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Analysis of Distributed Generation and Impact on Distribution System

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ABSTRACT: The Energy demand is increasing because of a growing rate of urbanization, economic growth, increasing prosperity and rising per capita energy consumption. To fulfil the increasing energy demand India need better cost effective and environment friendly solution.Renewable energy source based Distributed Power Generation is cost effective and environment friendly solution to fulfil the demand. Small scale Distributed Generation is connected to distribution systems. It is difficult to achieve the good quality power with wind power generation because of vacillatingbehaviour of wind speed, which affects the voltage and active power output of electrical machine connected to wind turbine. Similarly solar power generation affects the voltage profile and frequency response of the system .This paper presents a review of Distributed Power Generation and issues related to integration with distribution power system.

KEYWORDS: Distributed Generation, Distribution System, wind energy, and Power Quality

I. INTRODUCTION

India is fourth largest electricity producer with 1052 terrawatthour (TWH) and fourth largest electricity consumer in the world. As of October 2014 India has 255GW installed capacity and it is 5th largest in the world at Compound annual growth rate (CAGR) of 10.4 per cent in FY09-Oct-14.Electricity production in India is 1173.8 TWH during FY14.The production increases with CAGR of 6.3 per cent during FY08-14. Total Thermal installed capacity is 177.4GW while hydro and renewable energy installed capacity totalled 40.8GW & 31.7GW respectively. [13]

Demand for electricity is expected to increase 1915 TWH over FY07-22 with CAGR of 9 percent. Indian Govt. is enthusiastic for promotion of hydro, renewable and gas based power generation. Renewable energy is fast emerging as major source of power. Renewable energy capacity addition to 41GW is planned till 2017 to meet the growing energy demand. [13]

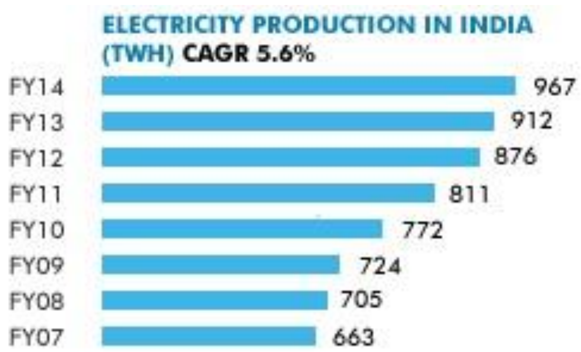

Fig- 1: Year wise total Electricity Production in India

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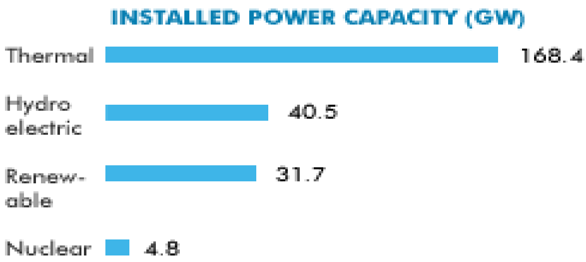

Fig- 2: Installed Power generation capacity in India as of OCT -14

To meet increasing energy demand fast emerging source of power are Renewable energy sources based Distributed Generation (DG). Distributed Generation has few more advantages then conventional power generation. Distributed Generation is reliable and it has reduced fuel cost. DG can improve power quality and reduced emissions. However the benefits of DG are highly dependent on the characteristic of each installation and the characteristic of local power system. Distributed Generation capable of providing constant, uninterrupted power. By reducing the flicker and voltage regulation problems DG can improve power quality. On the other hand Wind Turbine and Solar PV cell based distributed Generation connected to the grid via power electronics inverters can be main source of voltage waveform distortion.

II. LITERATURE SURVEY

Distributed generation (DG) units are placed near consumer end and the author has mentioned DG technologies including Wind Turbines, Micro turbines, Photovoltaic system and fuel cell [3].Benefits of Distributed Generation mentioned by author including: as power generated and distributed near consumer end reduction in transmission loss, power reliability increases, reduction ingreen house gas emissions compare to conventional power plants. However it is claimed that due to the vacillating nature of wind fluctuating power generates in the wind farm and it has negative impact on power quality and stability and voltage regulation in distribution system [1].Distributed Generation integration not only affects the local market price but also reduces the electricity price of adjacent interconnected system. Nevertheless large penetration of DG units in distribution power system network not only affects the grid planning but also has an impact on the operation of grid such as power quality, grid losses, fault level and voltage control [1]. It is suggested that advanced power devices with converter and control system such as STATCOMs and SVCs can reduce reactive power problem, voltage instability, flicker and harmonic distortion and also improve power quality [2].

III. DISTRIBUTED POWER GENRATION

Distributed Generation (DG) is defined as small generation units of 30MW or less which are sited at or near customer sites to meet specific customer needs, to support economic operation of the distribution power system or both. In DGthe energy generated and distributed by using small scale technology near to consumer end that's why it is also termed as decentralized power generation. Distributed Generation technologies include Photovoltaic systems,Wind Turbines, Micro Turbines, Fuel Cell, Biomass, Small Hydroelectric generators, Energy storage and synchronous generator application supply active power to distributed system connected in proximity of the consumer.

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2.1 Wind Turbines

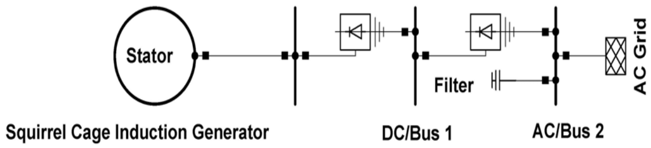

Fig-3: Variable speed Induction Generator [3]

Variable or Constant speed wind turbine exploit the wind energy to drive electrical power generator. The advantages of wind turbines compared to conventional power plants are pollution free, no fuel charges, potentially 24hrs source of energy and for large scale installation units are modular with fairly linear power vs. cost relationship. Disadvantages include high initial cost, unpredictability of energy production due to fluctuating wind speed and greater environmental impacts compared to solar.

There are mainly two types of Wind Turbines Horizontal axis and Vertical axis Wind turbines, In Horizontal axis Wind Turbines Yaw control mechanism is necessary in order to maintain power production and avoid operating problems such as resonance and vibrations. Vertical axis Wind Turbine has several advantages over Horizontal axis Wind Turbine. Vertical axis Wind Turbine has less maintenance, simple operations and reduces structural needs as majority of their electrical and mechanical machinery is located on the ground rather than 40-90 m in the air. **Fig -3** shows variable speed Induction Generator connected to a rectifier and inverter.

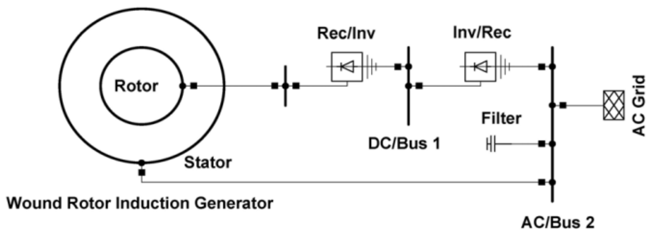

Fig- 4: Doubly Feed Induction Generator [3]

Nowadays Doubly feed Induction Generator is used to operate Wind Turbines. Doubly feed Induction Generator (DFIG) is electrical machine in which stator directly connected to AC grid and the rotor connected to grid through power electronics devices. DFIG offers support in power system stability and reliability during peak load condition so it is recommended for new Wind farm installation. **Fig - 4** shows Doubly Feed Induction Generator.

2.2 Photovoltaic

The array of solar cell which is made of semiconductor devices are used to converts solar energy in to electrical energy in Photovoltaic system. Solar cells generate DC electric power at low voltages, usually less than 0.5 Volts. A Single cell produce small amount of power as its size is very small approximately less than a square centimeter so numbers of cells are connected in series or parallel. To produce higher voltage solar cells are connected in series and to produce higher current the cells are connected in parallel.

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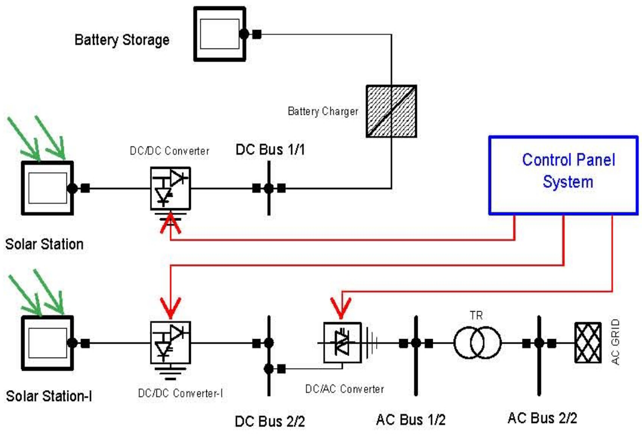

Fig -5: Photovoltaic system connected to a grid

To obtain Maximum Power Point Tracking (MPPT) using photovoltaic cells a DC/DC converter must be used at the output end of **Fig – 5**. This will extract maximum available power through a given insulation level, It means the voltage level will be maintained as close as possible to the maximum power point [8]. As there is not any moving parts so PV system required less maintenance.

2.3 Fuel Cells

Basically Fuel cell is energy conversation technology which converts chemical energy in to electrical energy directly. All the fuel cell technologies consume hydrogen which is received from fossil fuel and the oxygen from air. In the presence of catalyst, under monitored and controlled condition the hydrogen inside the fuel cell is oxidized. Then combines the hydrogen and oxygen to produce water. Fuel cell has many advantages with respect to fossil fuel generation including high efficiency, low pollution, very low noise, quick installation and re-usable heat output [5]. However fuel cell has many drawbacks including high initial cost, maintenance skills required, fuel sensitivity and unproven track record. Mainly five types of Fuel cells are available which include phosphoric acid fuel cell (PAFC), proton exchange membrane fuel cell (PEMFC), alkaline fuel cells (AFC), molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) [5]. Fig -6.Shows the basic structure of fuel cell.

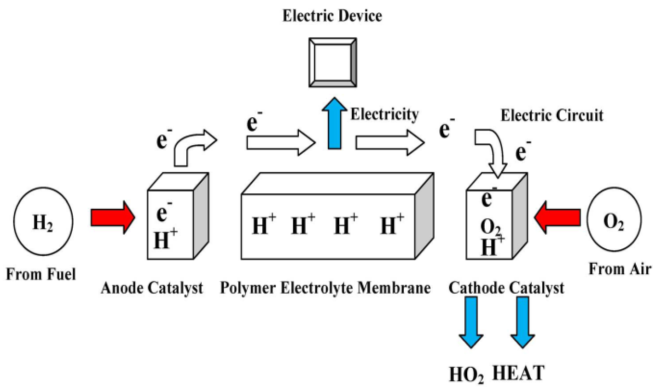

Fig - 6. Fuel Cell Electrolyte membrane [3]

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2.4 Micro-Gas Turbines

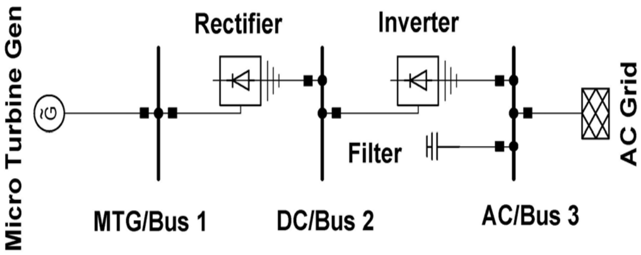

Fig- 7. Micro gas Turbine electrical system

As Micro-gas turbines are simple, robust and compact devices so it can be used as distributed generation system. It uses gas instead of steam to rotate the rotor of turbine and produce electricity.Most micro-gas turbines acquire their intake air from a recuperator. It is a device which manages heat from the turbines exhaust to pre-heat the intake air also raise the turbine internal temperature [5].The recuperator is type of heat exchanger or radiator that transfers heat from the exhaust to the incoming air. Micro-gas turbine systems are equipped with air bearings to run at speeds between 50,000 – 90,000 rpm. These systems can be mass produced at low cost in range of 25-100Kw [3]. **Fig- 7** shows a Micro-gas turbine system without integrating with the AC grid. The generated voltage is DC so it must be rectified using a diode rectifier.

IV. BENEFITS OF DISTRIBUTED GENERATION

Due to mentioned five major factors the concepts of many small scale energy sources spread over the grid.

- Fast developments in distributed generation technologies.
- Restraints on the construction of new transmission lines.
- Increased consumer’s requirements for highly reliable electricity.
- Liberalization of the electricity.
- Concerns about increased level of GHG emissions and climate change.

Distributed Generation have some advantages over conventional power generation.

3.1 Reliability Benefits

DG units maintain the supply to local loads at the time of fault or power outage as result system reliability is improved. “Islanding” is the action in which the “island” is created by disconnecting healthy section of distribution feeder from faulted area. Basic requirements for successful islanded operation are sufficient generation to meet local load demand and also the necessary distributed system control capabilities. The potential reliability benefits of generators depend on variable energy resources, generators with limited fuel reserves or generators with low individual reliability even if islanded operation is possible. [9]

3.2 Economic Benefits

It can be realize when utilities deploy DG to hold back investments in transmission or distribution infrastructure. As DG typically located closer to load relative to central plants, it can cut down system losses and reduce congestion in some instances. On the other hand DG placed near to consumer often reduces utility revenue but can offer customers long term electricity cost stability and sometimes also offer cost saving. This savings can be received in different forms. First, current rules allow customers with DG to deflect paying their share of fixed network cost. Second because electricity generated by DG installation is typically costlier than electricity generated in central plants, customers who are getting sufficient subsidies can earn energy cost savings with DG. [9]

3.3 Emission Benefits

The magnitudes of emission benefits depend upon the characteristics of power system to which they are connected and characteristics of individual DG units. It can be realized by renewable generators, such as solar photovoltaic (PV),

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which have minimum emissions, or Combined Heat and Power (CHP) systems whose use of waste heat can result in increased efficiencies than central generation units.[9]

3.4 Power Quality Benefits

Distributed generation can improve power quality by reducing the flicker, capable of providing constant, uninterrupted power and also mitigate other voltage regulation problems. However DG connected to the grid via power electronic inverter (i.e. solar PV, fuel cells, and most wind turbines) are widely empathized to be sources of voltage waveform distortion. But if designed and implemented properly, the power electronics inverter could

IV. IMPACT OF DISTRIBUTED GENERATION ON DISTRIBUTION POWER SYSTEM

As the configuration of power lines and protective relying in most existent power system assume a unidirectional power flow and are designed and operated on that presumption [9]. The integration of Distributed Generation presents new challenges for Distribution system planning and operations because of the above presumption. Previously the integration of DG was sufficiently small but nowadays integration of DG is growing. As far as utility concerned the high penetration level of DG in distribution systems may pose a threat to network in terms of Power Quality issues, voltage regulation, reliability and stability [1].

In recognition of the possible contrary impacts of DG on distribution systems and the requirement of uniform criteria and necessity for the interconnection of DG "IEEE Standard 1547" have been created. IEEE 1547 first released in 2003 and incorporated into the Energy Policy Act of 2005. The Standard includes several provisions to reduced DG's possible negative effects on power quality [9].
Several important effects of DG on electrical power systems are shown below.

4.1 Operation and Control

DG output is varied according to variation of the local demand. DG power output can also be controlled independently of the local load. This control mode is implemented if DG follows the availability of natural resources (i.e. solar or wind power) or DG operation follows price signal, which might or might not match up the local load variations [4]. DG might adversely affect the voltage control of the network by increasing the variations between the maximum and minimum voltage level with respect to the situation when DG is not available. Since the minimum voltage level could unaltered but the maximum voltage level could increase i.e. in low load situations with DG operating at maximum production and at a unity power factor. Most of the time DG affects the standard voltage,frequency and power control[10].
Large penetration of the DG to the grid affects the reliability and power quality of the system. There is also risk of control and stability of the system. When circuit breaker in a distribution system opens Islanding of DG could occurred. If Due to insufficient fault current the loss-of- mains is not detected the DG will continue to operate. The islanded system could continue to operate when the DG unit is able to match active and reactive power load demand precisely. On the other hand it is very unrealistic that DG will exactly meet the load demand in the system when the circuit breaker opens. Due to this when DG unit tries to supply the load large frequency and voltage variations will occur. So, loss ofmains detection system is mandatory for interconnection, which automatically disconnects the DG unit in case of a loss of mains and the unit remains disconnect till the grid is restored [10].

4.2 Change of Short Circuit capacity

The Short circuit capacity (SCC) of the distribution network may increases at the time of installation of new DG in network. It is desirable to have a high SCC in the presence of large loads with rapid varying demands or at the point of connection of the inverter of a line commutated HVDC stations. But the increase of the SCC potentially indicates a problem [4].

4.3 Stability

Conventionally the distribution network was passive, radial and stable under most of the circumstances, provided the transmission network was itself stable. So for the design of distribution network no need to consider the stability issues.

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However as the penetration of DG to distribution network increases and their contribution to network security becomes greater the design criteria will change. Hence the transient stability as well as long term dynamic stability and voltage collapse need to be considered [10].

4.3.1 Voltage Level

As the conventional distribution network designed unidirectional the voltage reduces with distance from the generator to transformer. These voltage drops are foreseeable and they are taken into account at the time of design of the network so that the voltage is within tolerance under normal conditions. But when a DG unit is connected the current flow are changed or even reversed, and the voltage will increase in a way that is not easy to anticipate. The requirement to meet standard voltage limits restricts the capacity of DG that can be connected to the system, particularly at the low voltage level [4].

4.3.2 Voltage Waveform

Depending on the type of DG unit connected to the grid, whether it is electronic converter or a rotating machine, it influences the level of voltage wave form distortion. Power electronics device interfaces provide advanced system support possibilities, but at the same time it will inject harmonic currents into the system. Excessive voltage harmonic levels may occur locally or anywhere in the grid that depends on the topology of the system and the impedance at the connection point. Due to the design of the winding and core non linearity rotating generators can also inject harmonics. The relevance of this aspect depends on the specific DG details as well as grid layout [4].

4.4Power Quality

The power quality of system depends on the characteristic of DGs and different DGs have different characteristics. Thus different DGs create different power quality issues. The effect of increasing the short circuit capacity of network by adding generation often leads to improve power quality. However a wind turbine connected to weak network may lead to power quality problems particularly during starting and stopping. Modern controls and excessive use of power electronics devices introduce power quality problems and these devices are very inclined to power quality problems. [10]

4.5 Unbalancing

Various DGs supply to the network in single phase is available. Which may cause the unbalancing to the system and it should not increase beyond the permissible limit. With unbalancing of loads in phase operation of DG suffers. Because of unbalancing their performance deteriorates [10].

4.6 Protection system

DG will have an impact on the protection scheme of distribution system .The impact of DG on the over current protection may vary, it depends on the location of DG, rated power, mode of operation, technology used and network configuration. DG will not interfere with the normal operation of the protection system but DG must be disconnected at the time of fault occurrence.

There is requirement for totally new solutions. However some solution may be adopted from the high voltage systems. When low power DG unit is supplying energy to a low voltage branch also supplied by LV transformer. If a fault occur far from the DG unit fault current from transformer will cause transformer protection to operate, leaving the DG unit supplying the fault current, due to relatively high impedance of the system may be insufficient to operate the DG protection [4].

However nowadays distribution networks are automated and equipped with SCADA systems, so the protection scheme must be designed and coordinated [10].

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V.CONCLUSION

Even though Distributed Generation is beneficial to the society as electricity generated near the place of consumption, reduction of power losses in the network, reduction of green house gas emissions, creating the more competitive market, it increase reliability of power system, It is not always economically viable. The economic viability of Distributed Generation is depends on energy prices and measures taken by the national governments to stimulate Distributed Generation. Distributed Generation has greater impact on energy losses, voltage profile, flicker, and harmonics, short-circuit level, islanding, reliability and network protection.

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BIOGRAPHY

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