Voltage stability of self excited wind induction generator using STATCOM

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Abstract- The transient Voltage stability is an important issue to achieve the uninterrupted operation of the system during grid faults. The wind turbine induction generator and STATCOM both are connected to the grid. A Static Synchronous Compensator (STATCOM) is applied to a power network which includes two wind turbine driven squirrel cage Induction generators (SCIG) driven by a wind turbine for transient voltage stability support. In the paper the STATCOM improves the performance of the power network under the varying demand of reactive power and the different fault condition on the power line. The system is simulating using MATLAB/ SIMULINK.

Keywords: Static Synchronous Compensator (STATCOM), Self excited induction generator (SEIG), Grid, Voltage stability, Wind turbine, Transmission line, faults.

1 INTRODUCTION

In recent period the demand of electrical power is rising continuously therefore due to this reason natural resources are utilizing and also from the opinion of environmental impact. Some re-newable energy resources are most widely utilizing e.g. solar, wind, hydro and biomass energy in several countries. Wind power utilization is rising in the field of electrical power-generation [1]. In wind energy-system many expansions and processing are running for its utilization in recent years [2]. Numerous wind power plants has been established and are bitterly running in several countries. From wind-energy the generation of electricity is the great expansion and in which electricity is generated from wind energy which uses wind-turbine and the kinetic-energy is converted from wind-energy to electrical power. In renewable energy application, the employment of induction generator is becoming more admired. For this purpose squirrel cage induction generator (SCIG) is employed to produce electricity from wind-energy. The excitation-capacitance is equipped near the SCIG which is known as self-excited induction generator (SEIG). This is a kind of AC electrical generator which is based on principle of induction. In generating mode slip value is negative for induction generator. The electrical power is produced when the rotor rotates faster as compared to the synchronous speed. Generally conventional synchronous generator is employed for electrical production but in recent period due to the inherent advantages, the induction generator is being used. The external-supply is needed by the induction generator to produce the rotating magnetic flux (RMF). For magnetization of induction generator reactive-power is necessitate and which is provided form the capacitor-bank or grid then it begin to generate power. In case of stand-alone induction generator, the capacitor-bank near the generator is used to establish the magnetizing flux and rather in case of grid connected induction generator, the magnetization is establish from the grid. When some disturbances occur then induction generators draw a huge quantity of reactive-current [3].

2 CONTROL OF STATCOM

STATCOM is the member of Flexible AC Transmission Systems (FACTs) family which contains series and shunt connected member and in which the STATCOM is the shunt connected static var compensator which is known as static-synchronous-compensator and it uses power electronics. In shunt a VSC is connected by a coupling transformer [5]. Voltage is regulated by the STATCOM at its terminal for which the amount of VAR is required to be control either by injecting-into or absorbing-form the power system. The STATCOM maintains the level of voltage of the power-system during the disturbance and also in the heavy load situations. The STATCOM produces VAR when system voltage goes down and in invert it absorbs VAR when system voltage goes high. Its dynamic-response is high as compared to the SVC and does not required additional network for its filtration as necessitated in SVC. Some improvement like transient stability, voltage level and dynamic voltage regulation is offered by STATCOM [8].

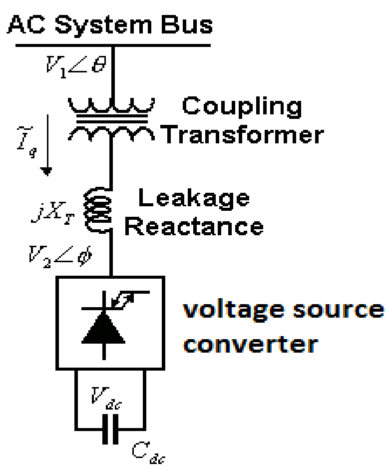

Fig. 2.1: STATCOM control model.

ISSN 2229-5518

2.1 The *V-I* Characteristic

The distinctive *V-I* characteristic for STATCOM is rendered in Fig. 4.2. As can be observed, capacitive and inductive compensation can be delivered through STATCOM and its output current is severally controlled by it at rated max.-capacitive or max.-inductive range regardless of quantity of ac system voltage. The potency of STATCOM characteristic is disclosed through this technology; by its capability of yielding the full output of capacitive production virtually independently of system voltage. When the voltage collapses the STATCOM has the capability for specific condition that it is necessitated to sustain the system voltage during and after fault occurs would or else be a limit factor.

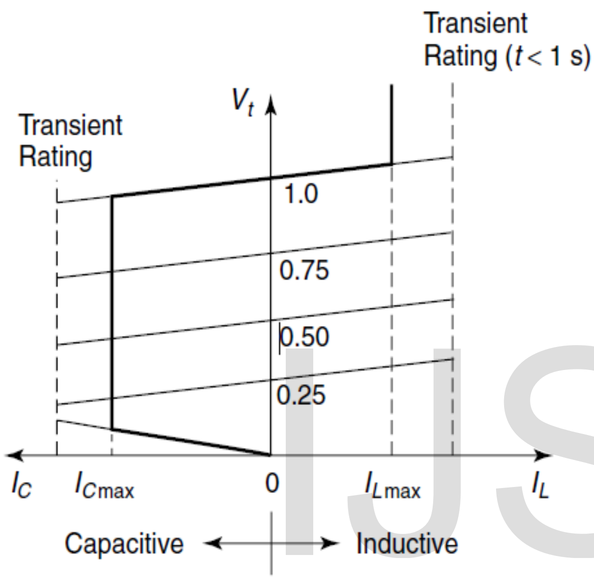

Fig. 2.2 V-I characteristics of STATCOM

Figure 4.2 demonstrate that at both the operating regions like capacitive and the inductive, the STATCOM has raised transient rating. In capacitive region, the maximum current turn-off ability of switches in converter is used to conclude the maximum accomplishable transient over-current and rather in inductive region, the switches are commutated naturally in converter thus, the max. permissible junction temp. of the converter switches are responsible to limit the transient current rating of STATCOM. There are no losses in the converter switches that are made up of semiconductor material, hence, the converter internal losses is minimized by using the storage energy in capacitor, also the dc-capacitor voltage reduces

3 WIND TURBINES

The natural and ultimate source of energy is the wind which has environmental benefit. There is no end of wind-energy because its renewable source and for future its sustainable energy-source [8]. As well as the wind-power plants are raising surround the world, their requirement is also increasing in control stability which is the key factor of wind-power plant. The power variation at the output for wind-power plant is main technical issue. The wind speed fluctuation creates the power variation at different power levels having time variation. Recently the wind power plant is the most popular option with rising energy requires because of public view in the direction of protecting the environment. Some time ago, the generated power was being sent to the power grid straightforwardly, not including devices for energy storage. Irrespective of power requires for the duration of peak and off-peak hours. The voltage variation increases due to the power fluctuation at the interconnection of grid in huge wind power plant. The power fluctuation is reduced when assist with energy storage devices which raise the power distribution and keeping up stability control of wind-power plant during flickering in voltage. The VAR variation is also a big problem in wind power system. Due to the power variation at different wind speed, the VAR varies that is absorbed or produced via grid. Several wind power plants and their size is continuously increasing for energy production. Since the wind power levels regularly enlarge, all the effect of wind power on energy superiority carried by power grid is not cost-effective and still too expensive. As a result, it is completely required to create suitable VAR compensation inside wind-farm.

3.1 Wind Turbine

The wind-turbine is a tool through which kinetic-energy is to be converted from wind-energy into electricity [4]. Wind-turbine generates electricity through the capacity of wind to force an electrical generator. The wind turbine shaft is rotated when the wind falls over the blades of wind-turbine. The rotational speed is boosted by the gear-box to build a magnetic field in the generators which is converted into electrical energy.

3.2 Classification of wind turbine

The wind turbines are generally classified as horizontal axis and vertical axis. The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types [4].

a. Horizontal Axis Wind Turbines (HAWT)

HAWT need of generator and rotor shaft at the peak of a tower. A simple wind vane is required to point out the small turbines. Wind sensor together with a servo motor is utilized for the large turbines. A gearbox is needed by the large turbine which gives the faster rotation to the rotor. In right way the HAWTs is point out so that they can contain maximum efficiency . Fatigue failure occurs due to turbulence. HAWTs are upwind machines.

b. Vertical axis Wind Turbines (VAWT)

The VAWT requires vertical arrangement of rotor shaft. There is no necessity of wind turbine to be in the way of wind. This is beneficial on site where the direction of wind is extremely changeable. The tower does not hold the generator and other components because they can be put on the land so there is no difficulty of mounting turbine on the tower. The drag is produced by the VAWT throughout rotation which is main trouble of VAWT. The offshore installation is not done through these kinds of model because offshore needs to be water proof and wants long towers. The very high tower is needed for offshore installations.

4 INDUCTION GENERATOR

4.1 INTRODUCTION

Induction generator (IG) comes in the category of AC electrical machine for which properties of electrical and mechanical alike to an induction motor (IM). Electrical power generated through IGs when their rotor is spin via prime mover beyond sync. speed corresponding to IM. IG is appropriate in wind turbine (WT) application therefore IGs are often utilized in WTs and under varying speeds the utile power is generated through micro-hydro installations beca use of their capability. In construction IGs are simple and easy both in electrical and mechanical opinion as compared to other kind of generator. The needed VAR for IGs can be provided either through grid or parallel connected capacitor-bank at terminals of generators [6]. It producing power when once starts and the current in the rotor is induced through the stator's RMF and magnetic field is also produced by it. The induction machine behaves like induction motor when its rotor rotates at the speed slower as compared to the rate of rotating flux and behaves like IG when its rotor rotates at the speed faster as compared to the rate of rotating flux then generating electrical power at the sync. frequency.

4.2 Simulation model

In simulation two phasor kind of wind turbine induction generator is employed to produce electricity. Three phase VI measurement is also connected to each of the generator for measurement of 3-phase voltage and current and for this purpose phase-to-ground voltage measurement parameter is selected. The delta shunt capacitor-bank is connected to the 3-phase line near the generator to provide the var. for excitation of the IG. Transformer is connected to each of the wind turbine induction generator which is used to step up the voltage. The three phase PI section line is used to transmit the electrical power. A three phase source is connected to PI section transmission line by which the power is transmitting and in between a 3-phase transformer is connected which is used to step down the voltage. A 3-phase transformer is also connected in shunt with the line and its one winding is connected in star with neutral which is grounded through resistance. When a phase-to-phase fault is applied to the three phase transmission line then it will unbalanced the operation of the system and voltage level of the system goes down. This dip in voltage is maintained with the help of a FACT device such as STATCOM. The STATCOM is situated at the middle of the line. The STATCOM is a device which is used to sustain the voltage level by injecting or absorbing the reactive power in the system.

4.3 Simulation diagram

In simulation diagram two wind turbine induction generator is connected with the grid and a STATCOM. Three faults are applied at three different locations as shown in figure and we will observe the behavior of the system during the different fault condition. The simulation diagram is shown below.

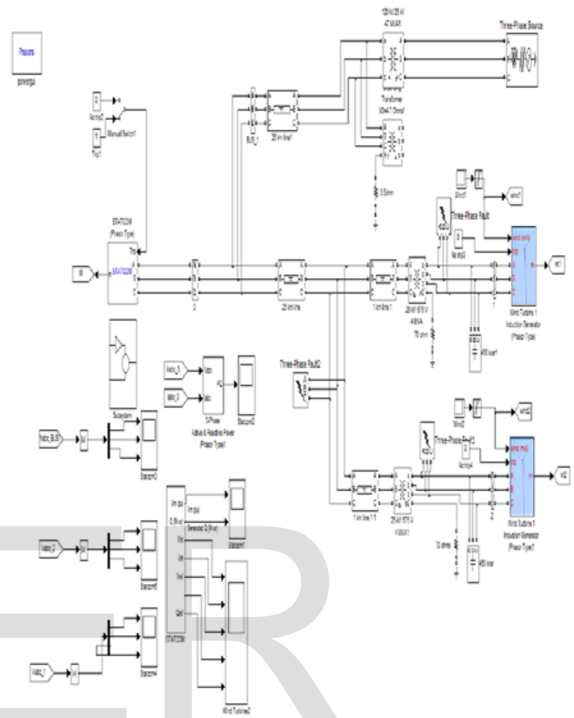

Fig 4.1 : Wind turbine induction generator is connected with the grid and a STATCOM.

There are two cases in which STATCOM take place into the system.

Case 1: Without STATCOM

When fault occur in the system then the performance of the system unbalanced by mean of voltage goes down and the reactive power is demanded by the induction generator for its excitation purpose. There is a delta capacitor-bank is connected in shunt near the wind turbine induction generator and it provides the VAR for excitation to the IG but it does not full-fill the requirement of reactive power during fault. Therefore in case of without STATCOM when fault cleared then voltage still goes down and finally it does not come in steady-state.

Case 2: With STATCOM

In case, when fault occurs in power system then it will be unbalanced the operation of system and thereby voltage of the system goes down and the VAR is demanded by the IG and this dip in voltage is maintain by the STATCOM. The STATCOM inject the demand of VAR required by IG and

ISSN 2229-5518

maintain the dip in voltage and voltage will come in steady state after clear the fault.

4.4 Comparison of bus voltage without STATCOM and with STATCOM

The comparison of bus voltages without and with STATCOM is depicted in figure. In case of without STATCOM it takes about 1sec. to achieve normal condition and with STATCOM, it takes only 0.1sec to achieve normal condition. When three faults are applied then bus voltage goes down and dip in voltage in case of STATCOM is less than the case of without STATCOM. When all the faults are cleared then in case of without STATCOM the bus voltage after 6sec. goes down but in case of with STATCOM the voltage level is maintain constant

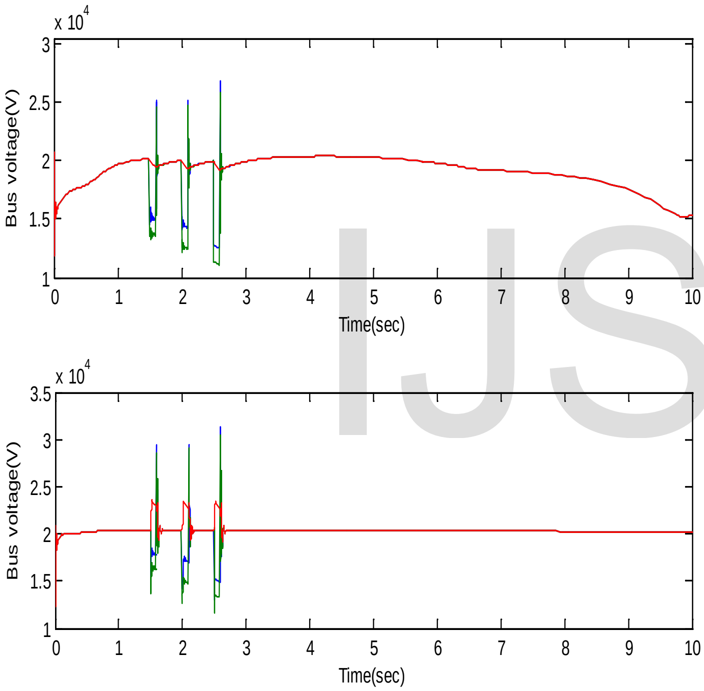

Fig. 4.2 : Comparison of bus voltage without STATCOM and with STATCOM

4.5 Bus voltage and Generated reactive power

In above figure (a) the bus voltage at the stating low and then achieve its normal condition at this time VAR at stating is high and then decreases as depicted in figure (b). When fault occur at 1.5, 2.0 and 2.5 then voltage goes down (figure a) at this time STATCOM inject the reactive power as shown in figure (b) and when cleared the fault the bus voltage again goes down after 6sec. and demand of VAR increases is depicted in figure (b). To maintain this voltage level STATCOM generate the reactive power which is supply into the system and generated reactive power is also depicted in figure (b).

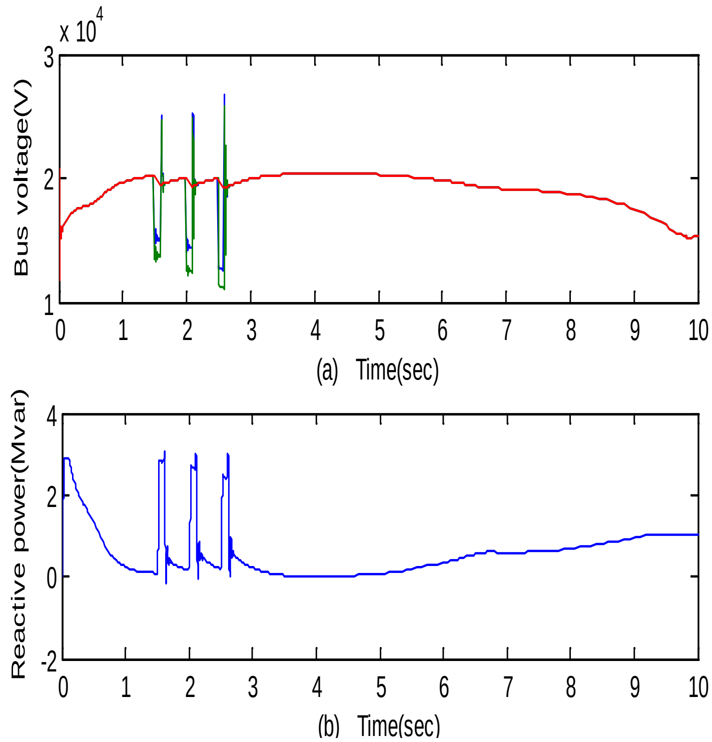

Fig. 4.3 : (a) Bus voltage (b) Generated reactive power ; Generation of reactive power by STATCOM to maintain the voltage level of wind turbine induction generator

5 CONCLUSION

The induction machine as a generator is utilizing in the field of electrical power generation from the wind energy. From the simulation results we concluded that when STATCOM applied to the system then time taken to achieve normal condition is very less about 0.1s. The STATCOM is employed to fulfill the demand of VAR due to disturbances occur in power system and also before and after the fault then thus the steady state condition.

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