The aspect of power quality in a wind generation: Overview

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Abstract. Because of fossil fuels cost is high and environmental issues pushes to renewable energy sources to be used significantly. One of these wind energy got a lot of investments. It is difficult for good power quality due to the behavior of wind turbine speed. It effects on the power and voltage of the component that connect with the wind turbine. A new technique must be developed and new control must be used to control the fluctuations and improve wind power performance. Also using possible excitation induction generators for safety issues. More over the smoothening wind power variation done by using some energy storage technologies. Using a static compensator for the harmonic current injection and reactive power compensation. Besides of improving power quality of wind turbine also the fault tolerance. Dynamic voltage restorer used to treat the reactive power compensation connected to a wind turbine.

1. Introduction

The aim of this research using modern techniques for mitigation the issues for power quality created by wind energy connected with the distribution grid. From about 30 years ago, the wind plants have taken significantly a good place [1]. Which brought to the power system engineering. A new challenge such as voltage sag, harmonic distortion, flickers, voltage swell, self-excitation and fault tolerance and give solutions for each. Section 2 states the issues of power quality that are taken in account. Section 3, deals with the utilizing of energy storage to make the system of wind energy reliable and more flexible. Section 4 deals with the using static compensator to mitigate all issues of power quality due to using wind energy. Section 5, state the improving of wind energy power by using wind energy power by using wind conversion and storage systems. Section 6 describes using DVR to treat the issues of the reactive power uncompensation.

2. Wind power quality issues

Converting the mechanical energy from the wind plant gives a random behavior for getting the easy electric energy. Because the change in speed of wind, the torque applied to the system will vary making different issue appears.

2.1. Peak power tracking and power coefficient

Not only the variation in wind speed makes it difficult for good power quality it also affects the power coefficient $C_p$. Which is the ratio of mechanical power of the wind turbine to the power of the wind.

$$P_{mech} = C_p \ast P_{wind}$$  \hspace{1cm} (1)
Which is not constant, depends on many factors such as wind speed, aerodynamic, blade pitch angle. In low wind speeds, the coefficient power it be zero. Making the turbine control more difficult.

\[ P_{\text{wind}} = \frac{1}{2} \cdot PA \cdot V_{\text{wind}}^3 \]  

(2) 

Where \( P_{\text{wind}} \) is the wind mechanical power. 

The variation of wind speed appears the effect of the tower shadow, which equivalent to distribution of the wind turbine horizontal axis. The effects of tower shadow appear into coefficient of power. If one of the blades be shaded, it will not transfer such power as it on other position. Which effect on the voltage, reactive and active power. Which affect the output of a synchronous generator. 

Many techniques like maximum power point tracking and peak power tracking utilize to increase the coefficient of power. Due to these two techniques to finding the rotor speed when the coefficient is maximized.

Strachan and Jovic [2] do experimental work and obtained the relationship between the rotor speed and the power and. By utilizing another techniques structures on slight changes in rotor speed where obtain the maximum power is. While the tracking of power technique gives a voltage fluctuation to the wind plant but exhibits an efficient conversion of energy.

2.2. Induction generators self-excitation

Adopting the induction, a synchronous generator in a wind power plants as a device. Its jobs the electromechanical energy conversion. It needs reactive power for producing active power. This technique used to compensate the reactive power with shunt capacitor. self-excitation can may occur during a grid fault leads to change in frequency and voltage. This situation is may damage equipment like wind turbine producing high voltage mat affect to human life.

2.3. Voltage transient

The mechanical switches are utilized with capacitor banks to give the induction generators a suitable reactive power. These switches give a high voltage transient, that can effect on the sensitive electronics equipment that utilize with the controller of wind energy system [3].

2.4. Unbalance voltage

Due to a big unbalanced loads with the distribution system causes a flow of negative sequence current into the induction machine. Making these machine to overheat, reducing the life time and maybe derated.

2.5. Voltage flicker and fluctuation

Wind speed variation causes Voltage fluctuation and flicker. Flicker occur when voltage fluctuates ranging frequency between 10-35 Hz and producing incandescent light that damage sensitive equipment. For avoiding flicker, energy storage techniques can utilize.

2.6. Harmonics

The total harmonic distortion of the voltage can presents:

\[ THD_v = \sqrt{\frac{\sum_{h=2}^{N} V_h^2}{V_1^2}} \]  

(3) 

Where:

\( V_h \): RMS voltage for harmonic in order of \( h \)

\( N \): 368 std ANSI must be 83 at 60 Hz

Total harmonic distortion of current defined as:

\[ THD_i = \sqrt{\frac{\sum_{h=2}^{N} I_h^2}{I_1^2}} \]  

(4)
The reduction in life equipment, power losses and heating of transformers all these causes due to harmonic distortion. Harmonics that present a frequency less than 60 Hz effect on power quality which can damage the generators. Rectifying the power from a wind plant and drive to the inverter to control injected current and minimizing the THD of current [4].

3. Wind power quality, predictability improvement and reliability
Using the energy storage with the wind plant it leads to increase the minimum power and make this power smoother by decreasing the voltage fluctuation. Also increase the wind energy availability of among the minutes and the days.

3.1. The motivation
The energy storage devices can supply 1 minute of the wind power plants to improve power quality by reducing the short voltage variations. While large energy produced supply the wind farm up to 15 minutes and it leads to shut down the smaller unit like local combined heat power unit [5]. Since large energy can be reserved for such an investment and leads to shut down the larger stand by reserves.

3.2. The energy storage device
Rasmussen [5] describes that the storage devices of less than 1MWH such as flywheel, super conducting magnetic energy storage and ultra-capacitor. Their cost per unit is high and have small storage capacity. The storage device exceeds 100MWH liked pumped hydro compressed air and fuel cells discussed in [3]. It need a large investment and the first type have lower cost per unit.

3.3. The power availability and improvements of the reliability
Rasmussen [5] focused on the availability of power on a definite time interval. Which capacity between 20%-40% of the total energy along with 80%-100% of the power rating. Means power available but it comes with high cost, this technique has more controller grid operation.

4. FACTS device to improve the power quality of wind turbine
By putting the static compensator on the point of common coupling connected with the BESS, utilizing the battery energy storage to reduce the problems of power quality. The diagram [6], used to maintain the power factor unity on the source side with supporting the power on the wind generator and load at the PCC, to prevent all the problems occurs by a synchronous generator, self-excitation in grid fault. Wind speed variation effect on the active power of the synchronous induction generator which reflect on the reactive power and the voltage.

4.1. The STATCOM
This device is a shunt connected device supporting reactive power in term to control the power system with a specific parameter [6]. It has the capability of independently either generating or absorbing reactive and active power on the output. The DC input of the device comes into the battery of the energy storage. STATCOM produce a 3 phase AC voltage output with the voltage system.

4.2. Applications
The problems of power quality can be reduced by using a STATCOM engaged with the BESS which operates the protection devices. These problems like sag or swell, harmonics and flicker may damage the equipment and decrease the life of equipment. This technique enables the STATCOM to inject the current to keep the voltage and current waveform sinusoidal at the same time and supporting the reactive power for induction generator besides to the load if there in a fault. Through a fast PI controller can measure the grid voltage and current to inject appropriate value needed.
5. Improve the power quality of wind system by utilizing the conversion of wind energy with the storage systems
WECSS which contains the pitch controller wind turbine supplying 2MW (PMSG) is discussed in Strachan and Jovicic [2]. The conversion of wind energy with a storage system is present in fig. 2. connect the PMSG to the grid through full-scale controlled of a power converter system. capacitor bank connected to the (PCS) for energy storage. This technique has objective in isolate the grid from the disturbance occur in wind speed and during the fault.

5.1. Track the peak power
Strachan and Jovicic [2], established the rotor speed function and power maximum to reach the optimal rotor speed to utilized to control rotor speed. This will increase the angle of blade pitch if these is an excessive in wind speed to safeguard wind turbine. The angle of blade pitch in a minimum value and the power coefficient will be high.

5.2. The controller of the fault
Removing the WECSS from the grid due to the fault making the dc voltage suffering from having a swell. To mitigate this fault controller must work. In Strachan and Jovicic [2], the technique operates by increase the speed of rotor over the rotor speed reference of. Due to this, the power generated will be dropped. Making the transfer energy deliver into the dc bus decreased.

6. Utilizing the dynamic voltage restorer to avert uncompensation reactive power
The DVR is device can inject series voltage to the system to regulate the voltage in load side. It utilizes to compensate the reactive power, compensate the voltage swell, sag, harmonics and flicker [3].

6.1. Compensation of reactive power
Reactive power compensation is very important to the system voltage, any lack of it will lead to collapse. In [7,8], it appears in numbers when reactive reach their limits, a bifurcation occurs. This will lead to collapse of voltage.

6.2. Application of DVR related with wind generation
Yuvaraj et al. [6] discussed the mitigation of transient done by DVR lead to more improve in power factor and in wind power planet can investigate reactive power for compensation. By utilizing the DVR in the system not only for the reduction the transient amplitude also the duration. In Amalorpavaraj et al. [9], provided the fault ride to the DFIG engaged in wind turbine by using the DVR. To compensates the terminal voltage at the time when the fault appears by use DVR to deliver the voltage to the PCC to maintain the constant voltage of DFIG. This controller of DVR good to improve fault ride. A combined of a feed-forward and the feedback based DVR provide a better transient response. The controller very simple and provides compensate of harmonic voltage. In Amalorpavaraj et al. [10] gives the farm wind with the DVR to regulate the voltage disturbances like sag/swell. Feed forward controller is utilizing to get the pulses for the PWM. This technique enhances the using of injecting voltage. The Feed Forward and Feedback to the Fault Ride of a DFIG based wind turbine generator delivered in Jerin et al. [11]. The control performance improves by effectiveness of compensation the balanced or unbalanced conditions of fault. The outcomes show a good transient response, steady state and reactive power in different conditions of faults.

7. Conclusion
From the techniques utilize, the grid can have prepared for a large penetration of wind energy to keep power quality of the grid. At first technique shows wind power availability besides the reduction of power and voltage fluctuations. It is renewable stand by energy sources and environmental friendly power. Must this power be reliable to put it into the power grid. Many issues are utilizing to solve the power quality. Using static compensator gives a reduction on the THD. Such information of power
quality problems like flicker, voltage sag/swell and the behavior of STATCOM during the faults. As in Li and Chiang [7] and Yue and Venkatasubramanian [8] voltage stability can increase in case of reactive power uncompensation.

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