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Analysis of Various Power Quality Issues of Wind/Solar System – A Review

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ABSTRACT

This paper presents a review on grid Integration and power quality issues associated with the integration of renewable energy systems in to grid and Role of power electronic devices and Flexible AC Transmission Systems related to these Issues. In this paper, recent trends in power electronics for the integration of wind and photovoltaic (PV) power generators are presented. Discussions about common and future trends in renewable energy systems based on reliability and maturity of each technology are presented. Classification of various Power Quality Issues used by different researchers has been done and put for reference. Application of various techniques as applied to mitigate the different Power Quality problems is also presented for consideration. Power Electronics interface not only plays a very important role in efficient integration of Wind and Solar energy system but also to its effects on the power-system operation especially where the renewable energy source constitutes a significant part of the total system capacity.

However there are various issues related to grid integration of RES keeping in the view of aforesaid trends it becomes necessary to investigate the possible solutions for these issues.

KEYWORDS: *Renewable Energy System, Doubly Fed Induction Generator (DFIG), Multilevel Converter Topologies, Power Quality (PQ), Grid Connected PV, Grid Connected Wind, FACTS Devices*

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I. INTRODUCTION

Renewable energy resources (RES) like solar and wind are going to become alternative for future energy needs. India is a country of continental size and this is helpful in balancing the variable output of renewable energy sources located in few states by integrating them into all India grids. As on March 31, 2012 the grid interactive power generation from RES is 24914 MW i.e. around 12.1 % of the total installed energy capacity. Further Ministry of New and Renewable Energy (MNRE), Government of India is targeting to achieve 20000 MWgrid

Interactive powers through solar and 38500 MW from wind by 2022. Wind energy and Solar energy, are considered to be the main attributes of renewable energy for electricity generation, and are growing at faster rate for the last two-three decades. Renewable generation from wind and solar has increased substantially during past few years and forms a significance proportion of the total generation in the grid. According to the annual report of the Global Wind Energy Council (GWEC), over 40 GW of new wind power generation capacity came on line worldwide in2011 attracting more than $68 billion. This brings the total global wind power capacity to over 238 GW through the end of 2011 as shown in Fig. 1. This indicates that there is huge and growing global demand for missions-free wind power which can be installed quickly and virtually everywhere in the world. Electricity generation using renewable resources is often taking place in small scale due to disperse nature of the recourses. The size of these generators typically varies from a few hundreds of kilowatts to several megawatts. The types of grid interfaces used with Photovoltaic's and Wind are Power electronics converter & Induction generator/ Power electronics converter. In this paper, recent ongoing trends in grid integration of solar and wind energy system is presented. This paper is organized as follows. In Section II, It is discuss about the current technology used in grid integration of renewable energy system like current wind turbine technology and PV technology. And a different integration issue has been discussed in this section which was presented by different researchers. Section III, is related to power quality issues here discuss different power quality problems like voltage regulation, voltage sag/swell, harmonics, real and reactive power has been discuss. And here the application of facts devices related power quality issues also presented. Section IV is about different issues and challenge related to grid integration and power quality problems of solar and wind energy system. In section V possible solution related to these grid integration and PQ issues and has been discussed.

II. INTEGRATION OF RENEWABLE ENERGY SYSTEMS

In this paper a literature review is carried out related to grid integration of RES. Number of authors/researchers has presented the various issues, challenges and their possible solutions related to grid integration of renewable energy system, mainly wind and solar energy system.

A. Wind Turbine Technology Review

Wind-turbine technology has undergone a dramatic transformation during the last 15 years, developing from a fringe science in the 1970s to the wind turbine of the2000s using the latest in power electronics, aerodynamics, and mechanical drive train designs [1], [2].Wind power is quite different from the conventional electricity generation with synchronous generators. Moreover, an introduction of variable speed turbine in the wind-power market is advantageous our conventional turbines. The advantages of variable-speed turbines are that their annual energy capture is about 5% greater than the fixed-speed technology, and the active and reactive powers problems can also be easily handled. There is also less mechanical stress, and rapid power fluctuations are scarce because the rotor acts as a flywheel (storing energy in kinetic form).The main disadvantage of variable-speed wind turbines that it need a power converter that increases the component count and make the control more complex. The overall cost of the power electronics is about 7% of the whole wind turbine.

1. Variable-speed concept utilizing doubly fed induction generator (DFIG)

The converter feeds the rotor winding, while the stator winding is connected directly to the grid in a variable-speed turbine with DFIG [3], [4]. This converter decoupling mechanical and electrical frequencies and thus making variable-speed operation possible. This turbine cannot operate in the full range from zero to the rated speed, but the speed range is quite sufficient. In addition to the fact that the converter is smaller, the losses are also lower. The control possibilities of the reactive power are similar to the full power-converter system. For instance, the Spanish company Gamesa supplies this kind of variable-speed wind turbines to the market. The forced switched power-converter scheme is shown in Fig. 1

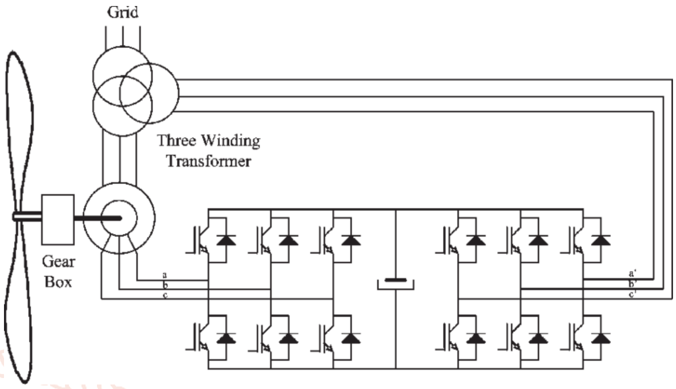

Fig. 1: Single Doubly Fed Induction Machine with Two Fully Controlled AC–DC Power Converters

2. Variable-Speed concept utilizing full-power converter

In Variable-Speed concept, the generator is completely decoupled from the grid [5]. Fig. 2 shows the scheme of a full power converter for a wind turbine. The energy from the generator is rectified to a dc link and after is converted to suitable ac energy for the grid. The majority of these wind turbines are equipped with a multiple synchronous generator, although it is quite possible (but rather rare) to use an induction generator and a gearbox. There are many advantage of removing the gearbox: lower losses, lower costs due to the elimination of this expensive component, and increased reliability due to the elimination of rotating mechanical components. Enercon supplies such technology. In this scheme the machine-side three-phase converter works as a driver controlling the torque generator, using a vector control strategy. The grid-side three-phase converter permits wind-energy transfer into the grid and enables to control the amount of the active and reactive powers delivered to the grid. There are several benefits of this scheme such as total-harmonic-distortion (THD) coefficient as low as possible, improving the quality of the energy injected into the public grid. The objective of the dc link is to act as energy storage, so that the captured energy from the wind is stored as a charge in the capacitors and may be instantaneously injected into the grid. The control signal is set to maintain a constant reference to the voltage of the dclink Vdc.

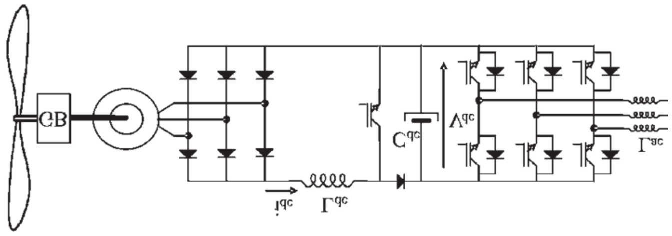

Fig. 2: Double Three-phase VSI

3. Variable-Speed concept utilizing permanent magnet synchronous generator (PMSG)

Figure 3 shows the block diagram of PMSG Wind energy conversion system (WECS) with two stages as optimization and electrical controllers. The various techniques are discussed as below.

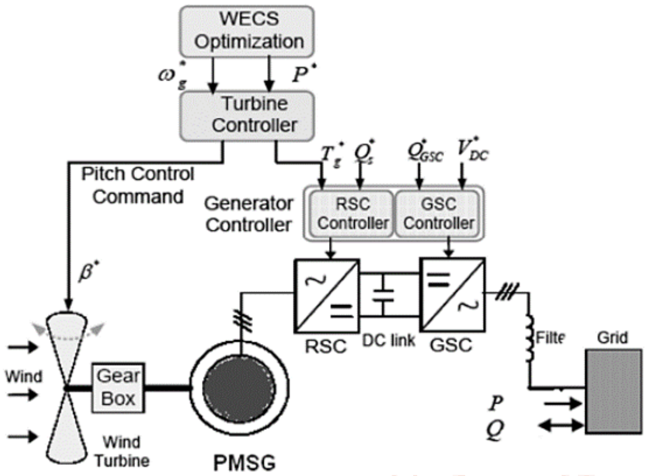

Fig. 3: Control Block Diagram of PMSG based WECS

A novel control scheme using a variable frequency transformer (VFT) of 100 MW to effectively reduce power fluctuations of an equivalent SO-MW aggregated doubly-fed induction generator (DFIG)-based offshore wind farm (OWF) connected to an onshore 120-kV utility grid is presented [14]. A frequency-domain approach based on a linear zed system model using eigen techniques and a time-domain scheme based on a nonlinear system model subject to disturbance conditions are both performed to examine the effectiveness of the proposed control scheme. It can be concluded from the simulation results that the proposed VFT is effective to smooth the fluctuating active power of the OWF injected into the power grid while the damping of the studied OWF can also be improved. A new control strategy for a grid connected doubly fed induction generator (DFIG)-based wind energy conversion system (WECS) is presented [15]. Control strategies for the grid side and rotor side converters placed in the rotor circuit of the DFIG are presented along with the mathematical modeling of the employed configuration of WECS. Battery energy storage system (BESS) to reduce the power fluctuations on the grid due to the varying nature and unpredictability of wind is also presented. This strategy is simulated in MATLAB/SIMULINK and the developed model is used to predict the behavior.

B. PV Technology Review

Nowadays renewable energy techniques for power production are mature and reliable. The photovoltaic (PV) energy is the most promising source of energy since it is pollution free and abundantly available everywhere in the world. PV energy is especially beneficial in remote sites like deserts or rural zones where the difficulties to transport fuel and the lack of energy grid lines make the use of conventional resources impossible.

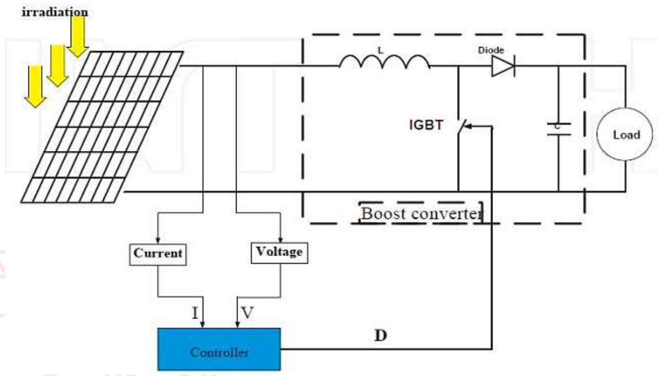

Fig. 4: Unified Diagram of PV System

Unified diagram of PV system is in fig 4 In the literature [18] numerous MPPT methods have been presented, such as the hill climbing, incremental conductance and the P&O. These algorithms consist of introducing a crisp values positive or negative (decrease or increase) all around the actual photovoltaic generator(PVG) operating point. From the previous power point position, the trajectory of the new one helps the algorithm to decide on the command output value. This algorithm may fail to act as an accurate MPPT because of the used crisp value (step size) that is mainly fixed by trial and tests running. Scheme to reduce harmonic current for grid connected PV generation system was developed. This control scheme effectively reduced harmonic current in the grid current of the PV generation system caused by voltage distortions at the grid. Experiments using a prototype of the power conditioning system (PCS) show edits validity. 400 kW PCSs with the control scheme have been installed and have been in service since the end of2009. In this project, three control methods were developed such as generation power control for fault ride through harmonic current reduction control scheme and grid voltage stabilization using optimal reactive power control. A high performance harmonic current reduction control scheme has been presented. The distributed generation systems that impose new requirements for the operation and management of the distribution grid, especially when high penetration levels are achieved [20]. In this paper an improved structure of power conditioning system (PCS) for the grid integration of PV solar systems is presented. The topology employed consists of a three-level cascaded Z-source inverter and allows the flexible, efficient and reliable generation of high quality electric power from the PV array. Validation of models and control schemes is carried out through digital simulation using Matlab/Simulink environment. A novel control strategy for achieving maximum benefits from these grid-interfacing inverters when installed in 3-phase 4-wire distribution systems is presented [21]. The inverter is controlled to perform as a multi-function device by incorporating active power filter (APF) functionality. The inverter can thus be utilized as:

1) Power converter to inject power generated from RES to the grid, and 2) shunt APF to compensate current unbalance, load current harmonics, load reactive power demand and load neutral current. All of these functions may be accomplished either individually or simultaneously. With such a control, the combination of grid-interfacing inverter and the 3-phase 4-wirelinear/non-linear unbalanced load at point of common coupling appears as balanced linear load to the grid. This new control concept is demonstrated with extensive MATLAB/Simulink simulation studies and validated through digital signal processor-based laboratory experimental results.

III. POWER QUALITY ISSUES

The integration of wind and solar energy into existing power system presents technical challenges such as voltage regulation, flicker, harmonic distortion, stability etc, these power quality issues are to be confined to IEC and IEEE standards. A review of many papers of last few years shows that these power quality issues can occur at the generation, transmission and distribution. The different power quality problems has been discussed in different papers and some of them is given below

A. Voltage Regulation

The droop characteristics are used, particularly for DFIGs to control the voltage magnitude and frequency [26]. This can be extended to WECS by doing a voltage sensitivity analysis to achieve voltage regulation at PCC. The high DC bus ripple is a result of the voltage-drive mode to provide the best AC power quality [27] and concludes that the bidirectional power flow and the bottom-up decentralized control methods make DG systems are well controlled and organized. To overcome this problem in [28] author focuses on the grid-interfacing architecture, with fuzzy logic controllers to improve voltage quality. For wind generators is landed micro grid. Here, the complex power droop the unbalances control systems use a virtual impedance loop to compensate.

B. Voltage Sags/ Swells

The operation of Sensitive loads connected to the grid is influenced by the voltage dips. To overcome this disadvantage author presented power electronic converter in [29] using a series compensator, which requires considerably less active power and is able to restore the voltage at the load side. Grid-interfacing power quality compensator for three-phase four-wire micro-grid applications was developed using the sequence components to inject voltages as a complementary measure Under the Net-metering scenario a Power Quality Control Center (PQCC) would regulate voltage due to the reversal of power flows from the DG and the increase in short circuit current [30].

C. Harmonics

The grid interaction and grid impact of wind turbines have been focused on during the past few years. The reason behind this interest is that wind turbines are among the utilities considered to be potential sources of bad power quality. Especially, variable-speed wind turbines have some advantages concerning flicker. But, a new problem arose with variable-speed wind turbines. Modern forced-commutated inverters used in variable-speed wind turbines produce not only harmonics but also inter harmonics. The International Electro technical Commission (IEC) initiated the standardization on the power quality for wind turbines in 1995 as part of the wind-turbine standardization in TC88, and ultimately 1998IEC issued a draft IEC-61400-21 standard for "power quality requirements for Grid Connected Wind Turbines"[31]. Recently, high-frequency (HF) harmonics and inter harmonics are treated in the IEC 61000-4-7 and IEC61000-3-6 [32], [33]. The methods for summing harmonics and inter harmonics in the IEC 61000-3-6 are applicable to wind turbines. In order to obtain a correct magnitude of the frequency components, the use of a well-defined window width, according to the IEC 61000-4-7, Amendment 1, is of a great importance, as has been reported in [34]. In [35] author introduces a new Adaptive Notch Filtering (ANF) approach which can address issues like, extracting harmonics, voltage regulation, complex power control, suppressing frequency variations and noise contents using the sequential components of voltages as reference. Some methods for harmonic damping are presented in [36] such as (i) a shunt harmonic impedance method adaptable for islanded micro-grids application, (ii)The voltage-based droop control strategy to have controllable harmonic current and PQ (iii) heuristic Optimization techniques such as differential evolution algorithm (DEA) are used to obtain the switching states of CPDs, as a nonlinear optimization problem.

D. Real and Reactive Power

The seasonal patterns and the diurnal variations of wind are to be addressed for grid connected wind turbine (GCWT) systems to achieve high-quality power from inverters meeting the specifications of grid codes. A droop control method is proposed based on the reactive power produced by the negative-sequence current and the positive-sequence line voltage [37]. A variant of the droop control strategy is used in [38], which combines P/V droop control with voltage droops to control the active power. A Lyapunov-function-based current tracking controller is proposed to control both active and reactive power flow for parallel-connected inverter. The THD levels were found satisfactory even for nonlinear loads.

IV. ISSUES AND CHALLENGES

Renewable energy sources are intermittent in nature hence it is therefore a challenging task to integrate renewable energy resources into the power grid. Some of the challenges and issues associated with the grid integration of various renewable energy sources particularly solar photovoltaic and wind energy conversion systems. Further these challenges are broadly classified into technical and non-technical and described below.

A. Technical Issues

1. Gird Integration Issues for small scale generation:

- Cost, Reliability & Efficiency of Grid Interface
- Grid congestion, weak grids
- Variability of renewable production
- Low Power Quality
- Protection issues
- Change of short circuit levels
- Reverse power flow
- Lack of sustained fault current
- Islanding
- Bidirectional power flow in distribution network,
- localized voltage stability problems

2. Issues related to grid integration of large scale generation:

Recent rapid growth of wind energy generation has resulted in the development of large wind farms with capacities in excess of 100 MW. Such large scale wind farms are generally interconnected to the grid.

- The requirement of reactive power for voltage support is one the key issues related to wind power generation.
- Turbine power electronic design and controller optimization.
- Problems of wind farms connected into series compensated systems.
- Power quality issues including voltage flicker.
- Starting and synchronizing of wind farms to the grid.
- Sub synchronous resonance issues due to interaction of the electric network and the complex shaft/gear system of the wind turbine

B. Non-Technical Issues

1. Lack of technical skilled man power
2. Less availability of transmission line to accommodate RES.
3. RES technologies are excluded from the competition by giving them priority to dispatch which discourage the installation of new power plant for reserve purpose.

V. CONCLUSION

In this paper, grid integration and power quality issues of Wind and Solar energy System and their possible solutions available in the literature have been presented. The causes, affects, mitigation technologies featuring their topologies, highlighting the advantages of the grid integrated solar and particularly wind power systems are examined. To minimize the fluctuations and intermittent problems power electronics devices are the viable options. Further, energy storage and use of dump load and MPPT could be used for reducing the power fluctuations in PV systems. In addition to the aforesaid, the up gradation in balance of systems by incorporating the new materials and storage elements could reduce the problems associated with grid integration. The cost effective solutions of custom power devices and FACTS devices are highlighted to give an insight to the scope of research in low and medium level voltage networks and for 1Ø and 3Ø grids technologies.

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