CONTROL OF SVC IN WIND FARMS BASED ON FIXED-SPEED INDUCTION GENERATOR UNDER ASYMMETRICAL FAULTS

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Abstract—This paper ensures the use of shunt facts device static var compensator (SVC) to improve the stability of wind farms based on fixed speed induction generator (FSIG) fed to an power system. Due to the occurrence of faults in the system, there is a voltage dip at the point of common coupling of wind farm and the power system. During the unbalanced condition FSIG absorbs large amount of reactive power from the grid due to its behaviour of asynchronous performance resulting into the instability of wind farms. To achieve a better dynamic operation and to obtain transient stability of the wind farm static var compensator (SVC) is connected to meet the wind farm integration. SVC can provide the required reactive power compensation and controls the voltage collapse in the system thus increasing the stability of wind energy conversion system.

Index Terms— Asymmetrical faults, squirrel cage induction generator, static var compensator (SVC), wind energy

I. INTRODUCTION

In the renewable energy sources electricity generation using wind turbine is the most developing technologies worldwide. In the early age of 80’s only few tens of kilowatts rated wind turbines were used which now-a-days has increased to wind turbines of megawatts power range. Previously the impact of wind farm on the utility grid is negligibly less insignificant but with the rapid growth in wind energy it becomes important to analyse the effect of wind farm on the grid. Due to the dynamic operation behaviour of the wind farm it is essential to control the voltage and power in the network for its steady state operation [1]. Under the fault condition, generator absorbs the reactive power from the grid causing instability in the system. The most popular generators used in the wind energy systems are doubly fed induction generator, synchronous generator and the permanent magnet synchronous generator [2], [3]. In Europe still 15% of wind energy conversion systems (WECSs) based on the fixed speed induction generator [4]. Though FSIG has the disadvantage of absorbing excessive reactive power from the grid and also its starting current is higher, it is still widely used due to its lower cost solution. Due to asynchronous operation of fixed speed induction generator, it produces large fluctuations in the voltage at the point of integration of wind farm with grid utility [1-3]. During disturbances it is essential to control the voltage of wind farms so that the wind turbine generating systems (WTGSs) performs its operation satisfactorily.

To fulfil the demand of reactive power compensation flexible AC transmission systems (FACTS) devices are the most promising widely used controllers. To increase the stability of FSIG the shunt facts device provides a possible control solution. Static synchronous compensator (STATCOM) gives a better dynamic operation by adjusting the voltage control and providing excessive reactive power needed for compensation purpose [5], [6]. Due to the fault in the network, positive and negative sequence voltage generated causing torqu oscillations and voltage dip [7]. The statcom controls the positive sequence current thus enhancing the fault ride through capability of WECSs. To limit the torque oscillations negative sequence voltage is compensated by statcom current control technique [8]. With various modern power control topologies, statcom is efficiently able to provide the reactive power compensation by proper control of voltage in the wind farm energy production. Indirect vector control of induction motor with statcom capabilities ensures the increase in the performance of wind energy fed to an power system [9]. The power converter technology of hexagram or multi-level converter combines with the facts controller to improve the system behaviour [10], [11]. Different kinds of wind generators has the impact on the overall system efficiency according to their operations. The shunt facts device and other controllers can also be useful in the stability enhancement of WTGSs.

II. WIND ENERGY

Different varieties of generators used in the wind energy conversion system are synchronous generators and cage induction generators. Most conventionally used among these are doubly fed induction generators and the permanent magnet synchronous generators due to the performance and controlling capabilities under abnormal fault conditions. Across the world with KWs to multi-megawatts wind farms implement these generators for the reliable energy generation.
A. INDUCTION GENERATOR

With the lower cost of induction machine and better operation, they are widely used generators globally ensuring stability increased in the system operation. The squirrel cage induction generators commonly used is variable speed mode. But with the present need of fixed speed IG based wind farms for conventional energy production making them as one of the most promising machine. It also provides less maintenance due to lack of brushes. The weight and size has not a major impact on the steady state operation of WECSs. In addition to robust construction IGs are very efficient and reliable.

B. WIND TURBINE STABILITY

The theoretical analysis of fixed speed induction generator shows the characteristics of torque vs. slip and reactive power vs. slip curves which are shown in the fig. 1. The steady state operation period shows how the machine operates on the small value of slip with very less fluctuations in speed of rotor as given in fig. 1(i). Similarly for the same steady state duration the reactive power consumption is minimum by the FSIG. From the reactive-slip graph of fig.1(ii), it can be observed that with the load increasing the rotor slip and thereby the absorption of reactive power increases by the induction generator due to asynchronous nature of operation. At the grid fault period induction generator tends to consumes large excessive amount of reactive power from grid causing instability in the wind energy conversion system. To achieve the stability facts controller are implemented in the wind energy which controls the voltage and reactive power level at the integration point.

III. STATIC VAR COMPENSATOR

Static var compensator (SVC) is one of the shunt facts controller device having the capacity of raising the stability by controlling and adjusting the voltage drops at various bus or points with proper reactive power compensation. SVC helps in reducing torque oscillations by improving generator electrical torque thus enhancing stability of the network. The typical structure of static var compensator is shown in fig. 2. SVC is the combination of number of thyristor switched capacitors (TSC) connected in parallel with a thyristor controlled reactor (TCR). TCR adjust continuous compensation of inductive power while TSC ensures controlling of capacitive reactive power parameter. The main aim of SVC is to provide necessary voltage control and fulfil reactive power need of the system.

The controller of the SVC works on the error signals generated from the difference value between the line voltage at the integration point and the actual reference voltage of the system. The proportional-integral controller analyzes the error signal to obtain suitable susceptance from which the firing angle of the TCR and requires ON/OFF switching of TSC can be calculated. Fig. 3. shows the operating regions of SVC clearly indicating the proportional relation of system voltage to maximum value of reactive current depending on which the device performs.
IV. SYSTEM ANALYSIS

Fig. 4. presents the system studies of fixed speed induction generator based wind farm connected to an power system. A model of wind farm of 50 MW is used and the turbine-generator set is then connected to low voltage bus which is further via a transformer connected to a medium voltage bus. Transformer of 100 MVA is utilised to convert it into high voltage. Fig. 5 and 7 shows the model for without and with compensation. At the point of common coupling SVC is connected and a three phase fault occurs for 0.5 s. Results with and without SVC is shown in fig. 6 and 8. Table 1. gives the parameters of the model.

V. SIMULATION RESULTS

Fig. 5. Simulation model of wind farm without SVC

Fig. 6. Results of speed, voltage and active-reactive power at LV bus and PCC without SVC during fault

Fig. 7. Simulation model of wind farm with SVC

Fig. 8. Results of speed, voltage and active-reactive power at LV bus and PCC with SVC during fault
VI. CONCLUSION

The main aim of using SVC is to adjust the voltage collapse in the network and compensate the reactive power need of the FSIG based wind farm fed to an power system. To successfully meet the integration, electricity generation SVC controlled is designed to achieve dynamic performance, increase efficiency thus making the complete system stable. Also SVC helps in improving the power quality by controlling the voltage levels.

VII. APPENDIX

Data of wind farm and IG

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MV Transformer</th>
<th>HV Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated active power</td>
<td>-</td>
<td>50 MW</td>
</tr>
<tr>
<td>Rated line to line voltage</td>
<td>-</td>
<td>690 V</td>
</tr>
<tr>
<td>Stator leakage resistance</td>
<td>- 0.107 pu</td>
<td></td>
</tr>
<tr>
<td>Rotor leakage resistance</td>
<td>- 0.1407 pu</td>
<td></td>
</tr>
<tr>
<td>Stator resistance</td>
<td>- 0.0108 pu</td>
<td></td>
</tr>
<tr>
<td>Rotor resistance</td>
<td>- 0.01214 pu</td>
<td></td>
</tr>
<tr>
<td>Mechanical time constant</td>
<td>- 3 s</td>
<td></td>
</tr>
<tr>
<td>Mutual inductance</td>
<td>- 4.4 pu</td>
<td></td>
</tr>
</tbody>
</table>

Values of modeled Transformers

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