# Performance of the Grid Connected Induction Generator under Fault Conditions

**Arun Pundir[1], Gagan Deep Yadav[2]**

[1]*Mtech Scholar, YIET Gadhauli, India*
[2]*Assistant Professor, YIET, Gadhauli, India*

---

***Abstract**—Developments in wind turbine technology are facilitating the increase of power generation capacity from renewable energy resources. As an electrical utility grid is generally unable to accept a large amount of wind power without imposing strict conditions, reactive power control, voltage fluctuation and fault ride through capability are the main areas of concern. The effective strategy to optimize the use of wind power in on grid area, develop the electric power generation driven wind power which is connected to grid. The utilization of the squirrel-cage induction generator on wind power generation has some advantages rather than conventional synchronous generators. This paper presents a simplified model of the induction generator which is driven by wind turbine and is connected to the grid. Some component model provided with in SIMULINK library of MATLAB construct the proposed model. Static var compensator (svc) and capacitor bank are used to improve the dynamic response of grid connected wind farm. The contributions of svc and capacitor bank of the wind farm and power grid are verified by the simulation. The result shows the competitive dynamic response of the system using capacitor bank and SVC.*

**Keywords- Wind Turbine Induction Generator, Cpacitorbank,SVC, Reactive Power compensation .**

## 1. INTRODUCTION

As a clean and renewable energy the wind energy resources have dramatically increased over the decade. The power system operation has become more competitive and many challenges will arise since it is a clean energy resource, has lesser impact to the environment, and never runs out, renewable energy is a hot issue in today competitive market. However, they still require a large amount capital investment when large generation plants are required. Because wind energy development is consumer and eco friendly, requires shorter construction time, is cost competitive. High penetration of wind energy into the current grid is prevented by many reasons, especially the high capital and maintenance cost of the system [2]. To some extent this is mitigated by utilizing SCIGs. The use of SCIG in wind energy generation is widely accepted as a simple and cheap option, as it is reliable and requires very little maintenance due to its brushless rotor. Hence, it offers significant cost advantage over other type of generators [1].In wind farms, fault on the transmission line can lead to wind generator over-speed and cause instability of the network voltage[2][3].

When, fault occurs, the terminal voltage of the IG drops. Therefore, the electrical torque abruptly decrease to zero due to the terminal IG voltage and the rotor speed starts to increase. After the clearance of the fault, the reactive power consumption increases resulting in reduced voltage of IG .Thus the IG voltage does not recover immediately after fault. Therefore generator becomes unstable. To minimize reactive power exchange between grid and wind generator, dynamic compensation of reactive power can be used. Further, the normal operation / restoration after the clearance of an external system fault can be improved with dynamic reactive compensation [3], [4].Capacitor bank and SVC can be used for dynamic reactive power compensation of power systems to provide voltage support and stability improvement [5]. The effect of capacitor bank and SVC in improving the stability performance of WTIG is analyzed.

## 2. DESCRIPTION OF SIMULINK MODEL

### The System Modeling

The modeling of the system considered is illustrated by Figure 1. The induction generator is driven by wind power and is connected to the grid system through distribution transformer. In this model, the wind turbines are an uncontrolled turbine, which its power depend on the effective head (H) and debit (Q). The mechanical power output of the turbine (Pm) is:

$$Pm = gHQ\eta_T$$

Where:

$g$ is gravity constant
$\eta_T$ is turbine efficiency
The mechanical torque ($T_m$) is used to drive the induction generator presenting as follow:

$$T_m = \frac{P_m}{w_m}$$

Where

$\omega_m$ is the rotor angle speed

In wind power generations, the head viable charge can be balanced physically utilizing the opening entryway. For using a standalone generation, the electronic load controller and ballast load are used for power balancing at varying load [5].The power that is produced by the induction generator that is traded to Low Voltage (LV) side distribution system. In the system considered, the capacity power of wind power generation is less than the capacity power of distribution transformer, so they empower supply the power simultaneously. The simplified equivalent of grid system on mv (medium voltage) side is assumed one generator with its impedance.

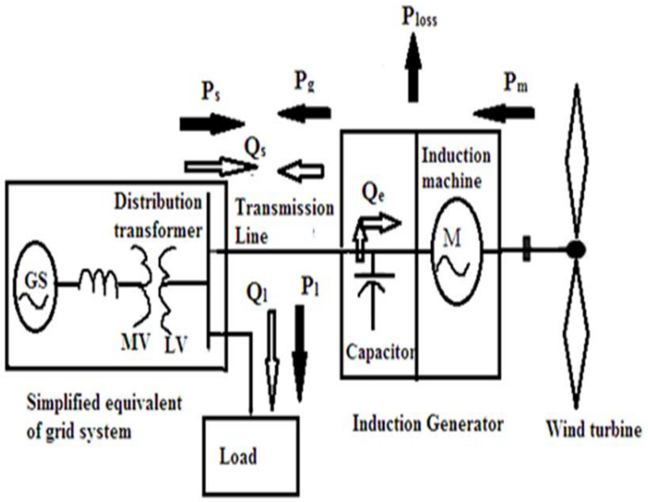

**Fig. 1.**Block Diagram Representation

## Active and Reactive Power Balance

As shown in Figure 1, the induction generator absorbs the mechanical power ($P_m$) from the turbine and produces the active power ($P_g$) to supply the load ($P_l$) and to lose in heat energy. The induction generator absorbs the reactive power ($Q_g$) from the excitation capacitor ($Q_e$)or/and grid system and produces the reactive power when the capacity of the excitation capacitor more than reactive power that is required by induction generators. While, the load absorbs the active and reactive power ($P_l$, $Q_l$) from the grid system and/or the induction generator. The grid system can exports or imports the active and reactive power ($P_s$, $Q_s$). In addition, the active and reactive power balances in the induction generator can be written as follows:

$$\sum P_{produce} = \sum P_{absorbs}$$

$$\sum Q_{produce} = \sum Q_{absorbs}$$

## Induction Generator Modeling

The induction generator modelling is derived from an induction machine and reactive load generations. There active load generations can be undertaken by excitation capacitor or grid systems. The squirrel-cage induction machine of the mathematical modelling for d-q frame, given as in this following equations:

*Electrical System*

$$v_{qs} = R_s i_{qs} + \frac{d\lambda_{qs}}{dt} + w\lambda_{ds}$$

$$v_{ds} = R_{si_{ds}} + \frac{d\lambda_{qs}}{dt} - w\lambda_{qs}$$

$$0 = R'_r i'_{qr} + \frac{d\lambda'_{qr}}{dt} + (w - w_m)\lambda'_{dr}$$

$$0 = R'_r i'_{qr} + \frac{d\lambda'_{dr}}{dt} - (w - w_m)\lambda'_{qr}$$

And

$$\lambda_{qs} = L_s iq_s + L_m i'_{qr}$$

$$\lambda_{qs} = L_s i_{ds} + L_m i'_{dr}$$

$$\lambda'_{qr} = L'_r i'_{qr} + L_m i_{qs}$$

$$\lambda'_{dr} = L'_r i'_{dr} + L_m i_{ds}$$

Where:

$$L_s = L_{ls} + L_m$$

$$L'_r = L'_{lr} + L_m$$

Where:

$v_{dqs}$, $v_{dqr}$ are the stator and rotor voltages in the d-q frame
$i_{dqs}$, $i_{dqr}$ are the stator and rotor currents in the d-q frame
$\lambda_{dqs}$, $\lambda_{dqr}$ are the stator and rotor fluxes in the d-q frame
$R_s$, $R_r$ are the stator and rotor resistances
$L_{ls}$, $L_{lr}$ are the stator and rotor leakage inductances
$L_m$ is the magnetizing inductance
ω is the arbitrary reference frame

*Electromagnetic Torque*

$$T_e = \frac{3}{2}P\{\lambda_{ds}i_{qs} - \lambda_{qs}i_{ds}\}$$

Where:

Electromagnetic torque is denoted by *T*e, and number of pole pair is denoted by *P*.

*Excitation system for a self excited mode*

$$i_{qs} = i_{ql} + wq_{dc} + \frac{dq_{qc}}{dt}$$

$$i_{ds} = i_{dl} - wq_{qc} + \frac{dq_{dc}}{dt}$$

And

$$q_{qc} = cv_{qs}$$

$$q_{dc} = cv_{ds}$$

Where:

$I_{dql}$ are the d line currents in the d-q frame

$Q\ i_{dqc}$ are the electric charge in the d-q frame

*C* is the capacity of capacitor excitation

*Mechanical System*

$$\frac{dW_m}{dt} = \frac{1}{2H}\{T_e - FW_m - T_m\}$$

Where:

ωm is the rotor angle speed

In above equation, the machine acts as a generator if *T*m is Negative.

## 3. METHEDOLOGY

Dynamic response of induction generator using capacitor bank The unbalance in grid voltage has been found to make significant impact on the generator and system performance. The self excitation mode operation uses excitation capacitor to create the reactive power. Shunt capacitor connected at the generator terminals maintains the terminal voltage near to nominal voltage and improves the power factor.

### Dynamic response of Induction generator using SVC.

A static Var compensator (or SVC) is an electrical device for providing fast acting reactive power compensation on high-voltage electricity transmission networks. Static Var Compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids. The SVC controls voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage decreases, the SVC produces reactive power. When system voltage increases, it absorbs reactive power. Typically SVC comprises of bank of individually switched capacitors in conjunction with thyristor controlled reactor. By means of phase-angle modulation switched by thyristor, the reactor may be variably switched into the circuit, and so provides a continuously variable VAR injection (or absorption) to the electrical network. Other arrangements like thyristor-switched reactor and thyristor-switched capacitor are also practical. In transmission application, SVC is used to regulate grid voltage. If the reactive load of power system is capacitive (leading), the SVC will use thyristor controlled reactor to consume VAR from the system, decreasing the system voltage. Under Inductive (lagging) conditions, switches of the capacitor banks are automatically switched in and provides a higher system voltage. The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank switch is operated by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR). By connecting a thyristor controlled reactor, which is continuously variable, along with a capacitor bank, that will result in continuously variable leading or lagging power. Fig. 2 shows a single-line diagram of a static var compensator and a simplified block diagram of its control system.

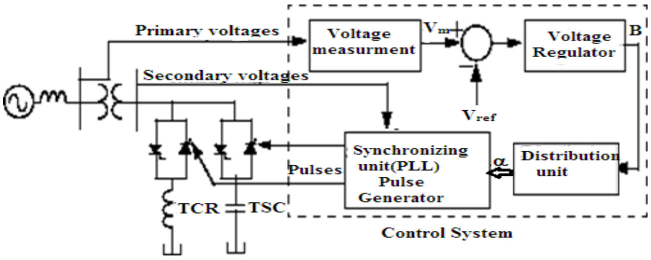

**Fig. 2.** Single-line diagram of an SVC and its control system block

The control system consists of a

- Measurement system, that measures the positive-sequence voltage to be controlled.
- Voltage regulator, that uses the voltage error (difference between the measured voltage $V_m$ and the reference voltage $V_{ref}$) to determine the SVC susceptance B.
- Distribution unit that determines the TSCs (and eventually TSRs) that must be switched on and off, and computes the firing angle α of TCRs.

## 4. Simulation and Results

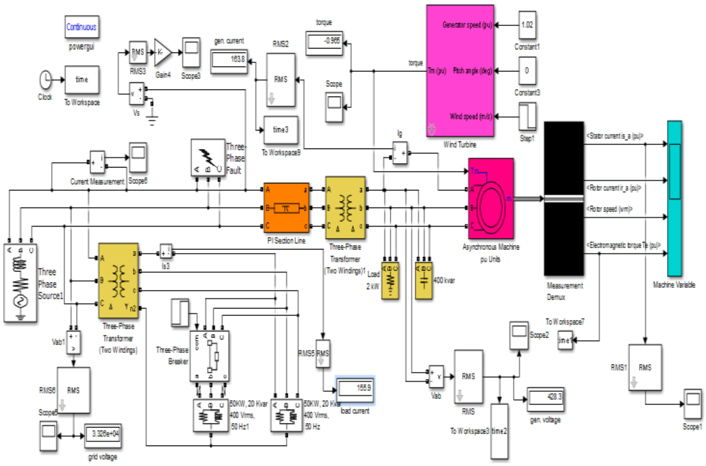

**Fig. 2.**Simulink model for a capacitor bank

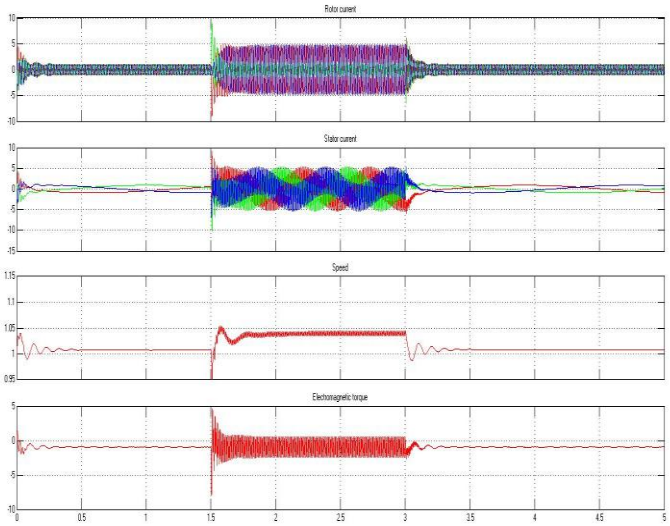

**Fig. 3.**Simulation results showing the machine variables with capacitor bank

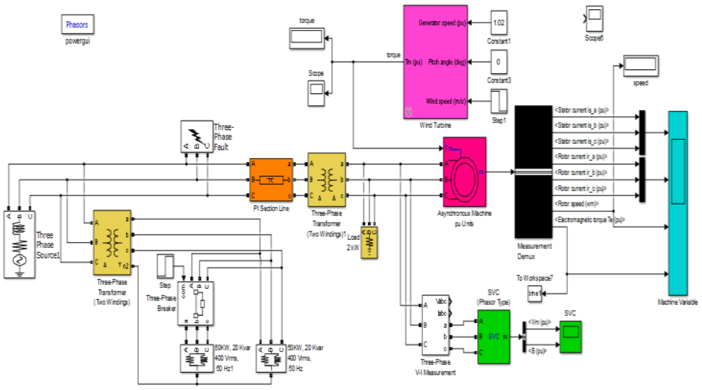

**Fig. 4.**Simulink model for a SVC

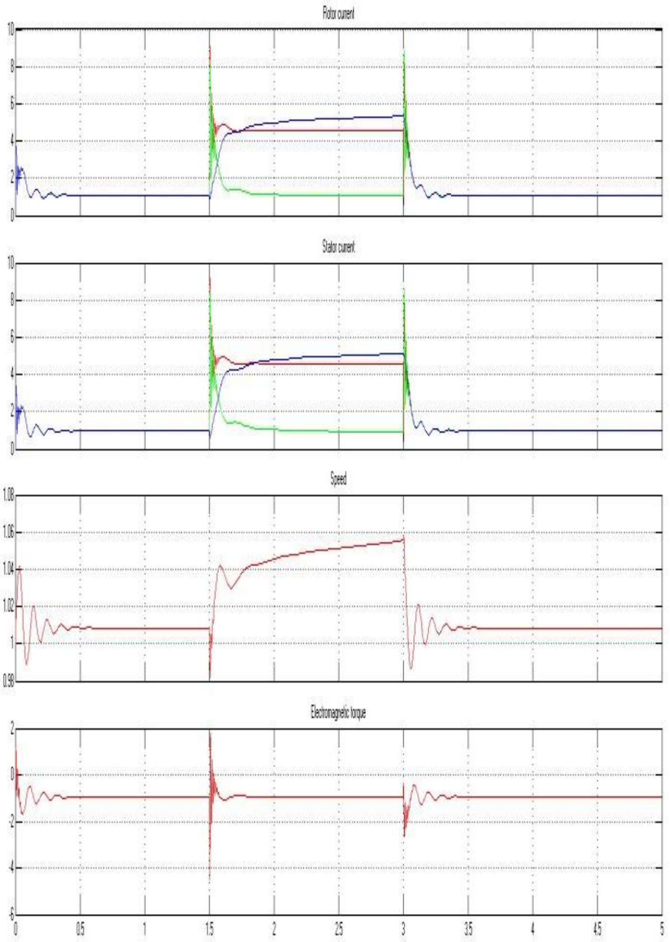

**Fig. 5.**Simulation results showing the machine variables with SVC

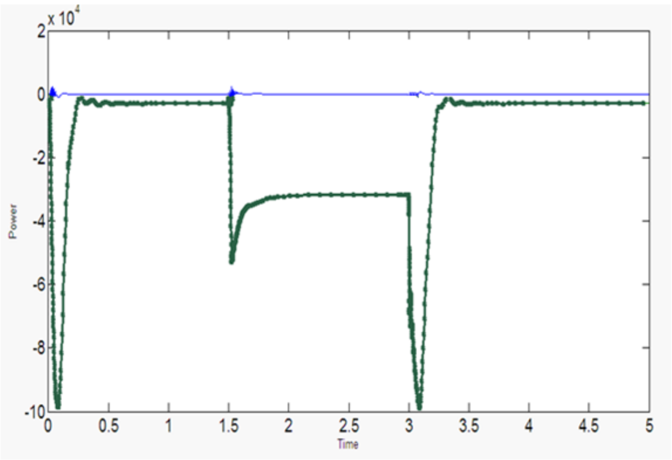

**Fig. 6.**Simulation result showing variation of power with SVC

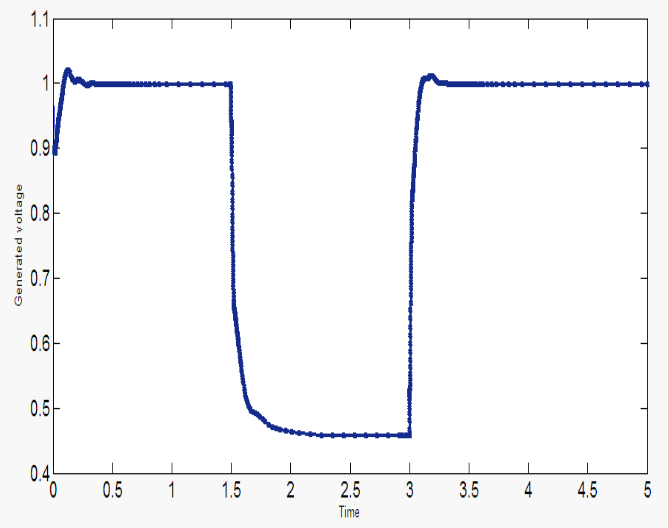

**Fig. 7.**Simuation result showing variation of generated voltage with SVC

### Simulation results for grid fault with capacitor bank

The increasing of mechanical power input raises the machine currents, rotor speed and electromagnetic torque w.r.t. to time. In this simulation the grid fault has been assumed to occur during a period 1.5 sec to 3.0 sec. the magnitude of rotor and stator current rise 4 to 5 times the normal current before the fault. Also, the rotor speed increases during the grid fault. The electromagnetic torque is also decreased. During the grid fault condition, the voltage of the system decreases to a very low value due to the voltage dip, speed of the rotor increases as such reactive power requirement of IG increases. The existing system is not capable of providing the necessary reactive power required for maintaining the generator voltage to nominal value, due to this generator tends to go out of synchronism.

### Simulation results for fault with static var compensator (SVC)-

To prevent the induction generator from going out of synchronism, the necessary reactive power required to build up the voltage is provided by using SVC. For controlling the reactive power during fault condition SVC is connected across the generator terminals. The simulation results shows the effect of grid fault on the rotor speed and electromagnetic torque .during the grid fault there is a drop in voltage from 1pu to 0.46pu and there is a slight increase in rotor speed from 1 Pu to 1.045 pu. The reactive power requirement of generator increased during the fault period. After time 3.0 sec, when fault is cleared, the rotor regains its normal value and voltage becomes constant to its normal value that is 1 Pu. From the above result, the necessary reactive power required for voltage build up IG is provided by SVC and the generated voltage can recover rapidly, and rotor speed can also recover to the stability mode.

## 5. Conclusion

Detailed performance characteristics of 110 KW induction generators under unbalanced grid voltage, and with varying wind speed have been studied. The performance of SCIG is presented under normal and grid fault conditions. They are as follows:

The adjustment of the mechanical input power and the load caused the system to build the new power balances through the change of the machine and system variables. The balancing power action is taken by the induction generator when the mechanical input power is adjusted, whereas the balancing power action is incorporated by the grid system when the load power is modified. The unbalance in grid voltage has been found to make significant impact on the generator and system performance. The result shows that if fault clearance time is less, then the IG restores its normal operation as before the occurrence of fault and for more fault clearance time, the speed becomes excessive; IG no longer remains under control. Thus, it is clear from the results that shunt capacitor connected at the generator terminals maintains the terminal voltage near to nominal voltage and improves the power factor and hence efficiency of the system. The results with SVC show that the dynamic response of the grid connected induction generator under fault condition has been improved as compared to capacitor bank. SVC can maintain the generated voltage to normal value and ensures system running continuously.

## References

[1] S.S. Murthy, C.S. Jha, A.H. Ghorashi, P.S.N. Rao, "Performance Analysis of Grid Connected Induction Generator Driven by Hydro/ Wind Turbines including Grid Abnormalities", Proceedings of the

[2] Zhanfeng Song, Changliang Xia, Wei Chen, "Analysis of Wind TurbineStructural Loads under Grid Fault", Proceedings of the Conference on Electrical Machine and System, pp. 2277-2282, October 2008.

[3] D. Dragomir, N. Golovanov, P. Postolache, C. Toader, "The Connection to the Grid of Wind Turbines," Proceedings of the IEEE power Technology Conference, Bucharest, Romania, pp. 1-8, June/ July, 2009.

[4] R. Jayashri, R.P. Kumudini Devi, "Effect of Tuned Unified Power Flow Controller to Mitigate the Rotor Speed Instability of Fixed Speed Wind Turbines", International Journal of Renewable Energy,Vol. 34, No. 3, pp. 591-596, March, 2009

[5] Magni P. Palsson, Trond Toftevaag, Kjetil Uhlen, John Olav Giæver Tande, "Large-scale Wind Power Integration and Voltage Stability Limits in Regional Networks ", SINTEF Energy Research Trondheim, Norway.