Low Voltage Ride through Solution for PMSG Wind Turbine Using STATCOM

Pravin S Phutane1, A. K. Jhala2

1PG Student, RKDF College of Engg, Bhopal, M.P., India
2 RKDF College of Engg, Bhopal, M.P., India

Abstract— This paper presents enhancement of power quality by means of LVRT capability of wind farm driven by PMSG. As the share of wind generated power is increasing continuously in all over the world, hence penetration of this wind power into grid become larger and larger, the grid connection condition of the wind turbine is more important. It is important that to avoid cascading effect wind turbine should stay connected to grid during grid disturbances. Connecting wind farm to grid posses some difficulties and challenging task for the TSOs as there are many connection requirements and description of these requirements are known as Grid Codes. Low voltage ride through capability is one of the dynamic requirements mentioned in E-ON NETZ grid code. This paper presents reactive power control to satisfy grid code requirement using STATCOM. Simulation results shows the presence of real power, reactive power with STATCOM and without STATCOM.

Keywords— permanent magnet synchronous generator (PMSG), Low Voltage Rude Through (LVRT), Grid Codes, STATCOM.

I. INTRODUCTION

Compare to last decade wind generation of power as a part of renewable energy is significantly increased all over the world. Reliability and stability point of view it is interesting and important to observe behavior of wind generators during grid disturbances. Nowadays variable speed wind turbine is most popular viz. is Doubly Fed Induction Generator (DFIG) or Permanent Magnet Synchronous Generator (PMSG). PMSG have advantages over DFIG which are presented in [8] such as higher efficiency and energy yield, for the magnet field excitation no additional power supply etc. Wind generators used in generation of power tend to drain or absorb large amount of VAR from grid. Induction generators need excitation hence in steady state operation absorbs reactive power; moreover in case of short circuit fault need to absorbing more reactive power due to over speeding this will cause low voltage and stability problems [5].market share of different wind generator types has been reported in [1].however PMSG becoming more and more popular and attracting due to its advantages and drawbacks of other wind generators.

II. GRID CODES AND LVRT REQUIREMENT

Wind power generation is one of the key parts of renewable energy. As the penetration of the wind power increases in the electrical grid, it becomes challenging to maintain stability of the system. Hence Integrating wind farm to grid requires some essential conditions; description of these connection conditions known as Grid Codes [7].These grid codes was originally proposed by E.ON, Germany in Europe in 2003 for large wind farms. Essential conditions are nothing but some technical requirements with in grid codes which varies for different grids.

Technically grid codes requirement divided into two parts as:

i) Static Requirement

ii) Dynamic Requirement
Static Requirement includes
i) Power Factor
ii) Voltage Control
iii) Quality of Voltage
iv) Harmonics
v) Frequency & Flicker

Dynamic Requirement includes, performance of wind turbine during disturbances and fault sequences i.e;

i) Fault Ride Through or Low Voltage Ride Through (LVRT) capability
ii) Fault recovery capability

The main objective of the grid codes to give idea regarding technical specification complies by generic wind turbine model. As presented in [7] LVRT is Dynamic Requirement of the grid codes which is demanded by most of the transmission system operators (TSO). In case of any disturbance or voltage dip, turbine should stay connected to grid. In other words large wind farms must stay connected to grid during voltage sags down to certain percentage of nominal voltage for specific time duration [9]. Interpretation of voltage verses time characteristics describes LVRT capability curve.

III. STATCOM

It was observed that STATCOM is effective in eliminating of the quality problems which may occur at the power systems which work by connecting to wind power plant.

If a VSC is connected to the transmission system through a shunt transformer to generate or absorb reactive power from the bus to which it is connected. Such a controller is known as Synchronous Static Compensator or STATCOM and is used for voltage control in transmission systems. If we compare STATCOM with a SVC, The major advantage is its reduced size, sometimes even to less than 50 %, and a potential cost reduction achieved from the elimination of capacitor and reactor banks as well as other passive components required by the SVC.

As it was mentioned before STATCOM can be treated as a synchronous voltage source, because its output voltage can be controlled as desired. Assuming that no active power is exchanged between STATCOM and the grid (lossless operation) the voltage of the controller is in phase with the grid voltage. In this case, If the compensator voltage magnitude is smaller than the voltage at the connection node current will flow from the grid to STATCOM. Hence the reactive power will be consumed or if the situation is to opposite the reactive power will be delivered to the grid.

STATCOM connection is to ac system bus. AC system voltage and the voltage-sourced converter terminal voltage is the same. This ensures that there is sending of only reactive power and no real power between the STATCOM and the AC system. The expressions sending current flowing from the STATCOM to the system and the reactive power injection are given as,

\[ I_s = \frac{(V_2-V_1)}{X_T} \quad (1) \]
\[ Q_s = V_1^2 \left( \frac{V_2}{V_1^2} - 1 \right) / X_T \quad (2) \]

The STATCOM is very convenient compared to other devices.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>FACTS Devices</th>
<th>Load flow</th>
<th>Vtg. control</th>
<th>Transient stability</th>
<th>Dyna. stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UPFC</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>2</td>
<td>TCSC</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>STATCOM</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>SVC</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>SSSC</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>
IV. CASE STUDY

Figure 5: Single line diagram of studied system

Fig shows the single line diagram of wind farm under study system. Wind farm consist of 3 no’s of PMSG driven wind turbine having 1.5MW capacity each. This wind farm is to be investigated for further study and connected to 25KV distribution system through a 25 KV transmission line. The rotor of PMSG is driven by variable pitch control turbine. In order to limit generator output power the pitch angle is controlled at its nominal value for winds exceeding 9 m/s. In this studied system bus b25 is the main bus which connects wind farm and grid.

In this paper this bus b25 is under study. For monitoring purpose monitoring equipments are placed at this bus. These equipments will monitor the total active power and reactive power from grid.

<table>
<thead>
<tr>
<th>Table II</th>
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<tbody>
<tr>
<td>PMSG Parameters</td>
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<tr>
<td>---------</td>
</tr>
<tr>
<td>Rated power (MW)</td>
</tr>
<tr>
<td>Rated voltage (V)</td>
</tr>
<tr>
<td>Stator resistance (Ω)</td>
</tr>
<tr>
<td>d-axis inductance (H)</td>
</tr>
<tr>
<td>q-axis inductance (H)</td>
</tr>
<tr>
<td>Flux Linkage(Wbturns)</td>
</tr>
<tr>
<td>Pole pair</td>
</tr>
<tr>
<td>Motor Inertia( kg m²)</td>
</tr>
</tbody>
</table>

V. SIMULATION RESULTS

To study the effect of STATCOM on the steady state operation, the operation of the wind farm is monitored twice, one without STATCOM and the other with STATCOM connection at the main bus B25 of the wind farm. Figure 6 shows Simulation results without STATCOM application and Figure 7 shows Simulation results with STATCOM application.

Table III

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Real power(watts)</th>
<th>Reactive power(VAR)</th>
<th>TIME CYCLE (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With STATCOM</td>
<td>0.072</td>
<td>0.038</td>
<td>0.3-0.37</td>
</tr>
<tr>
<td>Without STATCOM</td>
<td>0.029</td>
<td>0.147</td>
<td>0.3-0.48</td>
</tr>
</tbody>
</table>
VI. CONCLUSION

The main purpose of this paper is to investigate the use of STATCOM to support variable speed wind turbines in order to fulfill the required LVRT Curve. It is applied to a 4.5 MW variable speed wind farm (which consists of three 1.5 MW wind turbines) connected to the grid. Simulation studies show that reactive power support with STATCOM and without STATCOM.

In other words, this paper demonstrates reactive power compensation support by using STATCOM. Furthermore, this operation of STATCOM improves the behavior of the wind farm in steady state.

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