

# **Review paper on Study of Voltage Sag Compensation in Wind Farms to Weak Grid Connections using UPQC**

Shishir.S.Pande<sup>1</sup>, Radharaman Shaha<sup>2</sup>

Student, AGPCE, Nagpur, Maharashtra, India<sup>1</sup>

HOD, Department of Electrical Engineering, AGPCE, Nagpur, Maharashtra, India<sup>2</sup>

**ABSTRACT:** This paper mainly deals with the regulation of voltage at wind farm (WF) terminals and the improvement of power quality and WF stability in a WF to Weak-Grid connection. In this paper we study how the grid connection form a weak connection and which are the parameter is responsible for the voltage sag condition and how will occur on it and we study that parameter in details of the voltage sag. This is the review paper on the Investigation of UPQC for Sag Compensation in Wind Farms to Weak Grid Connections, subject of this paper is to review the main problems of the connection of wind farms to the weak grid and how the grid codes must be adapted in order to integrate wind power generation capacity without affecting the power quality.

**KEYWORDS:** Wind Energy, UPQC, weak grid, voltage sag, WF, PQ, PCC.

## **I. INTRODUCTION**

In the past, the penetration of wind energy into the electric power system was low. Then, in case of grid faults, the wind farms were simply disconnected without consequences on system stability. Then, in case of grid faults, the wind farms were simply disconnected without consequences on system stability. Under nominal power generated level, with wind velocity of 14m/s and the loads L1, L2 and L3 connected, the bus MV3 is short-circuited, causing voltage sag in the vicinity of this fault. Also, it is well known that given the random nature of wind resources, the WF generates fluctuating electric power. These fluctuations have a negative impact on stability and power quality in electric power systems. Then, in case of grid faults, the wind farms were simply disconnected without consequences on system stability. The location of generation facilities for wind energy is determined by wind energy resource availability.

## **II. RELATED WORK**

In the last years, the wind energy penetration has been increased significantly, and its need is to be increasing. This situation forced the revision of electric utilities grid codes requirements, to guarantee the reliability in systems with high penetration levels. In this work, the behaviour of a wind farm with squirrel cage induction generators, connected to a weak grid and facing three-phase voltage sag, is analysed. So to improve the wind farm low voltage ride-through capability, Magnitude restoration and phase jump compensation strategy for voltage sag compensation is used.

The active component of electrical power output at the generator bus bar is determined by the mechanical input of interconnected machines. These machines determine how the flow of power is controlled in the system. The active power output of the generators is determined by the mechanical power input from their prime movers (steam turbines, hydro, wind, etc.). The consequence of a mismatch between the supply (generation) and demand (load and network losses) for active power is a change in the rotational energy stored in the rotating mass of the generators, and hence, a drift in the system

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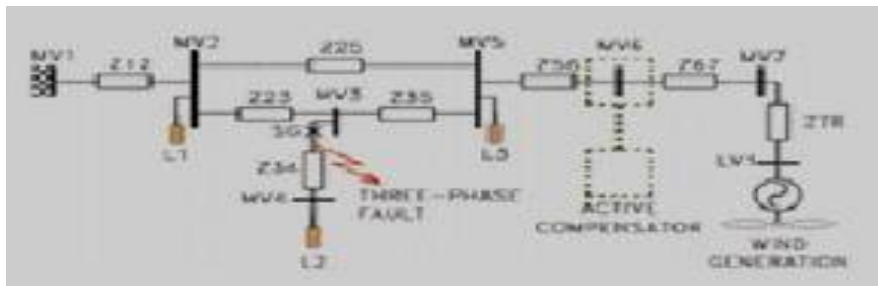
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frequency. A surplus in generation creates a frequency increase, and a shortage in generation leads to a decrease in the frequency. The stiffness,  $K$ , of a system is defined as the ratio of the change of power to change of frequency two types of operating reserve are required spinning reserve and supplementary reserve. Spinning reserve is the difference between the total on-line generator capacity and the total output of these generators, usually between 1.5% and 3% of peak demand. Supplementary reserve is the generation capacity that can be brought into operation in 10 min and fully available within 30 min. The operating reserve is dimensioned to cover the loss of the largest generating unit of the system. Frequency regulation ancillary service is composed by three functions.

The principal aim is to improve the stability of wind farm by means of active compensator. The system under study is composed by a wind farm connected to a distribution network, as show in the fig 2.1 where the three-phase fault and the switch-gear (SG) operation produce a voltage sag in the farm terminal MV6. A total of 36 fixed-speed induction-generator/wind turbines compose the generation, adding up to 21.6MW. Each turbine has attached a 175kVAr compensation capacitor bank and is connected to the grid by means of a 0.69/33kV, 630kVA transformer. This system is taken from a real case.



**Fig 2.1** Single Line Diagram of the System

The WF is composed by 36 wind turbines using squirrel cage induction generators, adding up to 21.6MW electric power. Each turbine has attached fixed reactive compensation capacitor banks (175kVAr), and is connected to the power grid via 630KVA 0.69/33kV transformer. This system is taken from and represents a real case. The ratio between short circuit power and rated WF power, give us an idea of the “connection weakness”. Thus considering that the value of short circuit power in MV6 is  $SSC \sim 120MV A$  this ratio can be calculated. Values of  $r < 20$  are considered as a “weak grid” connection. Turbine rotor and associated disturbances model. The power that can be extracted from a wind turbine is determined by the following expression.

$$P = \frac{1}{2} C_p \rho A V^3 \dots\dots\dots (2.1)$$

Where  $\rho$  is air density,  $R$  is the radius of the swept area,  $V$  the wind speed, and  $C_p$  is the power coefficient. For the considered turbines (600kW) the values are  $R = 31.2 \text{ m}$ ,  $\rho = 1.225 \text{ kg/m}^3$  and  $C_p$  calculation is taken Then, a complete model of the WF is obtained by turbine aggregation this implies that the whole WF can be modelled by International Journal of Innovations in Engineering and Technology (IJJET) Volume 6 Issue 4 April 2016 782 ISSN: 2319 – 1058 only one equivalent wind turbine, whose power is the arithmetic sum of the power generated by each turbine according to the following equation

$$P = \sum_{i=1}^n P_i \dots\dots\dots (2.2)$$

Moreover, wind speed  $v$  in can vary around its average value due to disturbances in the wind flow. Such disturbances

The UPQC serial converter is controlled to maintain the WF terminal voltage at nominal value, thus compensating the

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PCC voltage variations. In this way, the voltage disturbances which are 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. Fig.2.1 shows a block diagram of the 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 UPQC 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.. This shunt converter controller generates both voltages commands  $E_d \text{ shuC}^*$  and  $E_q \text{ shuC}^*$  based on power fluctuations  $\Delta P$  and  $\Delta Q$ , 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 in IEC61000-4-15 standard. In turn,  $E_d \text{ shuC}^*$  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.

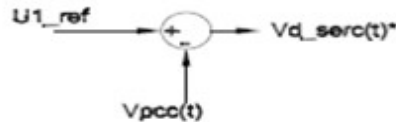


Fig 2.2 Series compensator controller

### Voltage Sag with UPQC

UPQC is validated to mitigate the problems of voltage sag caused due to sudden connection of large load.

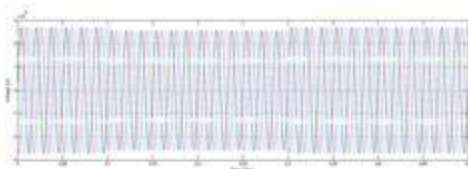


Fig 3 Voltage Sag with UPQC

In this Paper, a compensation strategy based on particular custom power device i.e. Unified Power Quality Conditioner (UPQC) has been proposed. The UPQC is controlled to mitigate voltage fluctuations and to regulate the WF terminal voltage at PCC caused by pulsating WF generated power and system load changes respectively using Synchronous Reference Frame control scheme.

In this paper we propose and analyse a compensation strategy using an UPQC, for the case of SCIG-based WF which is connected to be a weak distribution power grid. This system is taken from a real case. The UPQC is controlled to regulate the WF terminal voltage, and to mitigate voltage fluctuations at the point of common coupling

In this paper the custom power devices means CUPS devices is used. The concept of the custom power is tools of application of power electronics controller devices into power distribution system to supply a quality of power,

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demanding by the sensitive users. These power electronics controller devices are also called custom power devices because through these valuable powers is applied to the customers. They have good performance at medium distribution levels and most are available as commercial products. For the generation of custom power devices VSI is generally used, due to self-supporting of dc bus voltage with a large dc capacitor.

The UPQC is a combination of a shunt (SHUC) and a series (SERC) active filter, cascaded via a common DC link capacitor. Each compensator is an IGBT based full bridge inverter, which may be operated in a voltage or current controlled mode depending on the control scheme. The UPQC finds its application in mitigating various power quality problems. In the proposed solution the UPQC is connected at the Point of Common Coupling of the FSIG. The capital cost involved in the installation of this device is higher than any other FACTS based solution because of its twin inverter structure. In this paper a cost effective method of choosing the inverter VA rating without compromising on the overall performance of the device is proposed.

### III. COMPARATIVE ANALYSIS

Sr. Number	Title	Author	Methodology Used	Advantages	Dis-advantages
1	Investigation of UPQC for Sag Compensation in Wind Farms to Weak Grid Connections	M.F. Ferias P.E. Battaiotto M. G. Cendoya	Magnitude restoration and phase jump compensation strategy for voltage sag compensation	In this scheme higher power converters are not required	This scheme requires more custom power devices than the other scheme.
2	Connection requirements for wind farms: A survey on technical requirements and regulation	Inigo Martinez de Alegria, Jon Anduea, Jose Luis Marti'na, Pedro Iban'ezb, Jose Luis Villateb, Haritza Camblong	Here a performed a survey on technical requirements and regulation for wind farms	1) In this way we calculated different type of voltage sag and swell condition 2) Due to reactive power control power losses are reduced.	This survey consumes more time and did not got the accurate result due carless survey by human being.
3	Wind Farms in Weak Grids Enhancement of Ride- Through Capability Using Custom Power Systems	M. F. Ferias, M. G. Cendoya , P. E. Battaiotto	The principal aim is to improve the stability of wind farm by using of active compensators	We stabilized the voltage in normal condition	We need widely active capacitor compensator
4	Enhancement of Power for Wind Farm to Weak Grid Connection	K.Durga Manogna, V.Lakshma Naik	series and shunt converters of the UPQC	It is useful to all power system like generation, transmission and distribution	Its apparatus cost is very expensive
5	Power Quality Improvement by UPQC device in Doubly Fed Induction Generator Wind Farm to Weak-Grid Connection.	Miss. Sobha rani Injeti, K. Ratna Raju	back-to-back PWM voltage- source inverters	1) Induction Generator is nothing but the electric power generator source. 2) It required initially start up voltage, after attempting the synchronous speed, its fed by its own supply	This system is less accurate for voltage mitigation because of it is required one auto switch with operator.

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6	An Improvement of Power Quality for Wind Farm Connected to Weak Grid System using Unified Power Quality Conditioner (UPQC)	P. Siva Kumar, K. NarasimhaRao and G. Srinivas	Synchronous Reference Frame control	1) Voltage sag, voltage swell and THD will be reduces.	For the reduction of voltage fluctuation UPQC is needed. Without UPQC Voltage fluctuation cannot be reduced properly.
7	Analysis of Wind Farm to Weak-Grid Connection Using Unified Power Quality Compensator (UPQC)	Ch.chaitanya Kumar, V.Ram Prasad, Dr.K.Sumanth	Compensation strategy based on CUPS devices like UPQC	This scheme enhances the system power quality and active power sharing between UPQC converters.	The enhancement of the system power quality and active power sharing between UPQC converters, this feature is not present in DVR & D-STATCOM
8	Wind Farm to Weak-Grid Connection using UPQC Custom Power Device	G.Jagan Mohan reddy, Dr.M.Padmalaitha, M.sudheer babu	The new Compensation strategy using an UPQC to connect SCIG based wind farms to weak distribution power grid.	This scheme enhances the system power quality, exploiting fully DC- bus energy storage and active power sharing between UPQC converters.	The combination of weak grids, wind power fluctuation and system load changes produces disturbances in the PCC voltage
9	Method for enhancement of power quality at point of common coupling of wind energy system	Jyothilal Nayak Bharothu, Abdul Arif	The internal control strategy is based on the management of active and reactive power in the series and shunt converters of the UPQC	This scheme regulates the voltage in the WF terminals, and to mitigate voltage fluctuations at grid side.	Voltage fluctuation is occurs at PCC.
10	Power Quality Improvement Using Custom Power Devices in Squirrel Cage Induction Generator Wind Farm to Weak-Grid Connection by using Neuro- fuzzy Control	Kopella Sai Teja, R.B. R.prakash	SCIG based wind farms connected to weak grid	This scheme enhances the system power quality.	Various components are required for this scheme like series converter, shunt converters, DC link etc.hence the system is complex.
11	Power quality improvement in grid connected wind energy conversion systems by using custom power device	S.Siva Sasthri M.Manohara	A grid-connected WECS employing multipole permanent magnet synchronous generator (PMSG)	Installation of PMSG topologies is easy and has high efficiency compare to other topology.	Power quality problems such as current and voltage harmonics, voltage sag, voltage unbalance etc occurs.
12	Rating Requirements of the UPQC to integrate the FSIG Type Wind Generation to the Grid	Jayanti N. G., Malabika Basu, Michael F. Conlon, and Kevin Gaughan	This paper investigates the application of a Unified Power Quality Conditioner (UPQC) to overcome the grid integration problems of the	The performance of Static VAR Compensator (SVC) based reactive power compensation is better than a fixed capacitor.	1) The mechanical switching reduces the life span of the scheme. 2) Also the gearbox experiences excessive stress due to step voltage changes.

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			FSIG		
13	Power Quality Improvement Using UPQC for Wind Farm Generation System	G. Laxminarayana, G. Umesh Kumar.	The active compensators like FACTS devices and CUPS devices are used to improve integration of wind energy in weak grids.	This scheme increased voltage regulation sensitivity to changes in load.	1) The WF generates fluctuating electric power. 2) These fluctuations have a negative impact on stability and power quality in electric power systems. 3) Voltage fluctuation is produced.
14	Application of STATCOMs to wind farm	Z. Saad-Saoud M.L. Lisboa J.B.Ekanayake N.Jenkins G.Strbac	The strategies for steady state voltage and reactive power flow control of a wind farm equipped with a STATCOM were investigated.	1) A STATCOM can be used to mitigate voltage fluctuation at blade passing frequency 2) Improves the steady-state stability limit of the Network.	The damaging over voltages may be occurring under islanding conditions.
15	Simulation of Wind Farm Using UPQC in Weak Grid Connection.	Yashaswini Patel A. B, T.R.Narasimhe Gowda, B.Kantharaj, Ramesh G.B	Compensation strategy based on a particular CUPS device and SCIG is directly connected to the grid.	1) This approach increases the compensation capability of the UPQC with respect to other custom strategies that use reactive power only. 2) Increased voltage regulation to changes in load.	In the connection with wind energy a weak grid is a power supply system where the amount of wind energy that can be absorbed is limited by the grid capacity.
16	Enhancing voltage and current control techniques using Unified Power Quality Conditioner.	Charanjeet Madam, Puneet Pahuja, Charu Jain	Discrete proportional integral controller is used.	1) It improves the power quality of the system. 2) Reduce the distortion level of harmonics in case of non linear and sensitive loads.	Arises the various types of power Quality Problems.

#### IV. VOLTAGE SAG COMPENSATION STRATEGIES AND MAIN TECHNICAL ISSUES

In case of three phase fault, deep voltage sag is observed at wind farm terminals. In previous works [5], strategies using UPQC had been proposed to improve low voltage ride through of the wind farm, but mainly concentrated on magnitude restoration of Voltage sags, whereas no attention has been paid to phase jump. This phase jump usually does not affect induction generator operation, but may cause tripping of equipment and auxiliary devices, like contactors, battery chargers, etc., leading to wind farm power outage. In the following subsections, a classical full voltage magnitude restoration strategy, and the proposed magnitude restoration plus phase compensation strategy, are presented.



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## 4.1 Main technical Issues in wind farm connection to the grid

There are three main technical Issues which are as follows. (a) Voltage and reactive power control.

- (b) Frequency control.
- (c) Fault ride-through capabilities.

## V. THE WIND POWER EQUATION

The wind power developed by the turbine is given by the equation

$$P = \frac{1}{2} C_p \rho A V^3 \quad \text{..... (6.1)}$$

Where  $C_p$  is the Power Co-efficient,  $\rho$  is the air density in kg/m<sup>3</sup>,  $A$  is the area of the turbine blades in meter square and  $V$  is the wind velocity in m/sec.

The power coefficient  $C_p$  gives the fraction of the kinetic energy that is converted into mechanical energy by the wind turbine. It is a function of the tip speed ratio  $\lambda$  and depends on the blade pitch angle for pitch-controlled tip speed ratio. Tip speed ratio may be defined as the ratio of turbine blade linear speed and the wind speed.

## VI. CONCLUSION

In this paper the concept of voltage sag compensation in wind farm to weak grid connection has been surveyed. This paper discussed the voltage sag condition and to improve the stability of wind farm by means of active compensator. The main objective of this paper was to make a survey of various wind farms to weak grid connection, its handling techniques which handle a huge amount of voltage from different sources and improves overall performance of systems and its applications.

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### BIOGRAPHY



**Mr. Shishir S. Pande Has completed B.E (Electrical Eng) From P.I.G.C.E, Nagpur, He is pursuing M.Tech (Integrated Power system)From A.G.P.C.E, Nagpur**