A ROLE OF UPFC FOR REACTIVE POWER IMPROVEMENT IN WIND FARM

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Abstract— *At present, wind energy generation, utilization and its grid penetration is increased in worldwide. But wind generation is fluctuating due to time varying nature and causing stability problem. In power system, stability is one of the important factors for reliable power supply. In order to improve or maintain the reliable power, the real and reactive power has to be controlled or improved. In this paper, the reactive power improvement can be explained with FACTS device of UPFC (Unified Power Flow Controller) in wind farm model. Even utilizing some FACTS devices like SSSC, SVC, and STATCOM in the circuit, voltage regulation problems are raised. To overcome this problem, an UPFC device is adopted and explained in this paper. The internal control strategy is based on the series and shunt converters of UPFC. This model can be executed with MATLAB/SIMULINK software.*

Keywords—Reactive Power;UPFC;Control Stratagy

1. INTRODUCTION

Advancements in the technology of power electronics have developed interest in large capacity variable-speed wind turbines in the MW range. Today large-scale integration of wind sources into the grid via full-power converters is being increasingly adapted due to its high power density and controllability. With variable-speed wind turbines, the sensitivity of the power electronics to over currents caused by network voltage depressions can have serious consequences for the stability of the power system[3]. Also, the considerable amount of wind energy generated and delivered to the interconnected electrical network significantly depends on the wind conditions, which evidently raises a risk factor for the balance between energy offer and demand. Thus, to avoid reliability issues and network stability problems, grid operators launch guidelines for net connection of wind turbines. In some countries, the wind farm can also be used to stabilize the grid providing reactive power compensation. This feature becomes of particular interest in case of wind farms connected to weak grids and is achieved by proper control algorithms in a wind farm. Operators of the wind farms should be able to monitor and control the status and operating conditions of each turbine as well as the combined electrical response of the wind farm, keeping in view the grid interconnection requirements. It is therefore highly necessary to measure and monitor the point of connection of the wind farm to the grid as well as each individual turbine. Thus, the control system of each individual turbine should be connected to a supervision system that supervises the operation situation and power regulation of the whole wind farm. This supervision system also fetches operation data from grid regulation system of the whole wind farm and reactive power requirements[6][7].

The objective of this paper is set as the reactive power is improved and controlled in wind generation and distributed side with UPFC device. The wind plant is designed as variable speed turbine type of DFIG (Double Fed Induction Generator). Its reactive power consumption depends upon the real power production. Further, the reactive power improvement at the point of WECS network connection is provided by using FACTS devices. Among FACTS devices, UPFC is chosen due to its versatile regulating capabilities [8]. At the point of the WECS connection to the distribution network, it is made possible to simultaneously control the WECS bus voltage magnitude and/or series reactive power flow that WECS exchanges with the network. This countermeasure is expected to contribute in making assessed wind site viable for connecting larger number of wind turbines.

2. REACTIVE POWER

We always in practice to reduce reactive power to improve system efficiency. This is acceptable at some level. If system is purely resistively or capacitance it make cause some problem in Electrical system. Alternating systems supply or consume two kind of power real power and reactive power. Real power accomplishes useful work while reactive power supports the voltage that must be controlled for system reliability. Reactive power has a profound effect on the security of power systems because it affects voltages throughout the system. Find important discussion regarding importance about Reactive Power and how it is useful to maintain System voltage healthy. Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. Decreasing reactive power causing voltage to fall while increasing it causing voltage to rise. A voltage collapse may be occurs when the system try to serve much more load than the voltage can support [1][2].

When reactive power supply lower voltage, as voltage drops current must increase to maintain power supplied, causing system to consume more reactive power and the voltage drops further . If the current increase too much, transmission lines go off line, overloading other lines and potentially causing cascading failures. If the voltage drops too low, some generators will disconnect automatically to protect themselves. Voltage collapse occurs when an increase in load or less generation or transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitor and line charging, and still there further voltage reductions. If voltage reduction continues, these will cause additional elements to trip, leading further reduction in voltage and loss of the load. The result in these entire progressive and uncontrollable declines in voltage is that the system unable to provide the reactive power required supplying the reactive power demands. Voltage control and reactive power management are two aspects of a single activity that both supports reliability and facilitates commercial transactions across transmission networks. On an alternating current (AC) power system, voltage is controlled by managing production and absorption of reactive power [10].

Active power is the energy supplied to run a motor, heat a home, or illuminate an electric light bulb. Reactive power provides the important function of regulating voltage. If voltage on the system is not high enough, active power cannot be supplied. Reactive power is used to provide the voltage levels necessary for active power to do useful work. Reactive power is essential to move active power through the transmission and distribution system to the customer .Reactive power is required to maintain the voltage to deliver active power (watts) through transmission lines. Motor loads and other loads require reactive power to convert the flow of electrons into useful work. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines.

3. UPFC:

The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle) .It is a one of the FACTS family that used to optimum power flow in transmission. The UPFC is a combination of static synchronous compensator (STATCOM) and static synchronous compensator (SSSC)[5].Both converters are operated from a common dc link with a dc storage capacitor. The real power can freely flow in either direction between the two- ac branches. Each converter can independently generate or absorb reactive power at the ac output terminals. The controller provides the gating signals to the converter valves to provide the desired series voltages and simultaneously drawing the necessary shunt currents, In order to provide the required series injected voltage, the inverter requires a dc source with regenerative capabilities [2]. The possible solution is to use the shunt inverter to support the dc bus voltage The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The main reasons behind the wide spreads of UPFC are its ability to pass the real power flow bi-directionally, maintaining well-regulated DC voltage, workability in the wide range of operating conditions etc.

The basic components of the UPFC are two voltage source inverters (VSIs) [4], sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer. The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters. The UPFC can be used to control the flow of active and reactive power through the transmission line and to control the amount of reactive power supplied to the transmission line at the point of installation [8].

The two VSIs can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line. The UPFC can also provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. Configuration of UPFC is shown in fig.1

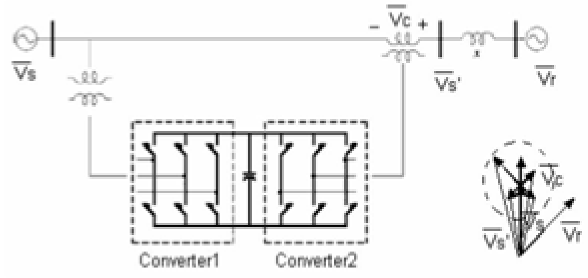

Fig 1. Configuration - UPFC

The UPFC can provide simultaneous control of all basic power system parameters (voltage, impedance and phase angle) and dynamic system compensation. The controller can fulfill functions of reactive shunt compensation, series compensation and phase shifting meeting multiple control objectives. From a functional perspective, the objectives are met by applying boosting transformer injected voltage and exciting transformer reactive current. The injected voltage is inserted by using series transformer. Its output value is added to the network bus voltage from the shunt side, and is controllable both in magnitude and angle. The reactive current is drawn or supplied by using shunt transformer.

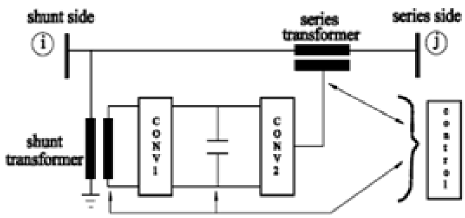

Fig 2. Circuit Arrangement- UPFC

Functional structure of the UPFC results with appropriate electric circuit arrangement. The series converter AC output voltage is injected in series with the line as shown in Fig.3. It exchanges only active power with shunt converter. Reactance Xs is the one seen from terminals of the series transformer[9].

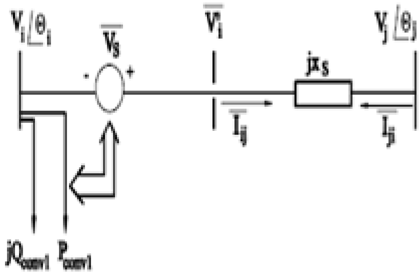

Fig 3.Elecric Circuit Model - UPFC

4. CONTROL STRATEGY:

A general topology of such a control system of a wind farm comprising of Full Power Converter wind turbines is shown in Figure 1

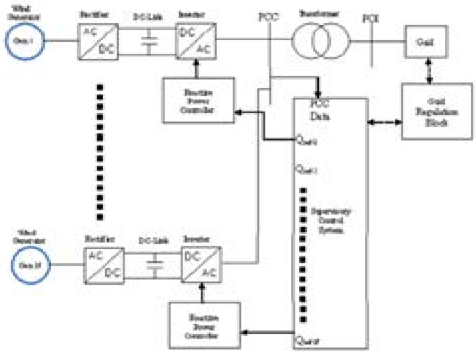

Fig 4. General Control Topology

The UPQC serial converter is controlled to maintain the WF terminal voltage at nominal value (see U1 bus-bar), thus compensating the PCC voltage variations. In this way, the voltage disturbances coming from the grid cannot spread to the WF facilities. As a side effect, this control action may increase the low voltage ride– through (LVRT) capability in the occurrence of voltage sags in the WF terminals[9].

4.1 Series converter controller:

A figure 4 shows series converter controller. The injected voltage is obtained subtracting the PCC voltage from the reference voltage, and is phase–aligned with the PCC voltage. On the other hand, the shunt converter of UPFC is used to filter the active and reactive power pulsations generated by the WF. Thus, the power injected into the grid from the WF compensator set will be free from pulsations, which are the origin of voltage fluctuation that can propagate into the system. This task is achieved by appropriate electrical currents injection in PCC. Also, the regulation of the DC bus voltage has been assigned to this converter.

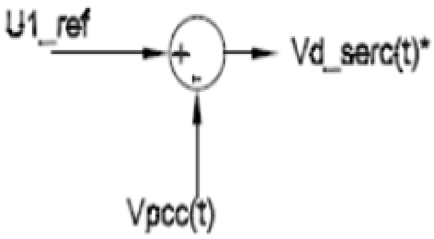

Fig 5. Series Converter

4.2 Shunt Converter Controller:

This controller generates both voltages commands Epshuc∗ and Eqshuc∗ based on power fluctuations P and Q, respectively. Such deviations are calculated subtracting the mean power from the instantaneous power measured in PCC. The mean values of active and reactive power are obtained by low–pass filtering, and the bandwidth of such filters are chosen so that the power fluctuation components selected for compensation, fall into the flicker band as stated standard. In turn, Eqshuc∗ also contains the control action for the DC–bus voltage loop. This control loop will not interact with the fluctuating power compensation, because its components are lower in frequency than the flicker–band.

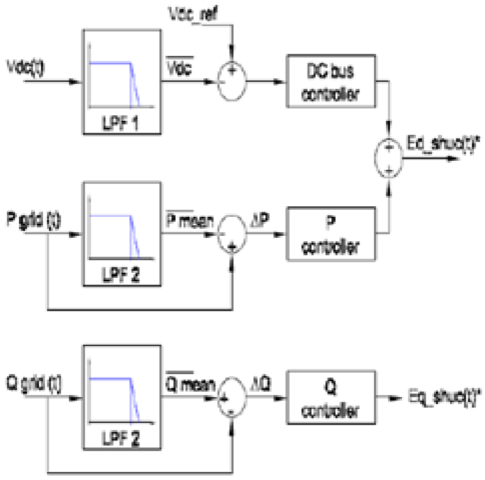

Fig 6. Shunt converter

The powers Pshuc and Qshuc are calculated in the rotating reference frame, as follows

Pshuc (t) = 3/2 * VPCCd (t) *Ishucd (t)

Qshuc (t) = −3/2 * VPCCd (t) * c(t)

Ignoring PCC voltage variation, these equations can bewritten as follows.

Pshuc (t) = k′p * Id shuc(t)

Qshuc (t) = k′q * Iqshuc(t)

Taking in consideration that the shunt converter is based on a VSI, we need to generate adequate voltages to obtain the currents. This is achieved using the VSI model proposed leading to a linear relationship between the generated power and the controller voltages. The equations are

Pshuc (t) = k′′p* Ed shuc(t)

Qshuc (t) = k′′q* Eqshuc(t)

P and Q control loops comprise proportional controllers, while DC–bus loop, a PI controller. In summary, the UPFC can be seen as a "power buffer", levelling the power injected into the power system grid.

5. SIMULATION & OUTPUT:

This paper is designed and executed as per Table 1 contents. The simulation model also executed with these parameters.

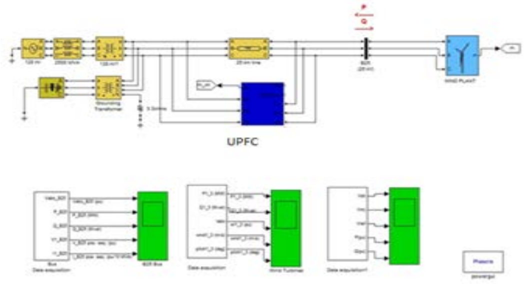

Fig 7.Simulation model – UPFC

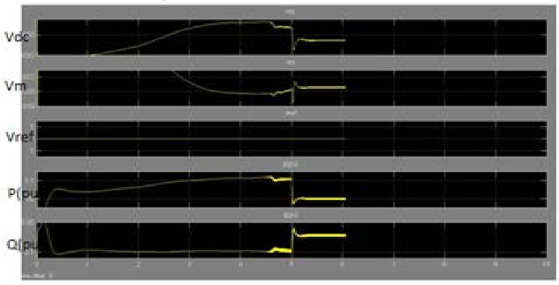

Fig 8.Reactive power output with UPFC

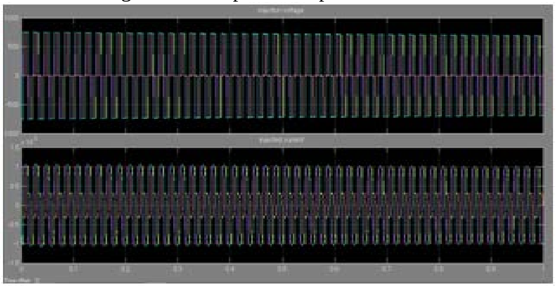

Fig 9. Injected Voltage and Current in UPFC

TABLE – 1: SYSTEM PARAMETERS

Sl. No	Parameters	Ratings
1.	Load Voltage	25 KV
2.	Grid Voltage	415 V
3.	Load current	1.5 KA
4.	Induction generator	3.35 KVA,415 V,50 Hz, P=4, Speed=1440 rpm, Rr=0.01Ω , Rs = 0.015Ω, Lr = 0.06H,Ls = 0.06H
5.	Line series Inductance	5.2mH
	Inverter parameters	DC link voltage = 1KV, DC Capacitance =100μF
6.	IGBT	Collector voltage = 1.2 KV, Current = 50 A, Gate voltage = 20 V, Power dissipation = 310 W
7.	Wind Plant	6 X1.5 MW
8.	Transformer	120 KVA
7.	Load	Non linear- 25 KW

6. CONCLUSION AND FUTURE WORK

In this project, a new compensation strategy implement using an UPFC type compensator is present to connect DFIG based wind farms to weak distribution power grid. The proposed compensation scheme enhances the system of power quality can be executed by using CPD Technology such as DVR and D–STATCOM and UPQC compensators. The simulation results will show a good performance in the rejection of power fluctuation due to "tower shadow effect" and the regulation of voltage due to a sudden load connection. So, the effectiveness of the proposed compensation approach is demonstrated in the distributed area. In future work, performance comparison between different compensator types will be made. Among above mentioned configurations, UPQC-DG could be the most interesting topology for a renewable-energy-based power system.

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