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A review on advance type of development wind turbine generators in power generation

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***Abstract* — This paper presents a wind power plant as a source of green and abundant energy is proposed as the one of main new energy sources. In the last few decades, wind energy conversion system has turbines with use various types of generators have been developed to increase the maximum power capture from atmosphere, minimize the cost, and expand the use of the wind turbines in both onshore and offshore applications. In this paper reviews the developments of different types of wind turbine generator technologies and discusses advantages and disadvantages of each type of generator. In addition, a comparison of different generator in wind turbine. To better understand the development of generator concepts on the market, the market trends of current large genrators with a capacity of 2.5MW and above across the world are evaluated.**

Index Terms:– Wind Energy Conversion System (WECS), Wind Turbine Generators (WTG), Induction generators, Synchronous generators, Permanent magnet generators, Wind power generation, Onshore/offshore wind turbines, Power electronics , Power quality , Wind farms

I. Introduction

In this time, renewable energy resources are gaining more attention in electrical power sectors due to efforts of reduce the usage of fossil fuels to generate the electrical energy [1]. In recent time, implementing renewable energies has moderate to strong support across the world. Some types of renewable energy such as hydropower are considered to be fully developed, and others such as solar power are limited to specific regions so that the wind power has been used for longe life windmills were capturing wind power[2]. Wind power as a free cost, abundant, globally available, and green energy source is a choice among all renewable energy sources for generation of electricity [3]. In Figure 1 is shows the world's total cumulative installed wind power capacity between 2008 and 2018, and Fig. 2 shows the shares of ten continents in the total installed wind power capacity between 2008 and 2018.

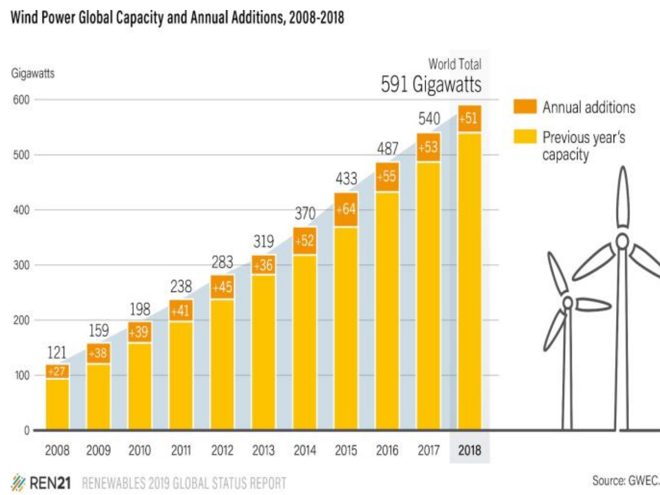

Fig.1.- World's installed wind power capacity during 2008 to 2018

So that the wind power in modern era has become the most established sources in generating the electricity amongst all the renewable sources because of its promising technical and economic prospects to each other types of renewable source. At this time wind power generation has continued to increase globally. With the latest wind annual report it is stated that in 2016 around 398 GW is installed all over the world which can sufficiently supply 4% of world's electricity demand [2]. And it will continue to grow approximately 24% per year globally[4]. With the worldwide rise of generation of electricity through wind turbines, the impact on the electric utility grids has also increased [5].

By the end of 2015, six countries including China (145362 MW), Spain (23,025 MW), Germany (44,947 MW), USA (74,471 MW), India (25,088 MW) and UK (13,603 MW) had over 10,000 MW of the installed capacity [3]. New installations declined to 54.9 GW in 2016 and 53.5 GW in 2017. In 2018, 60.9 GW of new installations were expected but only 51.3 GW were installed at year end [7]. In 2019, the Global Wind Energy Council (GWEC) forecasts 65.4 GW of new installations. For 2023, the forecast for new installations is 58.7 GW and a total installed capacity of 903.0 GW[10].

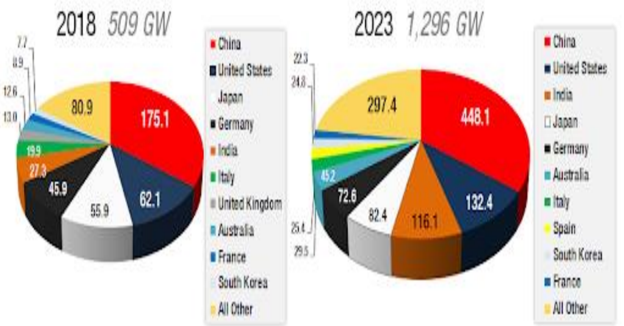

Fig.2.- Percentage share of top 10 countries in terms of cumulative capacity

A wind turbine converts the captured kinetic energy in the wind to electrical energy by means of a generator. Generators with more reliable, efficient, and compact designs should be used in wind turbines to maximize the wind power capture and produce a higher quality output power [13].

II. ELECTRICAL MACHINE

Electric machine can be classified based on the application of that implies the power level and principles of operation of output power [15]. This output power categorizes based on the generators principles of operation. Figure 3 shows differents types of electric machines or machine[10–12]. The main focus of this paper is on the AC poly-phase group, which is the main concept used in the wind power industry.

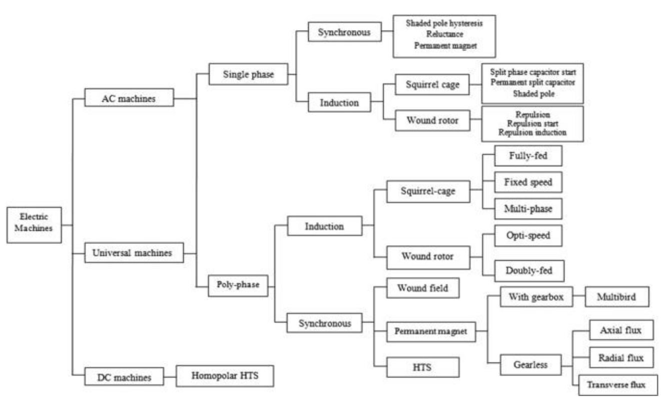

Fig .3.- Types of electrical machine

WOUND ROTOR INDUCTION GENERATOR (WRIG)

It is used for variable speed wind turbine method. It has wind turbine Wound Rotor Induction Generator, directly connected to the grid. The variable rotor resistance is for controlling slip and power output of the generator [18]. The soft starter used here is to reduce inrush current and reactive power compensator is used to eliminate the reactive power demand. The speed range is limited, poor control of active and reactive power, the slip power is dissipated in the variable resistance as losses are the disadvantages of this generator[8,9].

SQUIRREL CAGE INDUCTION GENERATOR (SCIG)

The fixed speed concept is used in this type of wind turbine. Squirrel Cage Induction Motor is directly connected to the wind through a transformer [11,12]. A capacitor bank is here for reactive power compensation and soft starter is used for smooth grid connection. It does not support any speed control system [12].

WOUND ROTOR GENERATOR (WRSG)

In this type of generator, there is no need of soft starter and reactive power comparator [15]. In this generator partial scale frequency converters are used in the system which will perform as reactive power compensation as well as smooth grid connection. In this wide range of dynamic speed control is depending on the size of frequency converter[14]. In the case of grid fault it requires additional protection and use slip rings to make electrical connection to the rotor.

PERMANENT MAGNET GENERATOR (PMSG)

The wind energy conversion system has used permanent-magnet synchronous generators (PMSGs) which are used for special characteristics of PMSGs such as low weight and volume, high performance and the elimination of the gearbox. The generator is connected to the grid via full scale frequency converter[16]. The frequency converter helps to control both the active and reactive power delivered by the generator to grid [18].

DOUBLY FED INDUCTION GENERATOR (DFIG)

A Doubly Fed Induction Generator as its name suggests is a 3 phase induction generator where both the rotor and stator windings are fed with 3 phase AC signal. It consists of multi phase windings placed on both the rotor and stator bodies. It also consists of a multiphase slip ring assembly to transfer power to the rotor [19]. It is typically used to generate electricity in wind turbine generators. Wind turbine generators work in a range of wind speed between the cut in speed (minimum wind speed required for the generator to connect to the power grid) and cut off speed (maximum wind speed required for the generator to disconnect from the power grid). The Double Fed Induction Generator (DFIG) connected directly to the grid, where the rotor speed is adjusted using back to back converters. The rotor terminal is connected to 3-phase AC power at variable frequency. Thus the stator as well as rotor provides power to the equipments. Hence they are called the doubly-fed induction generator (DFIG). It has stator which is directly connected to the grid[13,20]. The rotor is firstly connected to back to back converter then it is connected to grid. When the machine is operating in the generating mode, the mechanical power (Pm) is converted into electrical power in the stator (Ps) and in the rotor (Pr). So induction generator system is capable of generating the reactive power and reduces the reactive power burden on the connected grid under the variable speed wind turbine condition.

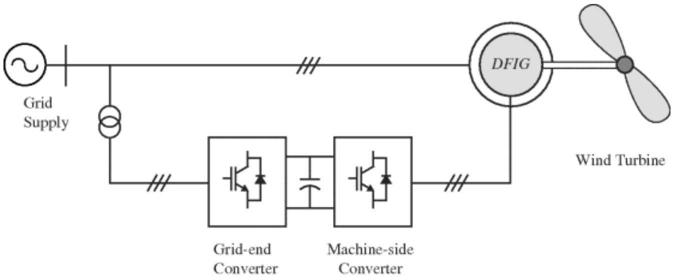

Figure 1.3 WECS with DFIG

DFIG can be modelled by using following mathematical equations [8]

$$V_{ds} = R_s i_{ds} + \frac{d\psi ds}{dt} - \omega_s \psi qs \quad (1)$$

$$V_{qs} = R_s i q_s + \frac{d\psi qs}{dt} - \omega_s \psi ds \quad (2)$$

$$V_{dr} = R_s i_{dr} + \frac{d\psi dr}{dt} - (\omega_s - \omega_r)\, \psi qr \quad (3)$$

$$V_{qr} = R_s i_{qr} + \frac{d\psi qr}{dt} - (\omega_s - \omega_r)\, \psi dr \quad (4)$$

And

$$\psi ds = L_s i_{ds} + L_m i_{dr} \quad (5)$$

$$\psi qs = L_s i_{qs} + L_m i_{qr} \quad (6)$$

$$\psi dr = Lr i_{dr} + L_m i_{dr} \quad (7)$$

$$\psi qr = Lr i_{qr} + L_m i_{qr} \quad (8)$$

where V, i, R, L and ψ are voltages, currents, resistance, winding inductance and flux linkage across winding respectively [21].

$$\text{Slip, } s = \frac{\omega s - \omega r}{\omega s} \quad (9)$$

Where ω_s and ω_r are represent the synchronous speed and rotor speed in (rad/s).

Electromagnetic torque

$$T_{em} = X_m(i_{dr} i_{qs} - i_{qr} i_{ds}) \quad (10)$$

In a given DFIG model which useful for the study of transient stability. This model has taken into account two assumptions:

(i):- Electromagnetic transients in the branch linking the grid & inverters and stator are neglected,

(ii):- By neglecting the current control loop dynamics, the current control can be taken into account as instantaneous value. MATLAB software is used for the study [9].

The studied the DFIG modelling and modelling of converters for stability analysis. A reduced- order model of DFIG is developed to facilitate proficient computation, which limits the calculation of the fundamental component of frequency [10]. In this paper improved model is presented which allows considering the alternating component of rotor current that is essential for initiation of the crowbar operation. Various appropriate models of RSCs and GSCs in addition to dc-link are presented which has considered all four possible modes of operation. For studies of power system simulation the model which is presented is useful [20.21].

V. CONCLUSION

In this paper, review on various types of generators use in models of WECS. By comparing various types of generators, results is found that DFIGs are the current market leader with more than 80 % share on the market. The advantages of new SGs with the second generation of HTS wires, in terms of having a smaller size and higher output power quality, and being more reliable and cost effective. So that the rapid growth of wind turbine generator advance technologies, together with worldwide support for implementation of wind energy projects, will produce more green energy and lead to more independency from conventional energy sources.

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