STATCOM CONTROL SCHEME FOR GRID CONNECTED WIND ENERGY SYSTEM FOR POWER QUALITY IMPROVEMENT

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Abstract — In this paper, The influence of the wind turbine in the gridsystemconcerningthepowerqualitymeasurementsare-theactivepower, reactive power, variation of voltage,flicker,harmonics,andelectricalbehaviorofswitchingoperationandthesearemeasuredaccordingtonational/internationalguidelines.Thepaperstudydemonstratesthepowerqualityproblemduetoinstallationofwindturbine withthegrid.InthisproposedschemeSTATicCOMpensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage isintegratedtosustaintherealpowersourceunderfluctuatingwindpower. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented.

INTRODUCTION

A STATCOM-based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. The proposed STATCOM control scheme for grid connected wind energy gen-eration for power quality improvement has following objectives.

- Unity power factor at the source side.
- Reactive power support only from STATCOM to wind Generator and Load.
- Simple bang-bang controller for STATCOM to achieve fast dynamic response.
- In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. The basic applications of FACTS-devices are:
- • Power flow control,

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Vol-12 Issue-01 No.01: 2022

- • Increase of transmission capability,
- • Voltage control,
- • Reactive power compensation,
- • Stability improvement,
- • Power quality improvement,
- • Power conditioning,
- • Flicker mitigation,
- • Interconnection of renewable and distributed generation and storages.
- Figure 1.1 shows the basic idea of FACTS for transmission systems. The usage of lines for active power transmission should be ideally up to the thermal limits. Voltage and stability limits shall be shifted with the means of the several different FACTS devices. It can be seen that with growing line length, the opportunity for FACTS devices gets more and more important.
- The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second.

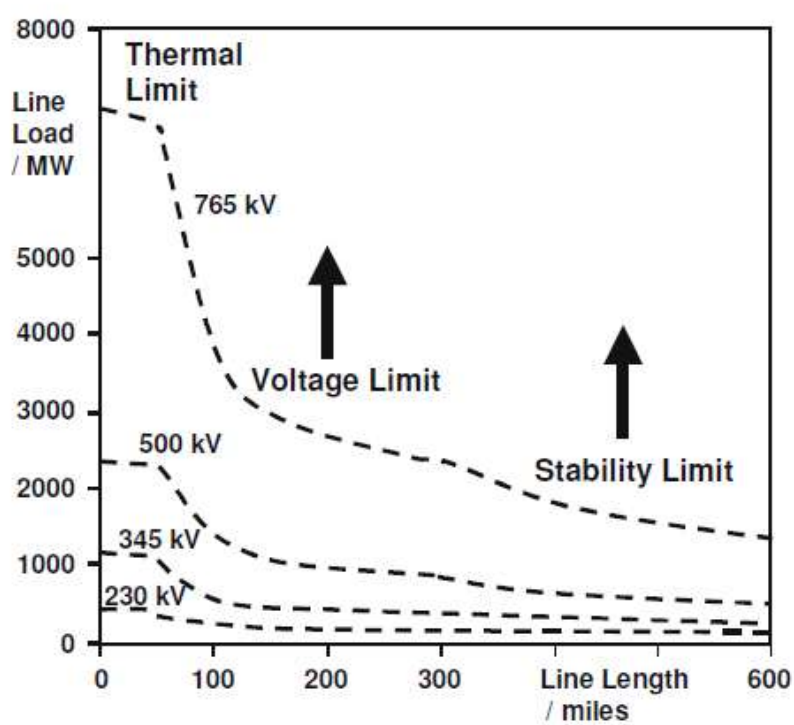


Fig. 1.1. Operational limits of transmission lines for different voltage levels

- The development of FACTS-devices has started with the growing capabilities of power electronic components. Devices for high power levels have been made available in converters for high and even highest voltage levels. The overall starting points are network elements influencing the reactive power or the impedance of a part of the power system. Figure 1.2 shows a number of basic devices separated into the conventional ones and the FACTS-devices.

- For the FACTS side the taxonomy in terms of 'dynamic' and 'static' needs some explanation. The term 'dynamic' is used to express the fast controllability of FACTS-devices provided by the power electronics. This is one of the main differentiation factors from the conventional devices. The term 'static' means that the devices have no moving parts like mechanical switches to perform the dynamic controllability. Therefore most of the FACTS-devices can equally be static and dynamic.

I. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. *International Electro Technical Commission Guidelines*

The guidelines are provided for measurement of power quality of wind turbine. The International standards are de- veloped by the working group of Technical Committee-88 of the International Electro-technical Commission (IEC), IEC standard 61400-21, describes the procedure for determining the power quality characteristics of the wind turbine [4].

The standard norms are specified.

1) IEC 61400-21: Wind turbine generating system, part-21. Measurement and Assessment of power quality character-istic of grid connected wind turbine

2) IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.

3) IEC 61400-3-7: Assessment of emission limit for fluctu- ating load IEC 61400-12: Wind Turbine performance.

The data sheet with electrical characteristic of wind turbine provides the base for the utility assessment regarding a grid connection.

B. *Voltage Variation*

The voltage variation issue results from the wind velocity and generator torque. The voltage variation is directly related to real and reactive power variations. The voltage variation is commonly classified as under:

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.

- Long duration voltage variation.

The voltage flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz. The IEC 61400-4-15 specifies a flickermeter that can be used to measure flicker directly.

C. *Harmonics*

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribu- tion, as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current com- pared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

D. *Wind Turbine Location in Power System*

The way of connecting the wind generating system into the power system highly influences the power quality. Thus the op- eration and its influence on power system depend on the struc- ture of the adjoining power network.

II. PERFORMANCE

The proposed control scheme is simulated using SIMULINK in power system block set. The system parameter for given system is given Table I.

The system performance of proposed system under dynamic condition is also presented.

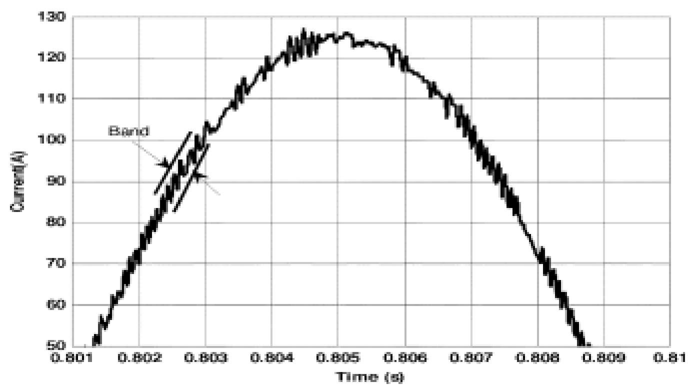
A. *Voltage Source Current Control—Inverter Operation*

The three phase injected current into the grid from STATCOM will cancel out the distortion caused by the non- linear load and wind generator. The IGBT based three-phase inverter is connected to grid through the transformer. The gen- eration of switching signals from reference current is simulated within hysteresis band of 0.08. The choice of narrow hysteresis band switching in the system improves the current quality. The control signal of switching frequency within its operating band, as shown in Fig. 4.

The choice of the current band depends on the operating voltage and the interfacing transformer impedance. The com- pensated current for the nonlinear load and demanded reactive power is provided by the inverter. The real power transfer from

B. STATCOM—Performance Under Load Variations

The wind energy generating system is connected with grid having the nonlinear load. The performance of the system is measured by switching the STATCOM at time $t = 0.7$ s in the system and how the STATCOM responds to the step change command for increase in additional load at 1.0 s is shown in the simulation. When STATCOM controller is made ON, without change in any other load condition parameters, it starts to mitigate for reactive demand as well as harmonic current. The dynamic performance is also carried out by



step change in a load, when applied at 1.0 s. This additional demand is fulfill by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The result of source current, load current are shown in Fig. 6(a) and (b) respectively. While the result of injected current from STATCOM are shown in Fig. 6(c) and the generated current from wind generator at PCC are depicted in Fig. 6(d).

The DC link voltage regulates the source current in the grid system, so the DC link voltage is maintained constant across the capacitor as shown in Fig. 7(a). The current through the dc link capacitor indicating the charging and discharging operation as shown in Fig. 7(b)

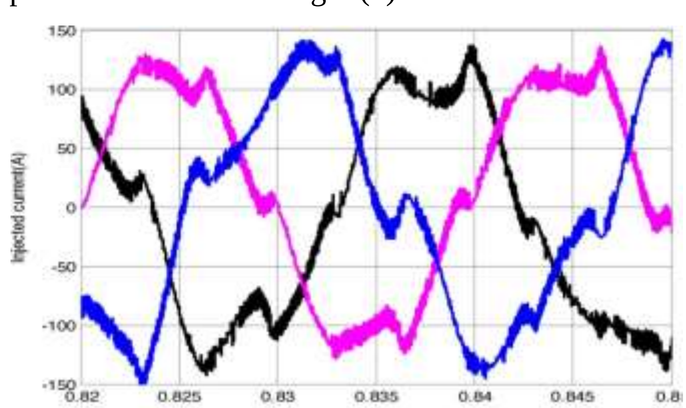


Fig. . Three phase injected inverter Current.

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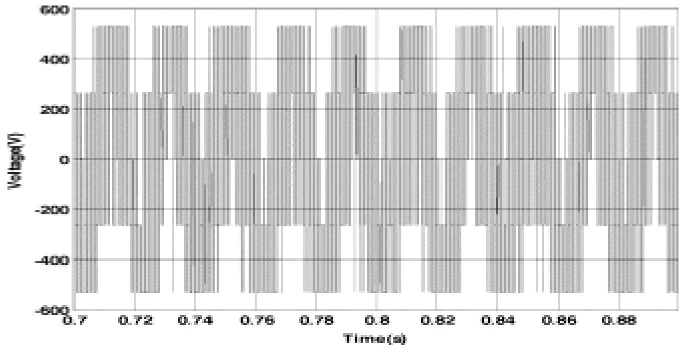

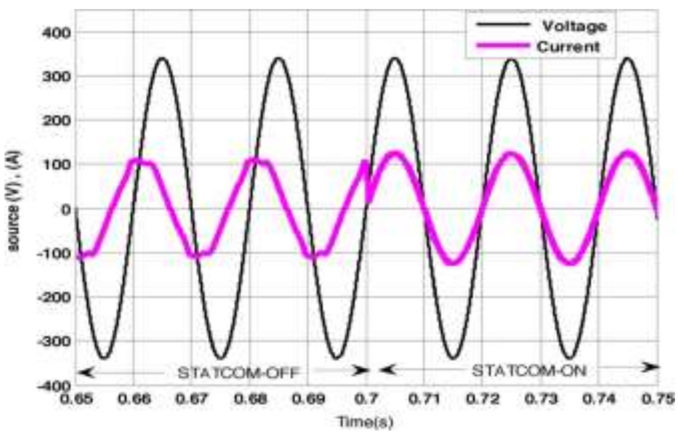

C. *Power Quality Improvement*

It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system. The inverter output voltage under STATCOM operation with load variation is shown in Fig. 8. The dynamic load does affect the inverter output voltage. The source current with and without STATCOM operation is shown in Fig. 9. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation. The current waveform before and after the STATCOM operation is analyzed. The Fourier analysis of this waveform is expressed and the THD of this source current at PCC without STATCOM is 4.71%, as shown in Fig. 10.

The power quality improvement is observed at point of common coupling, when the controller is in ON condition. The STATCOM is placed in the operation at 0.7 s and source current waveform is shown in Fig. 11 with its FFT. It is shown that the THD has been improved considerably and within the norms of the standard.

The above tests with proposed scheme has not only power quality improvement feature but it also has sustain capability tosupport the load with the energy storage through the batteries.

CONCLUSION

In this paper, The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and STATCOM with BESS have shown the outstanding per- formance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard61400-21.

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