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AN OVERVIEW ON POWER QUALITY ISSUES IN WIND ENERGY SYSTEM AND ITS IMPROVEMENT USING STATCOM-BESS

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ABSTRACT: The Renewable Sources such as wind power and solar power are promising energy sources to meet the increasing demand of load day by day. But, when the wind power is injected into the electric grid it affects the power quality of the grid because of varying nature of wind and hence the variable output power. The significant effect on the power quality is the change of active power and reactive power, variation of voltage, flicker, and harmonics in the system, etc. At the point of common coupling a Static Synchronous Compensator (STATCOM) with Battery Energy Storage system (BESS) is an ideal scheme to solve the problems of wind energy generating system. Battery Energy storage system is used to increase the operation mode of STATCOM from two to four modes by providing DC energy source. This paper presents STATCOM-BESS with wind energy system at point of common coupling to mitigate power quality issues.

I. INTRODUCTION

To have sustainable growth and social progress, it is necessary to meet the load demand by utilizing the renewable energy resources like wind, solar, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable energy sources are the key paradigm. We know that the Electrical power is expensive to store. Hence, the power produced at the generating station must be consumed by the load. Therefore, there must be a power balance between all the generating plant and the load demand. Any imbalance would affect the frequency of the system which could lead to loss of synchronism in certain cases. The accomplishment of a power balance between the load and the generating plants is more challenging in the case of wind power generation due to its unpredictable nature especially when the generating ratio is high. A system of high wind power integration would expand the reserve capacity due to the variability of the primary resources. A conventional power plant is expected to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental Impact on conventional plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network [3].
The integration of wind farms and other renewable energy conversion systems on weak distribution grids is a major issue for both the utilities planning offices and independent power plants investors, specially having in mind that the individual group/turbine capacity already surpasses 2 MW and wind farms with a capacity in the range of 150MW. One of the main problems in wind energy generation is the connection of the wind system to the grid. Injection of wind power into the grid affects the power quality of the grid and resulting in poor performance of the system. The wind energy system faces frequently fluctuating voltage due to the nature of wind and introduction of harmonics into the system. Injection of the wind power into an electric grid affects the power quality. [3] In normal operating system we need a control circuit for the active power production. For reducing the disturbance we use a battery storage system. This compensates the disturbance generated by wind turbine. A STATCOM has been proposed for improving the power quality. This STATCOM technically manages the power level associated with the commercial wind turbines. This system produces a proper voltage level having power quality improvements. This system provides energy saving and uninterruptible power [3]. The wind energy system is used to charge the battery as and when the wind power is available. The voltage source inverter is controlled by using thecurrent control mode.

II. OBJECTIVES

- Unity power factor and power quality at point of common coupling bus.
- Real and reactive power support only from wind generator and batteries to load.
- Self-operation in case of grid failure

POWER QUALITY ISSUES

Perfect power quality means that the voltage is continuous and sinusoidal having constant figures of amplitude and frequency. Power quality can be expressed in terms of physical characteristics and properties of electricity. It is most often described in terms of voltage, frequency and interruptions [1].

1. Grid side power quality issues:

The power quality problems in the grid side that affect the WEG (Wind Electric Generator) are mainly concerned with the quality of voltage that is being supplied by the utility [1].
(a) Voltage Variations: Voltage variation has implications on both real and reactive power associated with wind farms. A decreased voltage condition increases the current through the generator, making line losses to increase. Decreasing voltage also affects the power factor as the capacitive VAR generated out of the installed capacitor decrease as voltage decreases.

(b) Frequency Variations: The variation in frequency affects the power generation in WEG to a large extent changing the aerodynamic efficiency. Frequency changes lead to imperfect tip speed ratios and reduced aerodynamic efficiencies [2]. These leads to decrease the energy capture and output power of wind turbines.
(c) Voltage transients: Large transient's voltage could be created due to switching of capacitors using mechanical switches, which are the integral part of WEG for reactive power compensation. These internally generated transients could result in damage to sensitive electronic devices of the WEG control system.
(d) Voltage unbalance: Voltage unbalance is caused due to large unbalanced loads. The unbalance in voltage causes negative sequence currents to flow in induction machines, causing overheating.
2. Wind Energy Generation side power quality issues:
Power quality issues that affect the WEG are mainly concerned with the quality of current that is being drawn or generated by the WEG's [1]
(a) Reactive power consumption: Reactive power consumption in a wind farm is mainly due to the use of induction generators for energy saving. The basic principle of Induction generators is that they consume reactive power to set up the excitation or magnetic field in order to generate real power. This reactive power consumption leads to increased transmission and distribution losses [2].
(b) Generation of current harmonics: Current harmonics are generated due to soft starting of induction generators during motoring mode. This distorts the voltage on the line and affects all the consumers connected to the line.
(c) Injection of fluctuating power: Power in wind by nature is varied and is checked by annual, monthly, daily and hourly variations. This results in generation and supply of a power that is fluctuating and leading to operational problems [1].

III. STATCOM, BESS AND FACTS

1. Basics of FACTS
In power transmission and distribution systems, power electronics-based controllers are commonly named as flexible AC transmission system (FACTS) devices. By facilitating bulk power transfers, these FACTS networks help to build more transmission lines and power generation plants and thereby enhance neighbouring utilities and regions to economically and reliably exchange power. Continual advancements in power electronic technologies are acting to improve the stature of FACTS devices within the bulk power system. This in turn is restructuring the electric utility industry by moving steadily towards a more competitive scenario, in which power is bought and sold as a commodity. However, usually due to cost and lack of systematic control, although several FACTS topologies have been proposed to mitigate these potential problems, transmission service providers are reluctant to install them. The utility providers need to incorporate means of local control to address a number of potential utility problems such as uneven power flow through the system, transient and dynamic instability, sub synchronous oscillations, dynamic overvoltage, and under voltage.
There are numerous topologies of FACTS devices that are discussed in the literature [6]. All of them have certain advantages as well as disadvantages. Among them multilevel-converter-based FACTS has an added advantage of offering improved power quality, decreased switching frequencies, decreased power losses, and minimized stress on individual power-electronics devices. In addition, multilevel converter-based FACTS enable more effective use of BESS. Several multilevel power-electronics topologies have been proposed for FACTS devices. FACTS control scheme for several different types of applications and evaluation has been proposed in the literature. Comparison of several FACTS devices for stability enhancement has been discussed in [6].

2. Integration of Energy Storage Systems into FACTS Devices.
An energy storage system (ESS) can play an important role in power system control [5] and provide significant improvements over traditional STATCOM performance. Battery energy storage systems (BESS) in conjunction with STATCOM have recently emerged as one of the most promising near-term storage technologies for power applications [3]. By the addition of an energy storage system to the STATCOM it has been possible to control the active power flow between the STATCOM and the point of common coupling (PCC). Thus, the STATCOM compensates the reactive power and, in addition, stores energy in the storagesystem when the generated power exceeds the power limits that could be injected to the distribution grid. In addition, this solution provides promotes control of the power flow at the PCC, by adjusting the direction of power injection, such as downwards or upwards.
Recently, a considerable amount of attention has been given to developing control strategies for a variety of FACTS devices, such as static synchronous compensator(STATCOM), the static synchronous series compensator (SSSC), and the unified power flow controller (UPFC), to be able to address and mitigate a wide range of potential bulk power transmission problems. In the absence of energy storage, FACTS devices are limited in the degree of freedom and sustained action in which they can help the power grid. By the method of integration of energy storage system (ESS) into FACTS devices, an independent real and reactive power absorption or injection into and from the grid is possible. This integrated system leads to a more economical and flexible power transmission controller for the power system. When a transmission line experiences significant power transfer variations in an intermittent manner, a FACTS + BESS combination can be installed to regulate and adjust the power flow within the loaded transmission line. The enhanced superior performance of combined FACTS + ESS will have greater appeal to transmission service providers.
Power system deregulation, along with transmission limitations and generation shortage, has changed the power of grid conditions by creating situations where energy storage technology can play a very vital role in maintaining system reliability and power quality.

There are multiple benefits of energy storage devices such as the ability to rapidly damp oscillations, respond to sudden load transients, and continue to supply the load during transmission or distribution interruptions. In addition, this system can correct load voltage profiles with rapid reactive power control, and still allow the generators to balance with the system load at their normal speed. The static synchronous compensator, or STATCOM, is a shunt-connected power electronic converter-based FACTS device. Unlike static var compensator (SVC), the STATCOM does not employ capacitor or reactor banks to produce reactive power.

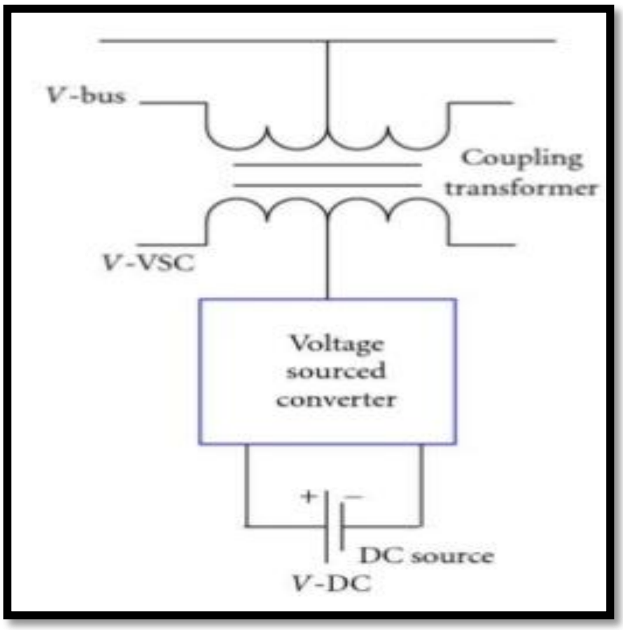

Fig.1 Single line diagram of STATCOM [5]

The major disadvantage of a traditional STATCOM (with no energy storage) is that it has only two possible steady-state operating modes, namely, inductive (lagging) and capacitive (leading). Even though both the traditional STATCOM output voltage magnitude and phase angle can be controlled, they cannot be independently adjusted in steady state due to the lack of significant active power capability of STATCOM. Typically, the STATCOM converter voltage is maintained in phase with the PCC voltage, thus ensuring that only reactive power flows from the STATCOM to the system. However, owing to some losses in the coupling transformer and converter, the converter voltage is generally maintained with a small phase shift with the PCC voltage. Thus, practically, a small amount of real power flows through the system from PCC to DC bus, to compensate for the losses. However, the real power capability of the STATCOM is very limited due to the absence of any energy storage the DC bus. Compared with the traditional STATCOM, the STATCOM + BESS offer more flexibility. In case of STATCOM + BESS, the number of steady-state operating modes is extended to various situations such as inductive mode with DC charge and DC discharge, capacitive mode with DC charge and discharge. Thus, in steady state, the STATCOM + BESS have four operating modes and can operate at every point in the steady-state characteristic circle. In addition, depending on the energy output of the battery or other ESS, the discharge/charge profile is generally sufficient to provide enough energy to stabilize the power regulation in the system and maintain operation until other long-term energy sources are brought into operation. Architecture of connecting BESS with STACOM and control architecture have been shown in Figures 2. One of the drawbacks of FACTS + ESS is that for FACTS integration, the size of the storage systems, particularly battery energy storage (BESS), may be too large for practical use in large-scale transmission-level applications. On certain occasions, large battery systems tend to exhibit voltage instability when numerous cells are placed in series. However, typically it is seen that even large oscillations can be mitigated with modest power injection from a storage system. The ability to independently control both active and reactive powers in STATCOM + BESS makes them ideal controllers for various types of power regulation system applications, including voltage fluctuation mitigation and oscillation damping. Among them, the most important use of the STATCOM + BESS is to stabilize any disturbances occurring in the power system.

3. Application of STATCOM with BESS

STATCOM with storage have several advantages for operation and control of power system [3]. Some of these applications include reactive and active power control, stability enhancement, and system security enhancement, integration of renewable generation, avoidance of new transmission line construction, power flow congestion management, and providing control mechanism for remedial action schemes. Wind power generation is one of the important renewable energy, which need to be controlled given inherent intermittency [2]. Power electronic interface have proven an important facilitator in integrating renewable energy. Due to the high wind power generation penetration into the grid network, the power quality of the wind generator and their continuous long-term operation becomes significantly important. The pulsating nature of the wind turbinetorqueproducesoscillatoryactiveandreactivepower outputs at blade passing frequencies. This oscillatory nature worsens the power quality of the wind farm in terms of voltage fluctuationat the PCC andsometimescausesdamage the generators connected to the network.

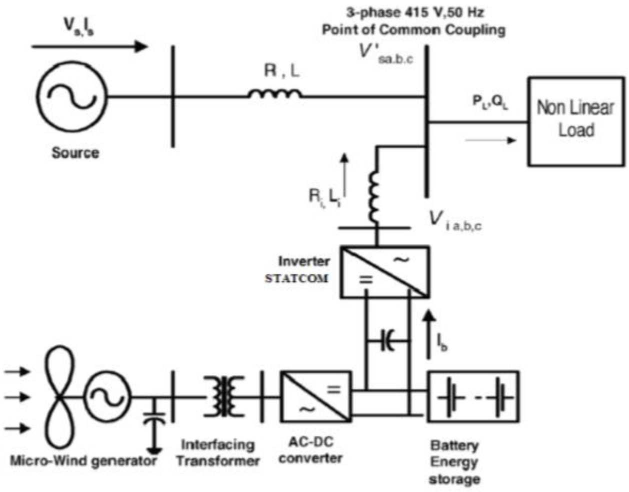

Figure2. Scheme of wind generator with battery storage [4]

During sudden severe disturbances, such as line sag or other fault situations, turbine would transmit less power to the grid. However, due to the imbalance created between the mechanical and electrical power, the speed of the turbine would eventually increase. This increase in speed of the induction generator would result in consumption of more reactive power, which causes the voltage to dip. In such situations, stability can only be retained if the increased generator speed is below the prescribed critical speed limit. Thus, in order to sustains table operation in the event of such fault conditions of the wind farm, reactive power must be supplied externally. Also, with the increasing amount of wind power generation, the wind systems cannot disconnect from the power system in case of any faults but needs to support the grid in case of faults. As a result, many countries are developing grid code requirements to have fault ride through of the wind power systems.The benefit of using a battery in parallel to the wind turbine is that it gives the chance to produce always as much power as possible and store the energy that cannot be injected to the grid. A battery connected to the STATCOM can be the best solution to maximize the power that can be injected in a weak network in a distributed generator (DG) system [5]. The generator can be sized to produce more power than the maximum power because the excessive power can be absorbed by the battery. For a case where this situation will be possible but not probable, the BESS can be used as a dump load to absorb the power.STATCOM can be used for stability enhancement even in offshore wind farms as they are weakly connected. If there is an excess of DG power than the maximum power that can be injected to the power system, then the battery will act to absorb the extra surplus power. On the other hand, if the power consumption is excessive as well, the battery will provide the necessary power. If the battery is fully charged, then a dump load can be used to absorb this excessive power production, while the only solution for excessive consumption will be the limitation of the power. STACOM with storage can be used for low voltage ride through capability and reactive power compensation. There are number of additional examples for using STATCOM with storage for stability enhancement in.

Generally BESS units are designed and installed in existing systems for the purposes of load levelling, stabilizing, and load frequency control. Depending upon the specific application in conjunction with the power system, the optimal installation site and capacity of BESS can be determined. This is widely implemented for load-levelling applications. In addition, the integration of battery energy storage with a FACTS power flow controller can improve the power system operation, regulation, and control. It is quite natural that due to the intermittent nature of wind the active power P-wind generated by the wind power generator always fluctuates. Since active and reactive power is directly related hence the reactive power Q-wind absorbed by the wind power generator unit also fluctuates. There are Different types of Batteries are available in the market. We have to choose from it according to requirements. The Comparison between various types of batteries is shown below.

Table 1: Comparison Between Different Types of batteries

Parameter	Lead acid	Nickel cadmium	Sodium sulphur	Lithium ion	Sodium nickel chloride
Achieved/demonstrated Upper limit power	Multiple tens of MW	Tens of MW	MW scale	Tens of KW	Tens/low hundreds of kW
Specific energy (Wh/kg)	35 to 50	75	150 to 240	150 to 200	125
Specific power (W/kg)	75 to 300	150 to 300	90 to 230	200 to 315	130 to 160
Life Cycle	500 to 1500	2500	2500	1000 to 10000+	2500+
Charge/discharge energy efficiency (%)	80	70	Up to 90	95	90
Self-discharge	2 to 5% per month	5 to 20% per month	-	1 % per month	-

IV. CONCLUSION

This paper is focused on power quality issues when wind energy system is integrated with existing power system. Reviews of the benefits of using STATCOM in conjunction with battery energy storage systems are discussed. The importance and technical significance of BESS with STATCOM is elaborated here. Advantages of using BESS in connection to STATCOM in the power system for minimizing the transient dynamics, and to improve power quality of power system is discussed in this paper. It should also be noted that in this study the STATCOM provides a real power flow path for battery, but the operation of the battery is independent of the STATCOM controller. While the STATCOM is controlled to absorb or inject reactive power, the battery is controlled to absorb or inject real power.

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