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Issues, Challenges, Causes, Impacts and Utilization of Renewable Energy Sources - Grid Integration

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ABSTRACT
The renewable energy sources have increased significantly due to environmental issues and fossil fuels elevated cost. Integration of renewable energy sources to utility grid depends on the scale of power generation. Large scale power generations are connected to transmission systems where as small scale distributed power generation is connected to distribution systems. There are certain challenges in the integration of both types of systems directly. Due to this, wind energy has gained a lot of investments from all over the world. However, due to the wind speed's uncertain behavior it is difficult to obtain good quality power, since wind speed fluctuations reflect on the voltage and active power output of the electric machine connected to the wind turbine. Solar penetration also changes the voltage profile and frequency response of the system and affects the transmission and distribution systems of utility grid. This paper presents a review in the issues, challenges, causes, impacts and utilization of renewable energy sources (RES) - Grid Integration.
Keywords - Wind energy, solar energy, Grid integration, Power Quality, Distributed Generation, etc

I. INTRODUCTION

In power system most of the complexities occur due to the interconnections of different types of generator, transmission line, transformer, and load. After some small disturbance stability is affected by the loading effect of transmission line [1]. Distributed Generation (DG), is used to minimize the loading effect of transmission line, the recent trend of distribution network service providers is to introduce significant generation at distribution level. Integration of DG causes bi-directional power flow [2], [3] which reduces the capacity of feeder and transmission line [4]. The other benefits of distributed generation include the reduction of power loss, better voltage support, peak shaving [5], [6], and the improvement of overall efficiency, stability and reliability [7], [8]. Micro grid is an important auxiliary part of the distribution system proposed in America by the consortium for electrical reliability technology solutions (CERTS) [9]. They consists of some micro sources and loads [10] which can operate in both islanded and grid connected mode [9]. The advantages of micro-grid systems are flexible installation and the control active and reactive power separately [11]. RES are used as distributed generation in micro-grid. Major advantages of RES are: sustainability, less maintenance cost, low operation cost [12], environmental friendly [13], reduction of greenhouse gas emission [14], reduction of pollution [15], etc. Renewable energy penetration not only affects the local market price, but also reduces the electricity price of adjacent interconnected systems [16]. RES increases the consistency of the system by Low percentage [17], but difficulty arises due to the high penetration of renewable generation into the grid. Several renewable energy sources are used to generate electrical power, such as wind energy, photovoltaic energy, wave energy, tidal energy, thermal energy, bio-mass energy, etc.

II. CAUSES OF LOW POWER QUALITY:

Due to the high penetration level of wind energy in distribution systems, the utility is concerned, as it may pose a threat to network is terms of Power Quality (PQ) issues, voltage regulation and stability. DG systems are required to comply with strict technical and regularity frameworks to ensure safe, reliable and efficient operation of overall network.[18] The random nature of wind resources, in the wind farm generates fluctuating electric power. These fluctuations have a negative impact on stability and power quality in electric power systems. [3] Due to the wind disturbances (mech. speed), the wind farm active (reactive) power injected (demanded) into the power grid, leading to variations of wind farm terminal voltage because of system impedance. This power disturbance propagates into the power systems and can produce a phenomenon known as "flicker", which consists of fluctuations in the illumination level caused by voltage variations. Also the normal operation of wind farm is impaired due to such disturbances as shown in following Fig.1.

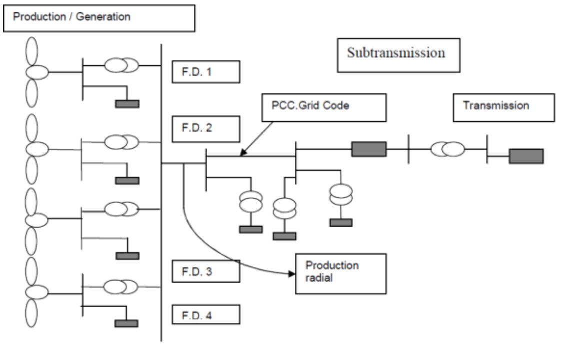

Fig.1. Grid Connection of a Wind Farm

[4] For large wind farms, Low voltage ride through (LVRT) is now required in most power systems. Although variable speeds wind turbines are dominant technology. Now days, fixed speed wind turbines still retains a sizeable market shares as the simplest wind turbine. [5] Integrating these large numbers of wind farms into the power system within this short time span leads to serious challenges for the grid operators in order to stay in compliance with the regularity and legal framework. [6] Large scale integration of DG units in the distributed grid not only affects the grid planning but also has an impact on the operation of the distribution grid such as voltage control, power quality, protection system, fault level and grid losses. The power flow in the distribution grid as well as the grid losses and voltage control are affected. The effect of the integration of the DG on power quality concerns three major aspects. 1) Dips and Steady state voltage rise 2) Voltage flicker 3) Harmonics. Inverter connected DG units might cause harmonics. The magnitude and order of the harmonic currents depends on the technology of the converter and mode of operation. The injection of harmonics current can distort the voltage waveforms which can propagates through the grid. [19-20] Integration of renewable energy systems to the grid takes place through power electronics converters. There is increase in total harmonics distortion (current) with number of grid connected induction generators. A sharp increase is seen in reactive power requirements from grid when machines are switched in simultaneously. Higher current harmonics distortion is seen in the lines which are lightly loaded. Therefore there is necessity to keep the load perfectly balanced. Power factor, also drops significantly with more number of induction generators connected to grid. [21] Voltage swell is caused by system faults, load switching and capacitor switching and voltage sags caused by faults, increased load demand, etc. [22] - [23] under unsymmetrical voltage dip the Double fed induction generators behavior is studied. Instead of the large transient rotor current caused by the symmetrical voltage dip, the large electric torque pulsation and dc voltage ripple in back to back VSCs are identified as the most severe problems of DFIG under unsymmetrical voltage dip. [24] The variable speed wind turbines 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. [25] Grid connection brings problems of voltage fluctuations and harmonic distortion. [26] Both during grid faults and in normal conditions, active power control will play an important role. [27] Regulators based on symmetrical components are well suited to control grid connected converters. [27-28] with increase in number of grid connected induction generators in the circuit, reactive power consumption increases. There is increase in total harmonic distortion (current) with number of grid connected induction generators, hence there is need to compensate this effect, has the number of induction machines increases in the circuit.

III. ISSUES OF RENEWABLE ENERGY SOURCES SYSTEMS – GRID INTEGRATION

3.1 WIND ENERGY SYSTEM

Due to availability of wind renewable energy sources abundantly, wind energy generation is increasing day by day [13], [29] to develop rural electrification, increase job opportunities in technology [30]. But there are some limitations to the penetrating of wind energy into the grid. Wind speed forecasting has high uncertainty, high volatility and low predictability [12], [31] reduces the system security [32] and wind revenue [33]. Problem in maintaining voltage profile [34]–[36]. Most of the wind turbines are coupled with SCIG [37], which are not able to support reactive power within the system. More stress on breaker, transmission line, bus bar at the time of fault occurs, due to high penetration of wind energy resources [15], [38] due to low fault ride-through (FRT) capability of wind generator [39], [40]. High penetration of wind energy creates stability problem, and possible blackouts [12], [35] thus wind energy penetration is limited by ATC (available transfer capability) of the system [29]. Frequency behavior of the system also changes with wind penetration [34], [35], [40] due to lower inertia of distributed wind generators [41]. Finally, wind energy penetration reduces overall efficiency and power quality [15], [35].

From the design perspective it is found that some generators are directly connected to the grid through a dedicated transformer while others incorporate power electronics, many designs, however, include some level of power electronics to improve controllability and operating range. [42] shows that the impact of the yaw error and horizontal wind shear on the power (torque) and voltage oscillations over the tower shadow and vertical wind shear effects. [43] A literature survey [44] of the new grid codes adopted for the problems of integrating large amounts of wind energy to the electric grid. By the above survey it shows that, the new wind farms must be able to provide voltage and reactive power control, frequency control and fault ride through capability in order to maintain the electric systems stability, For the existing wind farms with variable speed, double-fed induction generators (DFIG) and synchronous generators (SG), a frequency response in the turbine control system can be incorporated by a software upgrade. Wind farms with fixed speed induction generators (FSIG) have to be phased out because they cannot offer the required voltage or frequency control. An overview of the developed controllers for the converter of grid connected system [45] shows that, DFIG has now the most efficient design for the regulation of reactive power and the adjustment of angular velocity to maximize the output power efficiency. These generators can also support the system during voltage sags. However, the drawbacks of converter-based [46] systems are harmonic distortion injected into the system. Anti islanding is one of the important issues for grid connected DG systems, major challenge for the islanding operation and control schemes is the protection coordination of distribution systems with bidirectional flows of fault current. This is unlike the conventional over-current protection for radical system with unidirectional flow of current. Therefore extensive research is being carried out on the overview of the existing protection techniques with islanding operation and control, for preventing disconnection of DGs during loss of grid, as discussed in [47].

3.2 SOLAR ENERGY SYSTEM

The huge amount of solar energy is available on the earth. Humans consume almost 15 TW of solar energy [48]. Customers are interested in solar power due to low cost, environment friendly [49], flexible installation and no reactive power consumption by solar panel. But constraints of solar generation are: high installation cost of solar panels [50], low generation capacity [4], uncertainty of solar irradiance [51], and power fluctuation due to intermittency behavior of sunlight [52]. Solar penetration also changes the voltage profile and frequency response of the system [2], [3]. PV system is designed with unity power factor and the characteristics of output power are dependent on the inverter [53]. There is no LVRT (Low voltage-ride through) capability and it does not contribute at the time of fault or any transient condition of the system [4]. Since photovoltaic system has no inertia, some extra devices are required to maintain frequency oscillation [53].

Generation size of solar cell is small. In practical, solar panel is distributed all over the system (like small solar panel in every house). A photovoltaic system supplies the real power to the system and does not consume any reactive power. [54] examined cloud transient effects if the PV were deployed as a central-station plant, and it was found that the maximum tolerable system level penetration level of PV was approximately 5%, the limit being imposed by the transient following capabilities (ramp rates) of the conventional generators. [55] the operating experience of the Southern California Edison central-station PV plant at Hesperia, CA, suggests that this plant had a very ‘‘stiff’’ connection to the grid and represented a very low PV penetration level at its point of interconnection. [56] Voltage regulation issues on the Public Service Company of Oklahoma system during the passage of clouds over an area with high PV penetration levels, if the PV were distributed over a wide area. At penetration levels of 15%, cloud transients were found to cause significant but solvable power swing issues at the system level, and thus 15% was deemed to be the maximum system level penetration level.

A European consortium called distributed generation with high penetration of renewable energy sources (DISPOWER) that includes universities, research institutes, manufacturers, and representatives of several segments of the utility community [58]. This report examined many different types of DG in many configurations. Items in the DISPOWER report that are of specific interest. The report describes the Power Quality Management System (PQMS), which uses TCP/IP as its protocol and Ethernet cables as the physical communications channel. Initial field tests appear to be promising. One section of the report deals specifically with problems expected as DGs approach high penetration levels. Harmonics increased slightly when the DGs were present, but never did they reach a problematic level. This study does not include a suggestion of a maximum penetration level. [59] Examined the impact of PV penetration in the UK, where utility source series impedances are typically higher than in the U.S. It examined the probability distributions of voltages in a simulated 11 kV distribution system with varying levels of PV penetration, using an unbalanced load flow model. The probability density functions indicated that PV causes the distribution to shift toward higher voltages, but only by a small amount. The study’s findings include: If one employs very strict reading of the applicable standard in the UK (BS EN 50160), then PV penetration is limited to approximately 33% by voltage rise issues. However, at 50% penetration, the voltage rise above the allowed limits is small, and so the authors suggest that the 33% limit is somewhat arbitrary. As per the results in [57], the authors of [59] found that at 50% penetration distribution system losses were reduced below the base-case values, largely because of reductions in transformer loading. Voltage dips due to cloud transients might be an issue at 50% penetration, and the authors suggest further study of this issue.

IV. ISSUES AND CHALLENGES OF RES - GRID INTEGRATION

Renewable energy sources are intermittent in nature hence; it is therefore a challenging task to integrate renewable energy resources into the power grid. Challenges and issues associated with the grid integration of various renewable energy sources particularly solar photovoltaic and wind energy conversion systems. [67], further these challenges are broadly classified into technical and non-technical and described below.

A. Technical Issues:

The following are the technical issues are described as

1. Power quality
   a. Harmonics
   b. Frequency and voltage fluctuation
2. Power fluctuation
   a. Small time power fluctuations
   b. Long time or seasonal power fluctuations
3. Storage
4. Protection issues
5. Optimal placement of RES
6. Islanding.

B. Non- Technical Issues:

1. Due to scarcity of technical skilled workers.
2. Less availability of transmission line to accommodate RES.
3. RES technologies are excluded from the competition which discourages the installation of new power plant for reserve purpose.

V. IMPACTS OF POWER QUALITY – GRID INTEGRATION

The impacts of poor quality are broadly classified as: direct, indirect and social. A detail has been described in [60]. A survey based on interviews and web based submission, conducted over a 2-years period in 8 European countries, reported in [61]. Survey reported PQ costs due to the effect of voltage dips and swells, short & long interruption, harmonics, surges and transient, flicker, unbalance, earthling and electromagnetic compatibility (EMC) problems. Dips and short interruptions account for almost 60% of the overall cost to industry and 57% for the total sample the study also shows that the economic impact of inadequate PQ costs industry and services sector some 4% and 0.15% of their annual turnover. It is necessary to consider the impact of DG in terms of cost of power Quality in [62-65].

The contemporary sophisticated requirements related to the dynamic performance of RES during system disturbances and their respective contribution to system recovery and voltage support, unsolicited impacts on the system that even can contradict the intention of system recovery is shown in [66].

VI. VARIOUS SOLUTIONS OF RES UTILIZATION

The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality. The renewable energy sources such as solar, wind etc. has accelerated the transition towards greener energy sources. [67], keeping in view of the aforesaid some of the key solutions for RES utilizations are:

1. The power balance using RES can be carried out by integrating RES with energy storage unit. The benefits of battery energy storage system (BESS) are classified based on end – users as:
Transmission level uses, System level uses, ISO Market uses.

2. The power-electronic technology plays an important role in distributed generation and in integration of renewable energy sources into the electrical grid, and rapidly expanding as these applications become more integrated with the grid-based systems. During the last few years, power electronics has undergone a fast evolution, due to two factors, the development of fast semiconductor switches that are capable of switching quickly and handling high powers and introduction of real- time computer controllers that can implement advanced and complex control algorithms. These factors have led to the development of cost- effective and grid-friendly converters. The performance of power electronic systems, especially in terms of efficiency and power density, has been continuously improved by the intensive research and advancements in circuit topologies, control schemes, semiconductors, passive components, digital signal processors, and system integration technologies, [68].

3. Intermittence of power generation from the RES can be controlled by generating the power from distributing RES to larger geographical area in small units instead of large unit concentrating in one area.

4. In case of irrigation load, the load is fed during the night time or off peak load time and this is fed by conventional grid. On other hand power generated by RES like solar PV is generated during day time so we can use this power for irrigation purposes instead of storing the energy for later time which increases the cost of the overall system. Using the solar water pumping for irrigation gives very high efficiency approx 80% to 90% and the cost of solar water pumping is much lesser than the induction motor pumping type.

5. In large solar PV plant output power is fluctuating during the whole day and this power is fed to the grid, continuously fluctuating power gives rise to the security concern to the grid for making stable grid.

Solar PV plant owner have to install the different type of storage system which gives additional cost to the plant owner. Once the storage system is fully charged then this storage elements gives no profit to the system owner. Therefore solar based water pumping system may be installed instead of storage system.

VII. CONCLUSIONS

Recent trends in the power generation and distribution system shows that penetration level of DG into the Grid has increased considerably. End user appliances are becoming more sensitive to the power quality condition. This Case presents a technical review of causes of Power quality Problems associated with renewable based distribution generation system (wind energy, solar energy). Voltage decrease with wind penetration and increase with solar penetration, thus this paper shows the effect of wind and solar penetration is different in nature. In this paper, some issues, impacts related to grid integration of RES and their utilization, available in the literature have been presented. To minimize the fluctuations and intermittent problems power electronic devices are viable options. Further, energy storage and use of dump load and MPPT could be used for reducing the power fluctuations in PV systems. The up-gradation in balance of systems by incorporating the new materials and storage elements could reduce the problems associated with grid integration.

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