The Journal of CPRI,
Vol. 13, No. 2, June 2017 pp. 327-332

Realizing the laboratory model for reverse power protection of alternator interfaced with GSM

Sumit Srivastava* and Ankit Niranjan**

Generators is one of the most important, delicate and costlier components of power system. Since power plant generators are very important part of an electrical energy network, so they should be protected in order to maintain the quality and reliability of power supply. This paper presents the design and implementation of reverse power protection of alternator during the failure of prime mover. Initially the system has been designed by using MATLAB Simulink for synchronous generator and then further implemented in laboratory with the of real time system using reverse power relay interfaced with GSM. The complete analysis of motoring protection system has been constructed on software as well as in hardware and various results have been obtained for the different conditions of prime mover failure.

Keywords: *Synchronous generator, motoring protection, reverse power relay, MATLAB/SIMULINK, GSM.*

1.0 INTRODUCTION

In view of the protection of the power system network, the Synchronous generators constitute a major category of power system because if any abnormality happens, the results can be extremely destructive. Integration of generators by most of the utilities must be protected from false tripping. Synchronous generators must be removed off from the grid under any abnormal situation. In order to detect such operation and prevent damages to both generators and prime mover.

As a reason of drastic developments in power system it is necessary to protect system with the help of latest technology. Therefore, GSM based technology has been discussed in this paper to send SMS during the motoring mode of the synchronous alternator. In this paper the motoring protection i.e. reverse power protection of a large turbo generator is considered, when there is a failure of prime mover especially steam turbine.

2.0 LIST OF ABBREVIATIONS

GSM: Global system for mobile communication

SIM: Subscriber Identity Module

RX: Receiver port

TX: Transmitter port

RP: Reverse power

CT: Current transformer

PT: Potential transformer

CB: Circuit breaker

DC: Direct Current

3.0 MOTORING CONDITION

However, if the input to the Prime mover (i.e. engine or turbine) of any generator fails due to

*Project Engineer, Wipro Technology Bhubaneswar, India sumitvit@yahoo.in
**Graduate Engineer Trainee Vedanta Resources PLC Goa, India ankit.94.niranjan@gmail.com

an unavoidable circumstance, the bus bars itself starts supplying active power from the power system network to the generator and it runs as synchronous motor to drive the prime mover. In such a situation the active power flows in reverse direction and the generator currents are still balanced. This condition do pose no harm or a little harm to the generator, though the generator windings will be overheated but the reversal of power is very detrimental to the prime mover. In order to detect such operation and prevent damages to both the prime mover and the generator, a directional active power relay must be used. In this context the modelling, simulation and analysis of complete motoring protection of a synchronous generator is presented. Motoring condition might take place during synchronization process also, when the frequency of the synchronous generator to be synchronized with the large power network is a little lesser than that of the bus bar and the circuit breaker is closed. Hence, the active power will flow from the bus bar to that synchronous generator. Therefore the frequency of the synchronous generator to be synchronized is kept a little higher than the frequency of the bus bar. This guarantees that the incoming synchronous generator takes on load immediately after the circuit breaker is closed.

4.0 GSM MODULE

GSM module SIM 900 is used in this paper. It is just like a cell phone having facilities of sending and receiving message, receiving and sending calls. It has a communication that can be programmable by using AT commands. The signal names for the GSM modem communication port includes the following; audio output and input pins, flash programming signal pins, mute control pin, external power pins, and receiver and transmitter pins.

The GSM modem can either be connected to PC serial port directly or to any microcontroller through MAX232. In this paper we have used RX and TX pins for the serial communication with the help of microcontroller. There are various AT commands to send SMS, to receive and send call, to check the signal strength and SIM status etc. The basic AT commands are loaded in the program of microcontroller to interface with GSM module. The idea of designing the setup is to realize the effects of reverse power and to see the various aspects of the power monitoring relay.

5.0 HARDWARE DESIGN APPROACH

In this paper, the designing of reverse power setup, for an alternator connected with a reverse power relay, to sense the motoring mode of the machine and also to send a SMS as a warning during the flow of Reverse Power has been shown. To the alternator, a dc shunt motor is coupled which acts as a prime mover or turbine for the alternator.

In the setup, the relay which has been used is RPF D2 detects the reverse power when current flows in the reverse direction (reverse power).

When the power is applied to the module, the relay energises immediately (under normal condition) and remains energised and the 'ON' led illuminates. Whenever the power flow direction changes the 'RP' led illuminates and the relay de energises because the reverse current exceeds the tripping level for longer than the trip delay time period. The trip time delay is adjustable up to 10 sec. The 'ON' led becomes off, when the reverse current level exceeded until the delay time expires (the time at which, relay de energises). If forward power is restored or the reverse current level drops below the hysteresis level before the trip delay expires, the 'ON' led constantly on and relay remains energised.

6.0 EQUATIONS

The setting of reverse power for different engines and different turbines depends upon the motoring power (in terms of rated power).

In this setup, we have considered the motoring power as 12% with the trip delay of 10 sec with the specification of alternator and DC shunt motor as given below:

Voltage, current, speed of alternator and motor are 415V, 7A,

1500rpm and 220VDC, 27.5A, 1500rpm respectively. The required setting in the reverse power relay would be:

- Required trip level: 12%.
- Generator rating: 7A at power factor of 0.8.
- Ip max: 7*0.8=5.6A.
- Current transformer rating: 20/5A.

Therefore, the reverse power setting in the relay will be formulated as: *(Ip max × mentioned RP setting)/Primary CT rating % or (12× 5.6)/20 =.36%.*

7.0 SOFTWARE DESIGN APPROACH

Modelling of reverse power relay consists of 3 parts i.e., directional element, delay element and hold element.

1) Directional Element

In the directional element, low voltage and current signals coming from CT and PT signals are converted to a perfect square wave form with ±1 values. Then the two level signals are multiplied to give an output '-1' during the non-overlapping and '1' for the overlapping interval. The product so obtained is then integrated from 0 to '-L' (any value can be chosen depending upon the amount of reverse power flow i.e., threshold value).

2) Delay Element

The purpose of the delay element is to prevent the relay from sending a false trip signal to the CB during transient or a temporary fault conditions.

3) Hold Element

The purpose of the hold block is to keep the state of the relay stable after the relay has tripped. This is because once the Circuit Breaker has opened, the fault will cease to exist, indicating a normal condition and tempting the relay to again send signal to the Circuit Breaker, causing it to close again.

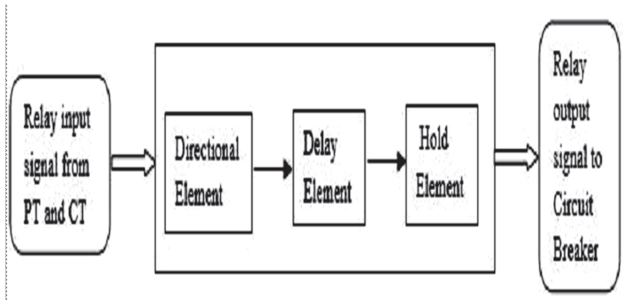

FIG 1: BLOCK DIAGRAM SHOWING RP RELAY

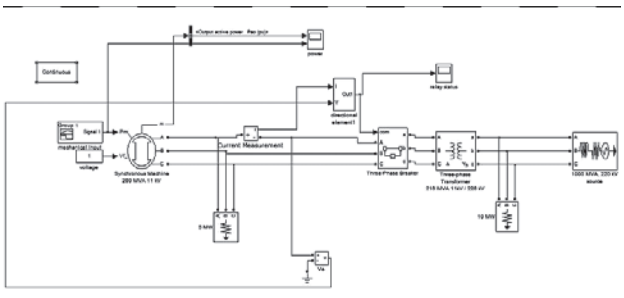

FIG 2: REVERSE POWER RELAY MODEL IN MATLAB

8.0 SIMULATION RESULTS

For testing and simulation of designed relay, a 200MVA 11kV synchronous machine is used, connected with 220kV network through a step up transformer 11/220kV as shown in Fig. 2. The relay is tested under different scenarios. The test conditions, results and discussions are given below.

Case 1: Forward power flow

In this case, normal mechanical input is given so that power will flow from alternator to the grid. Varying mechanical input from 0.3 to 0.7 at 30 sec. The input and output power and relay status can be observed as shown in various figures. In this case the relay will not trip however, the output power oscillates initially about the equilibrium point.

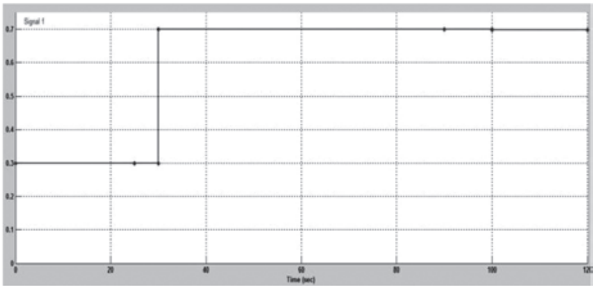

FIG 3: MECHANICAL INPUT VARIATION IN NORMAL CASE

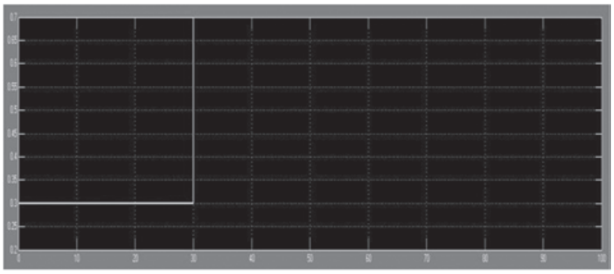

FIG 4: INPUT POWER TO THE ALTERNATOR

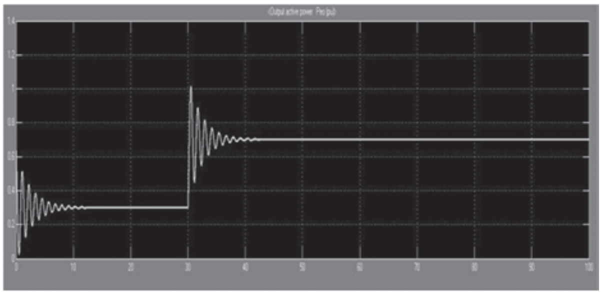

FIG 5: VARIATION IN OUTPUT POWER

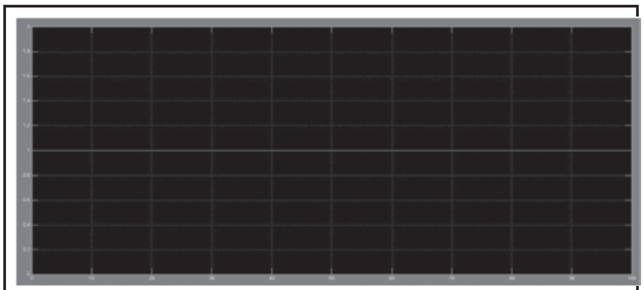

FIG 6: RELAY STATUS UNDER NORMAL CONDITION

Case 2: Reverse power flow

In this case mechanical input changes from 0.6 to 0.4 at 30 sec and then from 0.4 to -0.2 at 50 sec. Now input and output power can be observed from the figures. In this case we can see that initially relay will not trip since mechanical input given is positive at 40 sec but relay will trip after 60 sec and some delay time since mechanical input is changing from positive value to negative value.

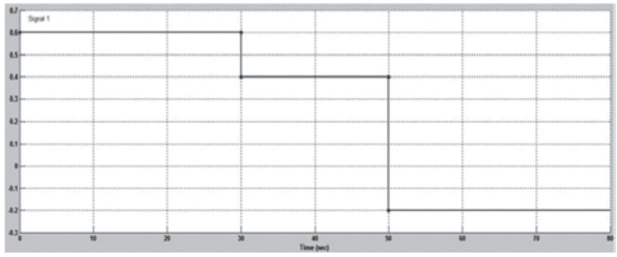

FIG 7: MECHANICAL INPUT VARIATION IN ABNORMAL CASE

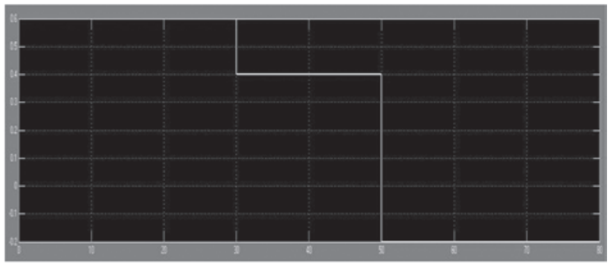

FIG 8: INPUT POWER TO THE ALTERNATOR

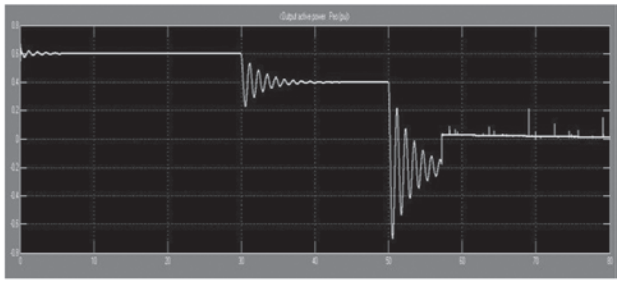

FIG 9: VARIATION IN OUTPUT POWER

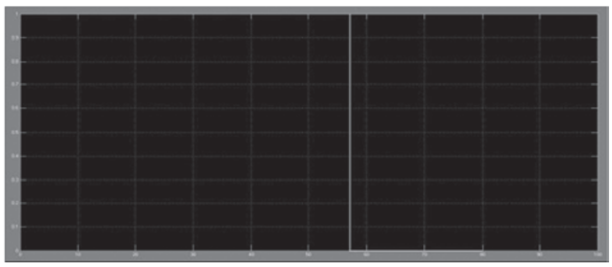

FIG 10: RELAY STATUS UNDER RP CONDITION

9.0 HARDWARE DEMONSTRATION

Now in hardware initially alternator is synchronized with the grid and normal flow has been achieved. Now switching off the DC shunt motor which is acting as prime mover for the synchronous alternator. This will lead to motoring of synchronous alternator and thus reverse power will start to flow i.e. flows from grid to generator. As reverse power will flow, the relay will trip after delay time which has been set as 5seconds and RP setting has been set as 4% and thus contactor will come into off state leading to removal of alternator with grid and SMS will be sent via GSM module.

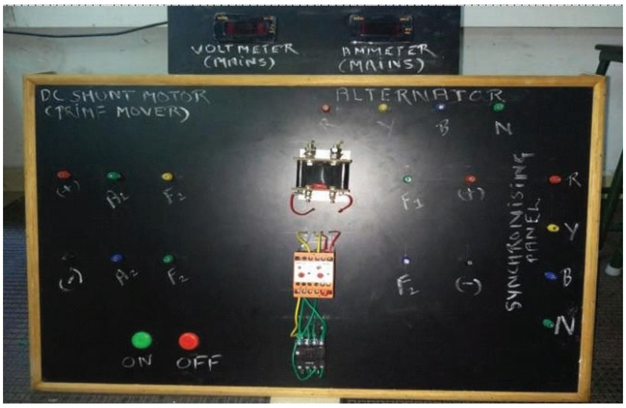

FIG 11: HARDWARE PRESENTATION

Now, the variation of Reverse Power setting with speed of DC shunt motor has been shown by keeping time as constant.

TABLE 1		
VARIATION OF REVERSE POWER SETTING		
S. No.	**Reverse Power Setting (In percentage)**	Speed (In rpm)
1	2	1488
2	4	1457
3	12	1303
4	16	1224
5	20	988

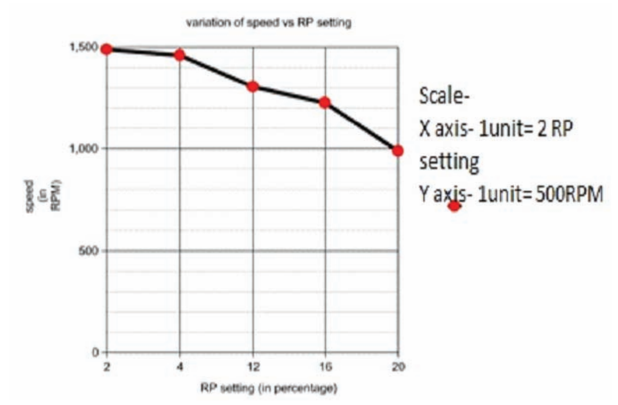

FIG. 12: GRAPH SHOWING VARIATION IN RP SETTING FOR DIFFERENT SPEEDS

10.0 CONCLUSION

In this paper, it has been shown that during synchronizing the alternator with the grid, it is very important to observe the flow of active power because any ambiguity during synchronizing can lead to destruction of generation site as well as can hugely impact the designed power system as well.

The severity of this problem has been eliminated by using a basic GSM module, which is cheap, robust and sufficiently faster for laboratory model to quickly address the responsible person so that the required decision can be taken to avoid such huge losses.

REFERENCES

[1] Muhammad MohsinAman et al., “Modeling and Simulation of Reverse Power Relay for Generator Protection”. In 2012 IEEE International Power Engineering and Optimization Conference (PEOCO2012), Melaka, Malaysia: 6-7 June 2012, 2012.

[2] “IEEE Tutorial on the Protection of Synchronous Generators”,Special Publication of the IEEE Power System Relaying Committee, John Wiley & Sons, Inc., Publication,© IEEE 2011.

[3] Muhammad MohsinAman, Ghauth Bin Jasmon, Hazlie BinMokhlis, Qadeer Ahmed Khan, Ab. Halim Bin Abu Bakar, and MazaherKarimi, “Modeling and Simulation of Digital Frequency Relay for Generator Protection”. In 2012 IEEE International Conference on Power and Energy (PECon), Kota Kinabalu Sabah, Malaysia: 2-5 December, 2102

[4] SezaiTaşkin, “Power Plants Monitoring for Reverse Power Flow Evaluation”, Journal of Electrical & Electronics Engineering, Istanbul University, Vol. 10, No. 1, 2010.

[5] Vahidi, B. and Esmaeeli, E., “MATLAB-SIMULINK-based simulation for digital differential relay protection of power transformer for educational purpose”.

Computer Applications in Engineering Education.

[6] K. Rajamani and U. K. Hambarde, "Islanding and load shedding schemes for captive power plants," Power Delivery, IEEE Transactions on, Vol. 14, pp. 805-809, 1999.