An Overview on Wind Power Generation System

Vipin Gupta[1] Barkha Khambra[2]
[1]M.Tech Student [2]Guide
[1,2]Department of Electrical & Electronics Engineering
[1,2]NRI Institute of Information Science and Technology, Bhopal (M.P.), India

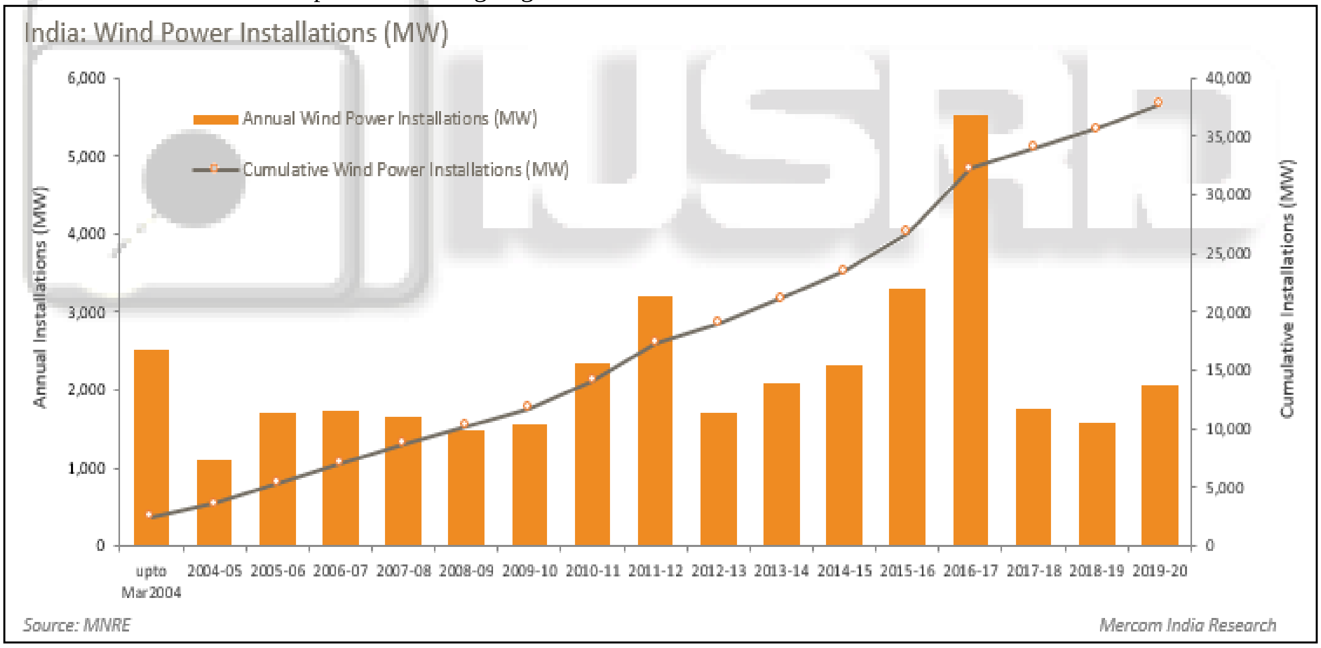
Abstract— An alternative source of energy which is environmental friendly and attracted most of the attention is wind energy. Wide spread generation has initiatives to increase the share of wind power in electricity generation. Wind power generation system (WPGS) may be fixed speed and variable speed. Variable speed is most widely used since it has high utility and can be more precisely controlled but it requires Power electronics interface. This paper presents brief review on various wind system which works efficiently on both constant and variable wind speed.

Keywords: Wind Power Generation System (WPGS), Doubly-Fed Induction Generators (DFIGS), Fixed Speed Generators (FSG), Adjustable Speed Generators (ASG)

I. Introduction

Wind power system fundamentally is an electric machines that are sustained with alternating current streams into both their stator and rotor windings. Tremendous research and on-field work has been reported for high growth in deployment of wind power system development. Beginning with the early 21st century the installed capacity was around 1000 MW in India and in 2019 it was around 35 MW marked as cumulative installed capacity of India as shown in figure 1. It accounts for 10% of total capacity. In the FY 2018-2019 total generated wind power was 62.03 TWh. India is very to increase the installed capacity to 175 GW at the end of 2022.

The results of deep penetration of wind energy into the existing utility system are the stringent grid code. The demand of the time is to retain the connectivity of Wind power generation system (WPGS) at all conditions even during and after grid fault. The reliability of the system can be increased further if WECS is capable of providing reactive demand of the system. The WPGS installation may be on-shore and off-shore. The essential for installation is wide open area such that wind does not get hurdled. And atleast a wind speed of 5m/s to convert the wind into power through blade and rotor-converter mechanism.



Doubly-Fed Induction Generators (DFIGs) are by a wide margin the most broadly utilized kind of doubly-bolstered electric machine, and are a standout amongst the most widely recognized kinds of generator used to create power in wind turbines. DFIG generators have various preferences over different sorts of generators when utilized as a part of wind turbines.

The essential favorable position of DFIG when utilized as a part of wind turbines is that they permit the sufficiency and recurrence of their yield voltages to be kept up at a consistent esteem, regardless of the speed of the wind blowing on the wind turbine rotor. Along these lines, DFIG can be specifically direct association with the AC power system and stay synchronized consistently with the AC power system. Other advantages include the ability to control the power factor (e.g., to maintain the power factor at unity), while keeping the power electronics devices in the wind turbine at a moderate size.

The DFIG based WECS is capable in meeting the above mentioned necessities. It is the most widely used wind system having a large world share now a days due to the several merits it possess in comparison to other WECS. This paper presents a brief review on DFIG based WECS, discussing about its merits, demerits, and construction and control strategies.

II. CLASSIFICATION OF WECS

The wind turbines are broadly classified as fixed speed generators (FSG) type and adjustable speed generators (ASG). The FSG are constructed based on "Danish concept" as shown in Fig-1. Generally FSG are low power rating WECS constructed with squirrel cage induction generators directly connected to the three phase utility grid. A fixed ratio gear box couples the rotor of turbine to the generator shaft. The design and operation of FSG generally depends on turbine mechanical system like; breaker switching rate, time constant of pitch control etc. the mechanical circuit requires sturdy control to absorb the high mechanical stress during sudden change in grid condition hence an expensive mechanical construction is required for stable operation at high power rating.

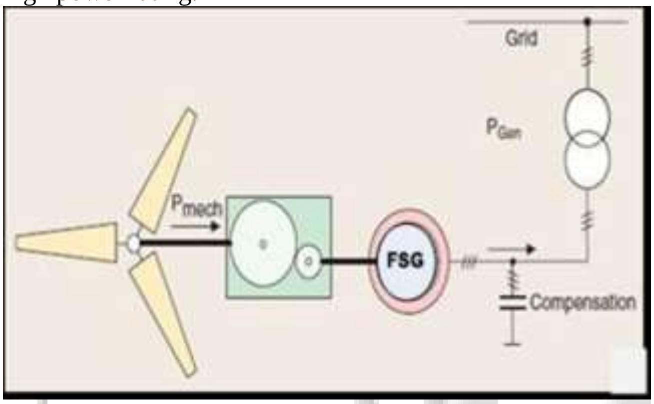


Fig. 1: Fixed speed generator type wind turbine

The ASG are available in two designs one is direct-in-line (fig-2) and other is DFIG (fig-3) based variable speed drives.In direct-in-line structure the variable frequency ac power is generated using synchronous generator. A power converter connected in series with the ASG transforms this variable-frequency ac power into fixed-frequency ac power. These direct- in-line systems have been built up to 1.5 MW.

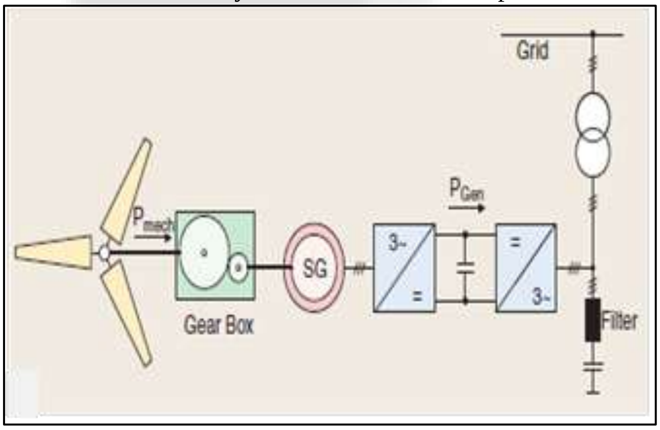


Fig. 2: Direct-in-line based wind turbine system.

DFIG is designed with three phase wound rotor induction machine operating as a synchronous machine. The speed of the rotor is varied by varying the frequency of the rotor current. Mechanical power at the machine shaft is converted into electrical power supplied to the ac power network via both the stator and rotor windings. The relationship between the stator frequency and the rotor speed can be expressed as;

$$f_{stator} = \frac{n_{rotor} \times N_{poles}}{120}$$

Where; f_{stator} is the frequency of the induced ac voltage of the stator in hertz,

n_{rotor} is speed of rotor in rpm,

N_{poles} no. of poles.

As compare to Direct-in-line type ASG, DFIG has various advantages like reduced inverter cost since only 30% of the rated power is required to design the inverter of the equivalent capacity. Reduced cost of filter since inverter size is reduced, only small fraction of harmonics is present. Improved efficiency and self-power factor control are also the advantages of DFIG. The comparison between FSG and ASG is discussed in Table-1.

Fixed Speed Generator	Adjustable Speed Generator
Available in low power ratings	Available in high power ratings
At high power they have complex pitch control and are expensive	They have simple pitch control and are efficient for high power ratings
They undergo high stress at high ratings	They have reduced mechanical stress
Poor power quality	High power quality
Since speed is fixed hence efficiency degrades	Improves system efficiency in variable wind speed by adjusting the rotor speed
High acoustic noise	Low acoustic noise

III. PRINCIPLE OF OPERATION OF DFIG

Despite of the variation of wind speed, it is possible to obtain constant output voltage and frequency of the generator by adjusting the ac current fed into the rotor winding. This can be achieved by employing quasi control mechanism.

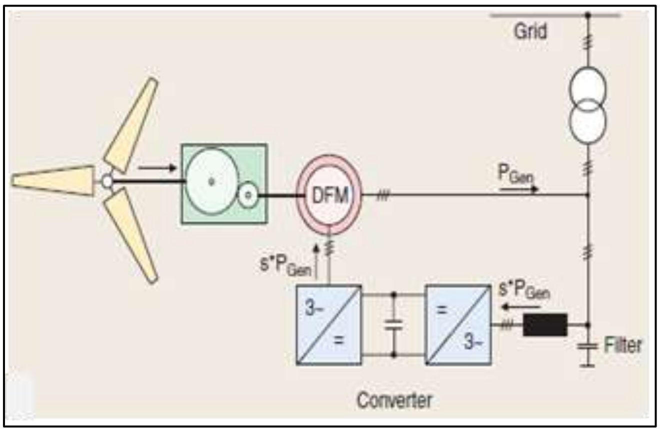


Fig. 3: Doubly fed induction generator based wind turbine system.

By employing DFIGin ASG it could be possible to generate electrical power at lower wind speeds than with fixed-speed wind turbines using an asynchronous generator. The power electronics devices used in doubly-fed induction generators require only processing a small ratio of the generator output power, i.e., the power that is supplied to or from the generator rotor windings, which is typically about 30% of the generator rated power. Consequently, the power electronics devices in variable-speed wind turbines using doubly-fed induction generators typically need only to be about 30% of the size of the power electronics devices used for comparatively sized three-phase synchronous generators, as shown in Fig-4. This reduces the cost of the power electronics devices, as well as the power losses in these devices. DFIG is constructed using two DC/AC converters and one three phase PWM inverter designed with IGBT. TheDC/AC converters allow power to flow from the ac power source to thegenerator rotor windings only. This makes sure that the switchon the IGBT Inverter is set to the on position. This allows power that comes from the generator rotor windings under certain operating conditions tobe dissipated into a dump resistor integrated into the three-phase PWMinverter, as is done in many actual doubly-fed induction generators. In certain some DFIG based WECS two bidirectional AC/DC converters(three-phase PWM rectifier/inverter) are used to allow power flow in bothdirections. This allows power coming from the generator rotor winding to bereturned to the ac power source, thereby increasing the total power supplied tothe source. This operation also helps in compensating reactive power of the system. In literature many papers has been sited were DFIG is also performing the function of static reactive power compensator or employed with universal filtering capability to mitigate load current harmonics or to reduce the Total Harmonic Distortion of output voltages. Hence DFIG can perform many functions and can fulfill the need of present day power scenario where all the utility systems are operating near stability limit and any thrust may lead to system failure.

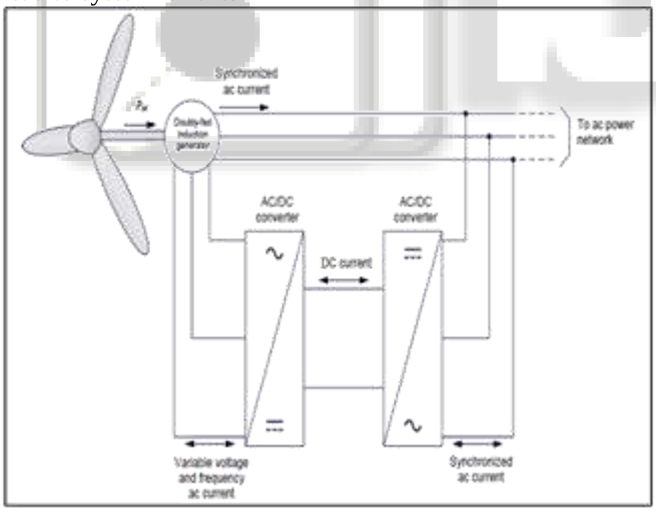


Fig. 4: Circuit topology of DFIG based WECS.

IV. CONCLUSION

In literature two types of variable speed wind turbine system are mentioned, this paper presents a general overview of Direct-in-line and DFIG based WECS. There comparative analysis and advantages and disadvantages are also been discussed here. Circuit topology of DFIG based WECS has been shown with control architecture. In general Fixed speed wind turbine are used for lower power rating of about few hundreds of kilowatts and for rating above it variable speed type wind turbines are installed. The DFIF based WECS are used for power rating upto1.5 MW, since it is more economical and efficient.