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Integration of Renewable Energy Sources to Indian Grid: Issues and Challenges- A Review

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ABSTRACT

Renewable energy resources (RES) are being increasingly connected in distribution systems due to ever increasing population coupled with a constant depletion of fossil fuel . India has large untapped resources of wind and solar energy, which if utilized properly, can fulfil the energy requirements of the country to a large extent. However, due to the wind speed's uncertain behaviour 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 the transmission and distribution systems of utility grid. This paper presents issues and challenges of large-scale integration of renewable energy resources to the Indian grid.

Keywords: Distributed Generation(DG), low fault ride-through (LFRT) capability, LVRT (Low voltage-ride through) capability, battery energy storage system (BESS), Renewable energy sources(RES)

1. 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. Distributed Generation (DG), is used to minimize the loading effect of transmission line. Integration of DG causes bi-directional power flow which reduces the capacity of feeder and transmission line. The other benefits of distributed generation[1] include the reduction of power loss, better voltage support, peak shaving and the improvement of overall efficiency, stability and reliability [2]. The advantages of micro-grid systems are flexible installation and the control of active and reactive power separately. RES are used as distributed generation in micro-grid. Major advantages of RES are: sustainability, less maintenance cost, low operation cost environmental friendly, reduction of greenhouse gas emission, reduction of pollution, etc. Energy demand and solutions are being sustainable scale using various measures [3-4] Renewable energy penetration not only affects the local market price, but also reduces the electricity price of adjacent interconnected systems [5]. Figure1 [6] represents grid connected RES.

2. 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. 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 [5]. Due to the wind disturbances (mech. speed), the wind farm active (reactive) power injected (demanded) into the power grid, leads to

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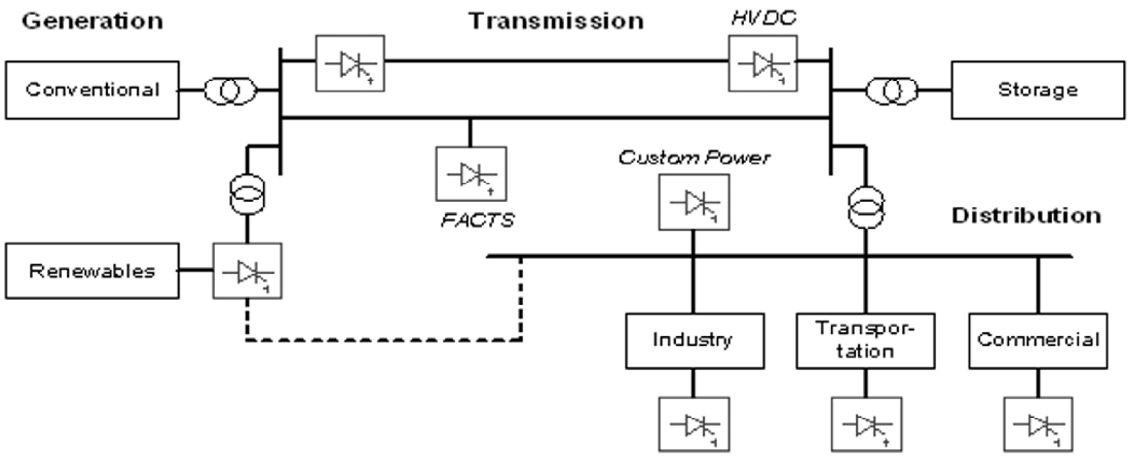

Figure 1: Electrical power system–renewable generation [6]

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. 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 [6-9]. 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 [10-14]. 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, and 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.

3. CHALLENGES 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 .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 reduces the system security. Problem in maintaining voltage profile . Most of the wind turbines are coupled with SCIG, 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 due to low fault ride-through (LFRT) capability of wind generator. High penetration of wind energy creates stability problem, and possible blackouts thus wind energy penetration is limited by ATC (available transfer capability) of the system. Frequency behaviour of the system also changes with wind penetration due to lower inertia of distributed wind generators . Finally, wind energy penetration reduces overall efficiency and power quality. Literature [15] presents the new grid codes adopted for the problems of integrating large amounts of wind energy to the electric grid. An overview of the developed controllers for the converter of grid connected system 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 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 [16].

3.2. SOLAR ENERGY SYSTEM

The huge amount of solar energy is available on the earth. Humans consume almost 15 TW of solar energy. Customers are interested in solar power due to low cost, environment friendly, flexible installation and no reactive power consumption by solar panel. But constraints of solar generation are: high installation cost of solar panels, low generation capacity, uncertainty of solar irradiance, and power fluctuation due to intermittency behaviour of sunlight. Solar penetration also changes the voltage profile and frequency response of the system[17]. PV system is designed with unity power factor and the characteristics of output power are dependent on the inverter. 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 [18]. Since photovoltaic system has no inertia, some extra devices are required to maintain frequency oscillation. 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. Literature[19] presents that 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. 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. penetration levels. Harmonics increased slightly when the DGs were present, but never did they reach a problematic level. The probability density functions indicated that PV causes the distribution to shift toward higher voltages, but only by a small amount.

Many Indian states as well as the central government through the MNRE/SECI have been promoting rooftop photovoltaic's (RTPV) for the last few years. While most state regulations have referred to national CEA interconnection standards ("Technical Standards for Connectivity of the Distributed Generation Resources", 2013) with regard to technical issues, there have been two areas where there are some variations across states.

The first one is with regard to limits on system sizes and allowed inter-connection voltages. The details are provided in Table 1. These generally tend to be in line with state supply code regulations.

The second is with regard to metering requirements. Some state regulations mandate meters of a higher accuracy class in comparison with the CEA metering regulations, 2006 (with the 2013 amendment for renewables). Both these variations have a direct bearing on the cost, especially for small kW scale installations.

4. ISSUES AND CHALLENGES OF RES-GRID INTEGRATION IN INDIAN SCENARIO

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[20, 22] 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

Table1
Comparison of technical norms of system size and interconnection voltages by states

Voltage (Volts)	State	240	240/415	415	11,000	11,000/33,000
System size (KW)	Gujarat	<6		6-100	> 100	
	Uttarakhand	<4		4-75	75-1500	1500-3000
	Tamilnadu		<4	4-112		>112 (HV/EHT)
	Delhi (draft)		<10	10-100		>100 (HV/EHT)
	Kerala	<5		5-100	100-3000	
	Punjab (draft)	<7		7-100	>100	
	Karnataka	Up to 5		5-50	>50	
	West BengalLV or MV or 6 kV or 11 kV or any other voltage as found suitable by the DISCOM					
	Chhattisgarh			50-100	100-1000	
	MNRE[166]	Up to 10		10-100		100-500
	SECI Scheme		Up to 10	10-100		>100 (incl 66 kV)

a. Harmonics-IEEE 519, wherein THD < 5%

b. Flicker-IEC 61000

c. DC injection-IEEE 1547 standard, wherein the maximum permissible level is 0.5% of the full rated output at the interconnection point.

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.
4. Wind and Solar Resources are highly Location Dependent.
5. Quality wind and solar resources that are most feasible for RE generation are based on specific locations.
6. Transaction Costs: Another logistical worry for utilities is the significantly higher transaction effort in terms of metering, inspection and certifications.
7. Non-standard technical regulations, procedures and specifications across states can act as a strong barrier, resulting in additional costs for manufacturing and deployment and thereby slowing down the growth of this sector. This is especially important for metering regulations.
8. Lengthy procedures and delay in implementation.

9. Political interference.
10. State to state procedural mismatches.

As far as India is concerned, the CEA has not stipulated any penetration limit in its regulations. However some SERCs are specifying penetration limits in terms of a percentage of the DT's rated capacity. Tamil Nadu mandates that the penetration of distributed PV into the grid shall not exceed 30% of the distribution transformer (DT) rated capacity while Delhi and Punjab have proposed 15% and 30% respectively. Kerala, on the other hand, had initially proposed a limit of 50% of the DT capacity but has finalised a different metric allowing up to 80% of minimum daytime (8am-4pm) load. A safe penetration threshold is a factor of various variables like load patterns, grid quality, consumer behaviour, etc. and hence will vary from place to place. The learning's and experiences in these states would be very valuable to other states[21].

5. VARIOUS SOLUTIONS OF RES INTEGRATION

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. keeping in view of 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.
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.

6. 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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