Power Quality Enhancement of Wind Farm to Weak Grid Connection using UPQC: A Review

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ABSTRACT
Now a day wind power generation increased and largely incorporated in the grid. Through Medium voltage distribution line Wind farm (WF) connected to high voltage (HV) grid line represents wind energy conservation system. The wind farm connection at the point of common coupling (PCC) having problem due to system load change and varying wind speed cause power quality problem, PCC voltage variation and wind farm (WF) stability, is considered as WF connected to the weak grid. The quality related issue eliminated at generation or by using compensating method. The wind farm uses squirrel cage induction motor (SCIG) shows wind power conservation system. Stability concern of SCIG needs some alternative like compensating method. Custom Power Device (CUPS) technique useful compensating technique. This paper based on CUPS technique, unified power quality conditioner (UPQC). UPQC device controlled to regulate voltage and mitigate gird side voltage fluctuation caused by pulsating WF power generation and load change. The control strategy of UPQC is based on active and reactive power flow management in series and shunt converter and power exchange in DC-link.

Keywords
PCC, UPQC, SCIG, Wind Farm (WF).

1. INTRODUCTION
Wind energy is one of the most of the important renewable energy source among all non-conventional electrical energy source, and it is increasing all over the world. As an increasing concern of environmental issue, it is needed to find other sustainable energy sources. As in future, wind energy is considered to be largely integrated with grid. Wind turbine power generation reached in some area at several MW [1]. The individual wind turbine unit has capacity up to 2 MW feed in power system. The capacity of Wind power increased up to 336 GW in June 2014, and production of wind energy around 4% of total electric power usage all over the world. Wind farm connection creates some power quality related problem and needs to take attention. Availability of wind decides the location of the wind farm. Many times wind farm is far from the grid. If medium power rating system considered, then it connected through medium voltage line. Grid to which wind farm connected, the transfer capacity of the grid line is compared with wind farm power generation is known as weak grid or feeble grid connection [2].

Wind energy, turbine uses Squirrel cage induction generator (SCIG) to harness wind power. The operation of SCIG needs reactive power and which provided through the line or by external capacitor bank. Due to change in wind speed, cause a change in input mechanical speed. Because, of system impedance, there is variation in wind farm terminal voltage [3]. The disturbance in power fed from wind farm cause power quality problem in grid. Also the operation of WF flawed due to the disturbance. The impact is large in the case of wick grid. In order to minimize voltage fluctuation, many methods are proposed. One solution is upgrading to grid system, increasing short circuit level at PCC [4].

Recent technological developments in power electronics equipment are suited for power system application having fast response compared to line frequency. The custom power devices are useful for enhancing power quality in the distribution system and controlling of power flow in transmission system [5]. The use active compensator for enhancement of wind energy integration scheme considered for this study. Unified power quality conditioner is a custom power devise used as compensating device for SCIG based wind farm [6]. UPQC is used to maintain voltage regulation and mitigation of fluctuation from the system.

2. SYSTEM DESCRIPTION
The system considered for case study shown in Fig 1. The wind farm composed of 36 wind turbine using SCIG, having a total capacity of 21.6 MW. Each turbine provided with capacitor bank (175 kVAR) for reactive power compensation and is connected to grid via 630KVA 0.69/33kV transformer.

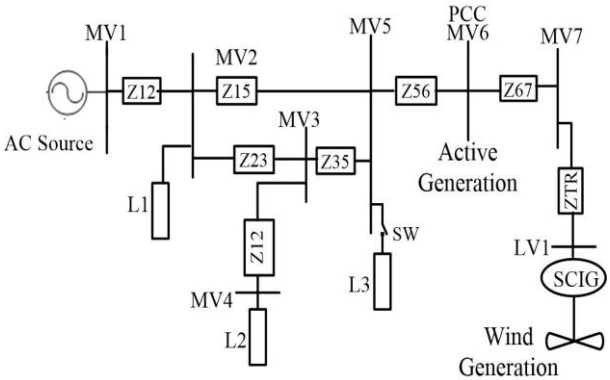

Fig. 1 Study case power system

This case considered as real system. The weakness of connection is the ratio of short circuit power and WF power. The short circuit power is considered at PCC connection point i.e MV6 which nearly equals to 120 MVA. The ratio of this asgiven (1)

$$r = \frac{S_{SC}}{P_{WF}} \qquad (1)$$

If r < 20, the connection is considered as week grid connection.

3. POWER FROM WIND

The power obtained from wind turbine is given by following expression:

$$P = \frac{1}{2}\rho\pi R^2 V^3 C_p \qquad (2)$$

ρ- density of air, R - Radius of the swept area, Vvelocity of wind, and Cp – power coefficient. Considering the power output of turbine is 600kW, R=31.2 m and ρ= 1.225kg/m3. By taking one wind turbine as a equivalent of wind farm .Thetotal powerobtained from wind farm is arithmetic sum of power at each turbine given by following equation

$$P_T = \sum_{1,2,\ldots,36} P_I \qquad (3)$$

The velocity of wind V is variable cause different disturbance as deterministic and random. The deterministic condition is depending on wind flow at the blade and atmospheric condition and turbulence cause the random condition. In this case disturbance due to physical supporting tower considered and wind turbine with 3 blade frequency of modulation is 3N by a sinusoidal modulation due to the value of V.

4. PROBLEM OF WEAK GRID

The weak grid used in various time to refer voltage of grid. Sometimes voltage in the grid is not constant. In stiff grid voltage is constant. The weak grid problem is different due to wind energy connection to the system. The grid impedance limits the amount of power absorbed at the point of connection is limited because of upper voltage limit. That is weak grid is power supply system where the energy absorbed limited by the capacity of the grid, not by operating parameter of generation. The problem like voltage fluctuation, flicker, noise etc occur in supply system causes problems in the normal operation of generation, transmission, and distribution network system. The wind turbine uses induction generator due to robustness and cost effective. The quality of power is customer focused measure and need to take into account.

4.1 Voltage Fluctuation

The power quality problem getting important day by day. Voltage fluctuation is now a day considering factor causing the problem to end user equipment operation. Voltage quality issue like sag, swell, interruption, voltage unbalance. In past only blackout get the attention of consumers. Now end users are paying attention to protect system against voltage quality problem by installing uninterrupted power supply which is one of the populous method.

4.2 VOLTAGE QUALITY

The problem due to wind farm connection to the grid can be assessed by the following concept:

- The rapid change in voltage
- Voltage fluctuation and flicker
- Harmonics

For the reliable connection point view, the harmonic factor is taken into consideration according to the agreement with the system operator.

5. UNIFIED POWER QUALITY COMPENSATOR

Power quality is one of the concerning issues in power system need to take into account. With the innovation of FACTS technique, the power system operation at its maximum limit is possible. There are various power quality problem controlling devices are available. With the use of D-STATCOM and DVR control of power quality problem concern with source current and load bus voltage is possible simultaneously when transient in source voltage, DVR supplies requirement of power to load and bus voltage maintained by D-STATCOM. By adjusting this controller only one device provides above requirement. The adjustment of devices gives unified power quality conditioner UPQC shown in Fig. 2

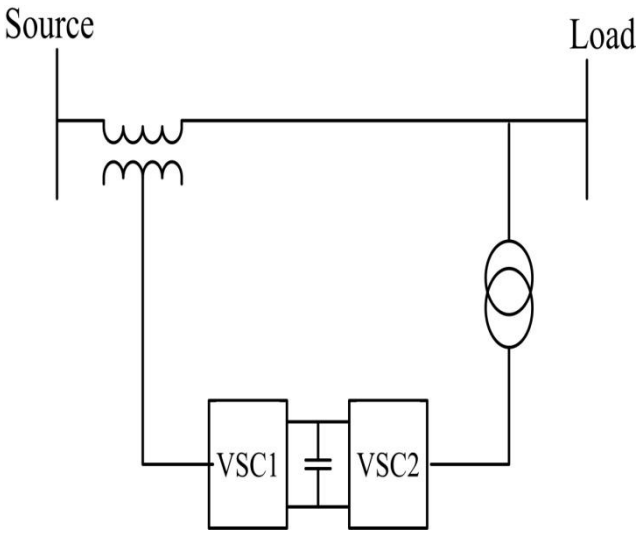

Fig. 2 UPQC configuration

5.1 OPERATION OF UPQC

UPQC solve problem-related to voltage and current simultaneously. UPQC connection to the system before load for making voltage distortion less at load and simultaneously source side current in phase with supply voltage. UPQC operation based on three phase voltage compensation by the power electronic converters system either by voltage source inverter (VSI) or by current source inverter system (CSI).

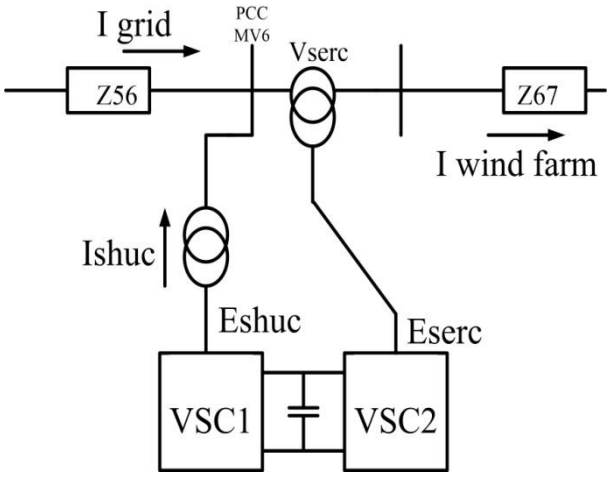

Fig. 3 Block diagram of UPQC

The series connection of converter injects voltage between PCC and U1. While shunt connection of converter injects current at PCC shown in phaser digram Fig. 4The important point of UPQC is DC link between both shunt and series enables reactive power exchange converter enables active power exchange.

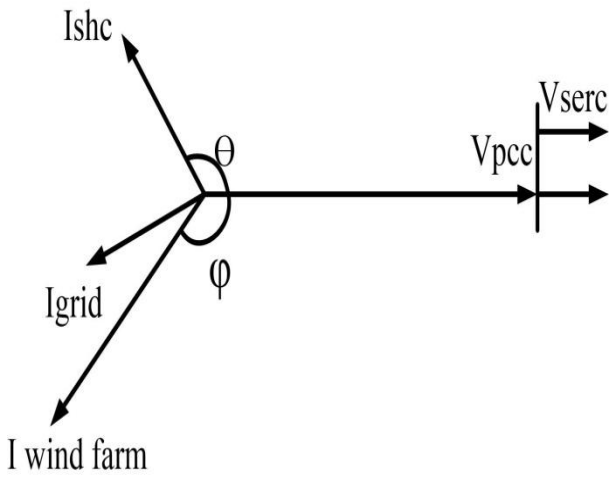

Fig. 4 Phasor Diagram of UPQC

5.2 DYNAMIC COMPENSATOR MODEL

This compensation in voltage fluctuation is performed by series injection at PCC bus bar this is done through UPQC figure shows basic compensator outline .voltage in series and active– reactive power in the MV6 (PCC) bus bar; this is accomplished by using a unified type compensator UPQC In Fig.5 we see the basic outline of this compensator; the bus bars and impedances numbering is referred to Fig.1

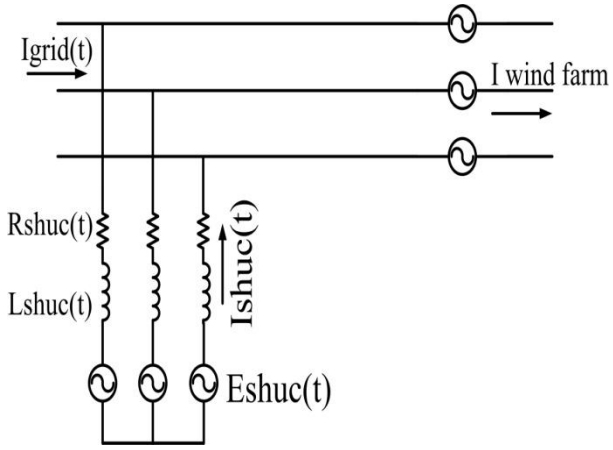

Fig. 5Dynamic Compensator model of UPQC

5.3 POWER BUFFER CONCEPT USING UPQC

The injected power levels the power in the system and this is done by UOQC hence it is seen as power buffer.

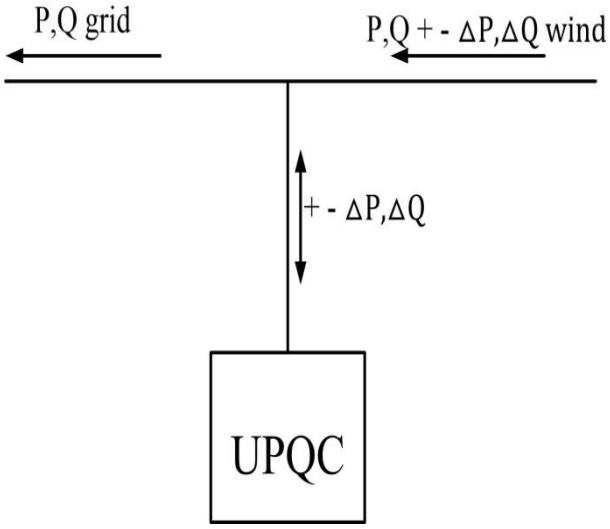

Fig. 6 Power buffer concept

The figure shows the process of operation and basic outline of UPQC. In which the storage element installed at the line in order to maintain the system parameter. Where non-appearance of outside DC source in UPQC bus to strengths power system. This is done through proper designing of DC voltage controller. This method cannot be executed in DVR or D-STATCOM. The reactive power supporting done by D-STATCOM, which is not done by DVR. Then the factor voltage regulation takes concern, where disturbance cannot be effective controls reactive power utilization by D-STATCOM at this condition DVR is useful.

6. CONTROL STRATEGIES

In order to store power, there are various control strategies available for power controller. These different control strategies provide different ratings of power and voltage variations and hence the size of storage capacity greatly depends on maintaining the ratings. The two different control strategies are voltage control strategy connection and power control strategy in which point in grid starts operation of controlling which results increased capacity and smoothing of power as well.

6.1 UPQC CONTROL STRATEGY

6.1.1 Series Converter Controller

Block diagram shows the controller of the series converter having nominal voltage level at WF terminal in order to compensate properly at PCC. The disturbance from grid prevented from WF offices. In the controller, PCC voltage is subtracted from the taken reference voltage which is phase alignment with PCC voltage. The control strategy is useful in the condition when voltage sag occurs useful to overcome low voltage at WF terminal..

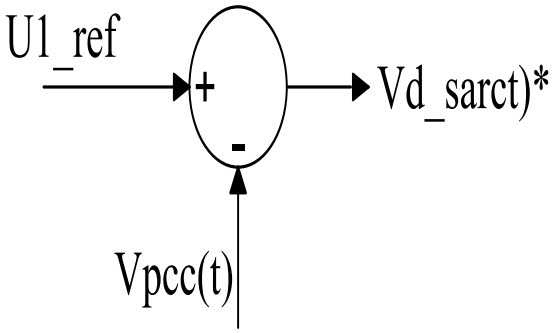

Fig. 7series compensator controller

$$T = \frac{2}{3}\begin{bmatrix} \sin(\theta) & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

$$\begin{bmatrix} f_d \\ f_q \\ f_0 \end{bmatrix} = T \begin{bmatrix} f_a \\ f_b \\ fc \end{bmatrix}$$

Where *fa,fb, fc* i.e*i=a,b,c* shows phase current or voltage and *fd, fq,f0* transferred magnitude to *d,q,0*. The transformer allows turning reference frame in the positive sequence of the PCC voltage space vector.

6.1.2 Shunt Converter Controller

To filter reactive and dynamic power pulsation generated by WF shunt converter used. The WF uses compensator which will free from pulsation. The main goal is to inject suitable electrical current at PCC. The block diagram of shunt converter in Fig.6 this controller has dc bus voltage. It produces both *EdshuC∗* and *EqshuC∗* which is determined by P and Q. the reactive and active mean power value obtained by low pass filter and bandwidth of filter selected, the fluctuation part of the compensator. the addition of dc voltage low pass filter compared with reference DC voltage are with the *EdshuC*. The power *PshuC*and *QshuC* calculated with the rotating reference frame as in,

$$PshuC = \frac{3}{2} V_d^{PCC}(t) I_d^{shuC}(t) \quad (4)$$

$$QshuC = -\frac{3}{2} V_d^{PCC}(t) I_d^{shuC}(t) \quad (5)$$

Ignoring PCC voltage variation,

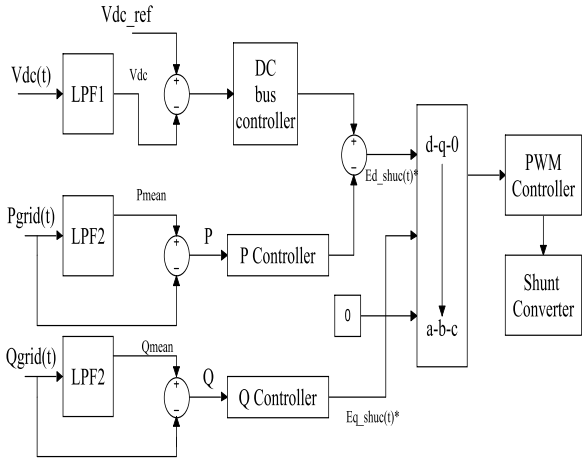

Fig. 8 Shunt Compensator Controller

$$PshuC = k_p^{'} I_d\_shuC(t) (6)$$

$$QshuC = k_q^{'} I_q\_shuC(t) \quad (7)$$

Shunt converter promotes the linear relationship of controller voltage of generating power and is based on VSI. The resultant mathematical equation are:

$$PshuC = k_p^{''} E_d\_shuC * (t) (8)$$

$$QshuC = k_q^{''} E_q\_shuC * (t) (9)$$

The active (P) and reactive (Q) power uses P controller while in DC loop bus PI controller.

7. CONCLUSION

In the system, the UPQC is placed at the PCC where the WF power generated compared to the capacity of the grid. The UPQC has two voltage source inverter which is in series or shunt injects voltage and current. The series converter injects voltage in between the point of common coupling in order to maintain terminal voltage and shunt controller injects current at PCC. It has two VSI shares the same dc bus voltage enables active power exchange between them. By this grid side voltage fluctuation reduces and improves voltage regulation, ultimately power quality and stability of WF. The proposed unified power quality conditioner (UPQC) employ PI controller instead of PI controller fuzzy controller can be used which also reduces voltage sag. Fuzzy controller with active power filter, there is two powers filter employed in series and shunt. The series filter useful in order to compensate problem-related with voltage and shunt for current compensation.

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