)

Case 3

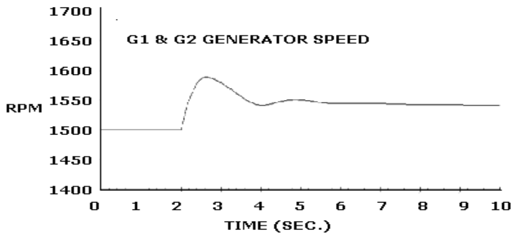

Figure 7. Generator speed (RPM) vs. Time (sec.)

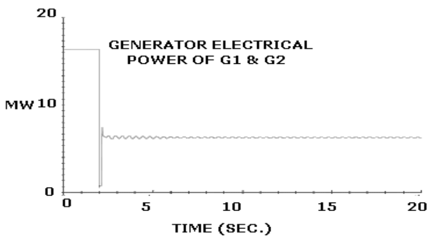

Figure 8. Generator active power (MW) vs. Time (sec.)

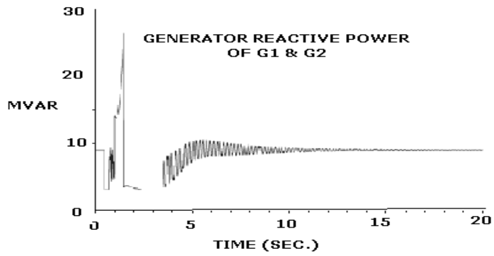

Figure 9. Generator reactive power (MVAR) vs. Time (sec.)

2.8. Analysis of the Graphs

Event ID & Reference Graph Number	Fault clearing time	Highest speed attained (rpm)	Final stabilized speed of generator	Time required to reach stabilization
Case 1 Graph 1, 2	180ms	1690 rpm	Oscillates between 1560-1530 rpm	---------------
Case 2 Graph 3, 4, 5	160ms	1620 rpm	1530 rom	6 seconds
Case 3 Graph 6, 7, 8	160ms	1620 rpm	1530 rpm	2 seconds

Event ID	Active power profile (G1 and G2)	Reactive power profile (G1 and G2)	Remarks
Case 1	Continuously oscillates	----------------	%variation of speed 12% active power profile and speed continuously oscillates; system unstable
Case 2	Before islanding 16MW, After islanding 8MW	Before islanding 9 MVAR, After 3.7 MVAR	Speed variation 8% and becomes stable after 6 seconds from islanding. Reactive power during fault condition increases and becomes stable at lower required value (3.7MVAR)
Case 3	Before islanding 16MW, After islanding 8MW	Before islanding 9 MVAR, After 3.7 MVAR. After connecting with SVC it oscillate and stable at 9 MVAR	Speed variation 8% and becomes stable after 2 seconds from islanding. Reactive power during fault condition increases and becomes stable at lower required value

3. Conclusion

As per analysis it was observed that, if the system sustained the fault for 180 ms and over, the system become unstable in terms of its speed and active power delivery. If a system loses full load and remain in service carrying auxiliary or just spinning with no load, it will subject to sudden, fairly large change in temperature at high pressure which results in thermal stresses both in boiler and turbine. If the magnitude of the thermal stress is very high then it exceeds the material yield strength which eventually damages the life of boiler and turbine. In case of captive power plant, the unit MW value, during consideration, needs load throw-off capability to be analyzed for transient stability. If the export is above the ‘load-throw-of-capability’ of the generator, it is difficult to restore the system from complete shutdown. As such, it is recommended that the generator capacity has to be chosen to comply with the transient stability of the generator sets during load throw-off. By adding SVC in the system, the magnitude of the speed of generator during load throw off situation, remain unaltered, but the time duration of oscillation reduced significantly (4 sec.). The reduction in time of oscillation results in reduction of time duration of thermal stress. This increases the life of the major expensive equipment like boiler and turbine.

References

[1] Rajamani K, Hambarde UK. Islanding and Loadshedding Scheme for Captive Power Plant Power Delivery. *IEEE Transactions, ISSN-0885-8977, INSPE Accession No.-6298305, Digital object identifier-10.1109/61.772318*. 14(3): 805-809.
[2] Mukhopadhyay S, Singh B. *Distributed Generation - Basic Policy, Perspective Planning, and Achievement.* India Power & Energy Society General Meeting, PES '09. IEEE, ISSN-1944-9925, ISBN-978-1-4244-4241-6, INSPEC Accession No.-10903297. Digital object identifier-10.1109/PES.2009.5275741. 2009.
[3] IEEE Standards Association. 141-1993. *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (ANSI).* IEEE Press; 1994. DOI:10.1109/IEEESTD.1994.121642
[4] IEEE Standards Association. 242-2001. *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (ANSI).* IEEE Press; 2001. DOI: 10.1109/IEEESTD.2001.93369
[5] 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.
[6] 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*.
[7] Krishnamurti P. Captive Power Plant Quality. *Journal of TCE Limited*. 2006; 4(1):10-14.
[8] Freitas W, Huang Z, Xu W. A practical Method of assessing for the effectiveness of Vector Surge relay For Distributed Generation Application. *IEEE*. 2005: 0885-8977.
[9] Giang LN, Thuy NTD, Ngoat TT. Assessment study of STATCOM's effectiveness in improving transient stability for power system. *TELKOMNIKA*. 2013; 11(10): 6095 ~ 6104.
[10] Bindon RE. *Emergency operation of large steam turbine generator.* South Eastern Electric Exchange. Atlanta, Georgia. 1966; 2(1):10-14.
[11] Singh S, Saini JS. *Fuzzy FPGA based captive power management*. Power India Conference. New Delhi, Delhi. 2006: 7.