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# Comparative study of different types of generators used in wind turbine and reactive power compensation

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***Abstract:*** *Wind turbines convert wind energy into electrical energy. Variable speed wind turbines are most used wind turbines now a days due to its advantages. Different types of generators are used in the wind turbine systems (WTS). The comparative study of different types of generators in wind turbines are briefly explained in this paper.*
*Today more and more wind farms are connected into the power grid. The active power at the output of wind farms is variable and intermittent due to the changeable wind speed, which affects the voltage stability problems in power grids. More reactive power is demanded to maintain the voltage when it drops. The doubly-fed induction generator (DFIG) is widely used in wind farms because it has many advantages. The reactive power control is mainly achieved by two modes, i.e. power factor control and voltage control.*
***Keywords:*** *DFIG, WTS, Reactive power compensation*

## I. Introduction

Wind is one of the renewable resource found in nature. Wind turbine is a device which converts kinetic energy of the wind into electrical energy. Horizontal axis wind turbine is the most used wind turbine now a days. Wind turbine is classified into two types. They are fixed speed turbines and variable speed turbines. In fixed speed turbines the maximum efficiency is obtained at a particular speed only. That is; regardless of the wind speed, the rotor speed of the wind turbine is fixed and it is determined by the gear ratio, frequency of the supply grid and design of the generator. The device consist of an induction generator connected directly to the grid as shown in Figure 1. An installation of soft starter unit along with capacitor bank is necessary for reducing reactive power consumption. Fixed speed turbines are being simple, reliable, cheap, robust and well proven. And the cost of electrical parts are also low the disadvantages are, limited power quality control an uncontrollable reactive power consumption ,and mechanical stresses due to fixed speed operation, all fluctuations in the wind speed are transmitted as fluctuations in mechanical torque and then it causes fluctuations in the electrical power on the grid.

In Variable speed wind turbines the maximum efficiency is obtained over a wide range of wind speeds. The electrical System design of the variable speed wind turbines are more complicated as compared with fixed speed wind turbine.it is equipped with an induction or synchronous generator which connected to the grid through a power converter. The power converter is used to control the generator speed. The disadvantages of the fixed wind turbines are rectified in the variable speed wind turbine. The advantages are, increased energy capture, improved power quality, and reduced mechanical stress. The cost of the equipment is high and the design structure is complex are the disadvantages. Currently used the most popular variable-speed wind turbine configurations as shown in in the figure2.The structure of the paper is organized as following. Section II addresses the different types of generators that used in the wind turbine systems and its comparison. Then find out the best generator which is used in the wind turbine and converter operation are in section III.
The advantages and disadvantages of the converter and compensation techniques are explained in section IV. Some concluding remarks are explained in section V.

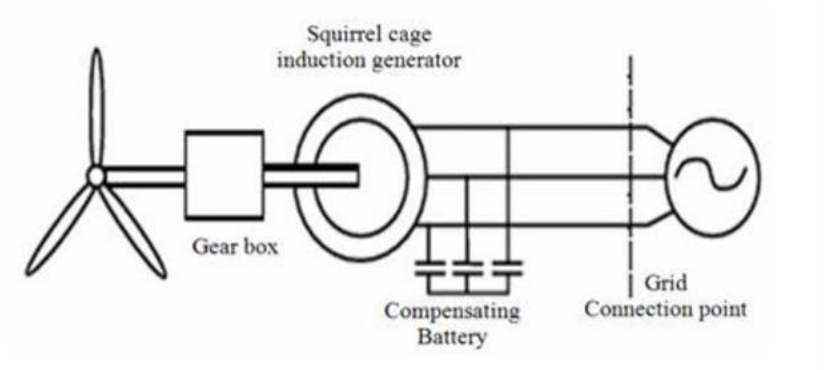


**Fig 1:** Fixed speed wind turbine

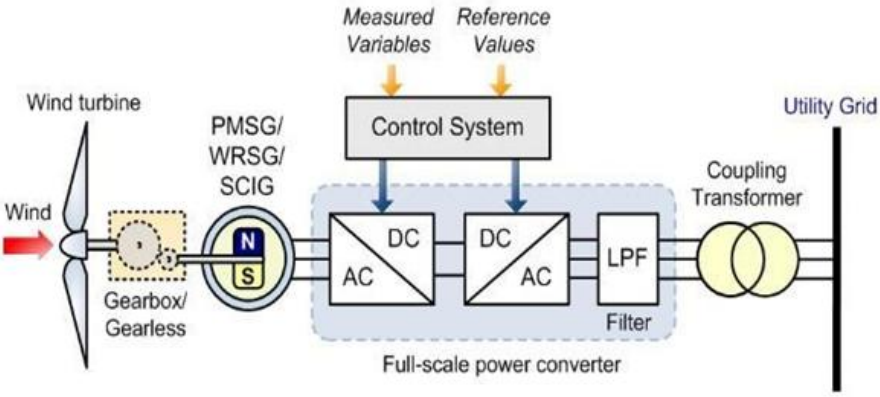


**Fig. 2:** Variable speed wind turbine

## II. Types Of Generators Used In Wind Turbine System

Any types of three-phase generator can connect to with a wind turbine. Several different types of generators which are used in wind turbines are as follows. Asynchronous (induction) generator and synchronous generator. Squirrel cage induction generator (SCIG) and wound rotor induction generator (WRIG) are comes under asynchronous generators. Wound rotor generator (WRSG) and permanent magnet generator (PMSG) are comes under synchronous generator. Detailed explanation is given.

### 2.1 Asynchronous Generator

Squirrel Cage Induction Generator The fixed speed concept is used in this type of wind turbine. In this configuration the Squirrel Cage Induction Motor is directly connected to the wind through a transformer is shown in the figure 3. 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 is the main disadvantage

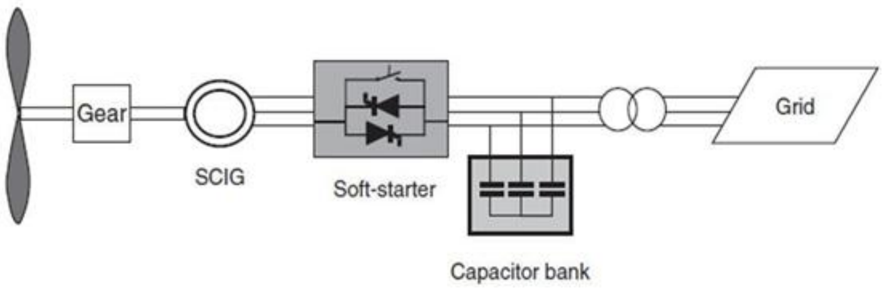


**Fig. 3:** SCIG wind turbine

#### 2.1.1 Wound rotor induction generator ( WRIG )

The variable speed concept is used in this type .In this type of turbine Wound Rotor Induction Generator is directly connected to the grid as shown in the figure. The variable rotor resistance is for controlling slip and power output of the generator. The soft starter used here for 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 configuration

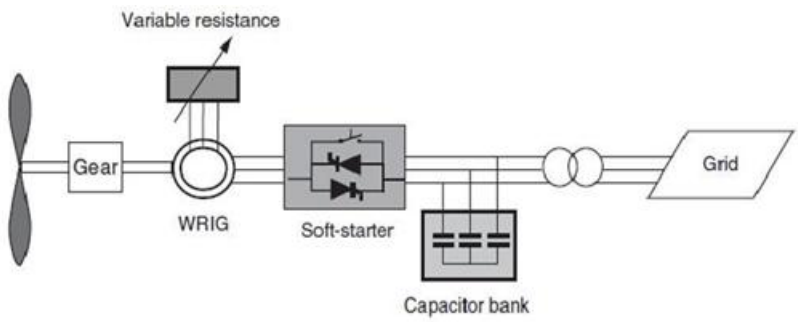


**Fig. 4:** WRIG wind turbine

**2.2 Synchronous Generator**

**2.2.1 Wound Rotor Generator**

Turbine with wound rotor connected to the grid is shown in fig.4.This configuration neither require soft starter nor a reactive power comparator is its main advantage. The partial scale frequency converter used in the system will perform reactive power compensation as well as smooth grid connection. The wide range of dynamic speed control is depends on the size of frequency converter .the main disadvantage is that in the case of grid fault it require additional protection and use slip rings, this makes electrical connection to the rotor.

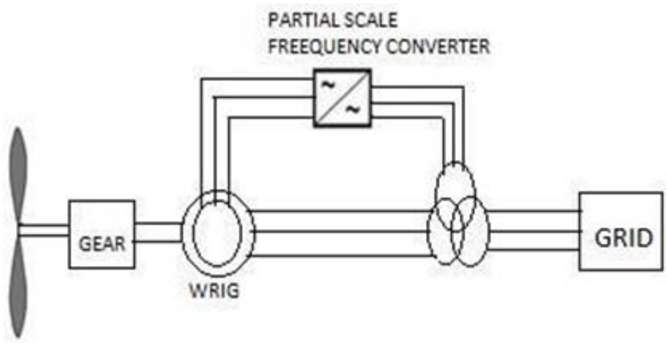


**Fig. 5:** WRIG wind turbine

**2.2.2 Permanent Magnet Generator**

The generator is connected to the grid via full scale frequency converter. The frequency converter helps to control both the active and reactive power delivered by the generator to grid.

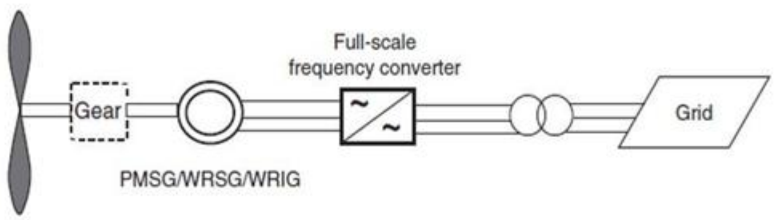


**Fig. 6:** PMSG wind turbine

**2.3 Doubly Fed Induction Generator**

In order to satisfy the modern grid codes, the grid turbine system have the capability of reactive power support. Doubly fed induction generator based wind turbine system have more advantages than others. DFIG wind turbine deliver power through the stator and rotor of the generator the reactive power can provide in two sides. Hence use the term doubly. Reactive power can be supported either through grid side converter or through rotor side converter. The stator part of the turbine is directly connected to the grid and the rotor is interfaced through a crowbar and a power converter. The voltage to the stator part is applied from the grid and the voltage to the rotor is induced by the power converter. The power is delivered from the rotor through the power converter to the grid if the generator is operates above synchronous speed.

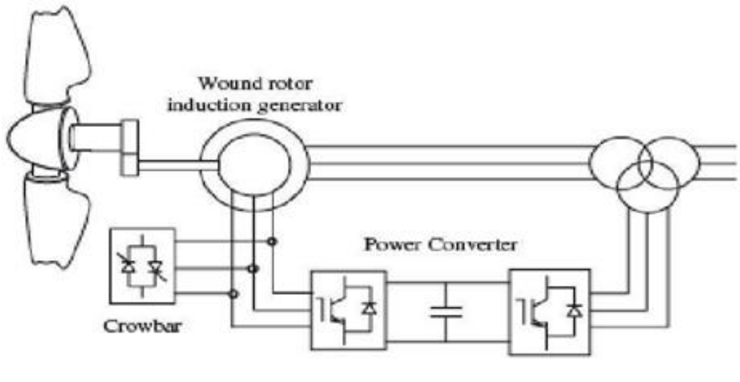


**Fig. 7:** Doubly Fed Induction Generator wind turbine

If the generator is operates below synchronous speed, then the power is delivered from the grid through the power converter to the rotor The power converter controls both the active and reactive power flow, the DC voltage of link capacitor between the grid and DFIG wind turbine by feeding the pulse width modules (PWM) to the converters .A crowbar is implemented between the generator and converter to prevent short circuit in the wind energy system. Which may result in high current and high voltage. The RSC converter controls the flux of the DFIG wind turbine .which operates at the slip frequency that depends on the rotor speed of the generator. According to the maximum active and reactive power control capability of converter, the power rating of the RSC is determined

## III. Reactive Power Compensation In Wind Turbine

DFIG wind turbine has the capability of absorbing as well as generating reactive power, a DFIG wind farm thus can not only generate active power, but also generate or absorb the reactive power to stabilize the grid voltage. The reactive power is mainly controlled by power factor control mode and voltage control mode.

### 3.1 Reactive Power Compensation Methods

Some reactive power compensation techniques used in DFIG wind turbine systems are explained below.

The customary reactive power remuneration gadgets like STATCOM and SVC will build expenses of the wind cultivate. The STATCOM and the SVC plays out similar capacities. Yet, STATCOM have a larger number of favorable circumstances than SVC. The STATCOM can create more responsive power at voltages lower than the ordinary voltage direction go, than SVC. Since the most extreme capacitive power created by the SVC is corresponding to the square of the framework voltage. This is one vital preferred standpoint of the STATCOM over the SVC. Likewise, the STATCOM will likewise display a speedier reaction than the SVC. Since, the STATCOM has no deferral related with the terminating of thyristor.

Another strategy for reactive power control in DFIG wind turbine is SFO vector control. The design comprises of the consecutive two level SPWM converters. One is utilized for RSC and another is utilized for GSC. The control of DFIG is accomplished by controlling the RSC and the GSC. The fundamental goal of the RSC is to controls the dynamic (Ps) and responsive power (Qs). The point of the GSC is to keep up the DC-connect voltage (Vdc) as steady .The vector control of the SFO is corresponding to the present controller. That is ,by managing rotor streams in direct and quadrature pivot , the control of the dynamic power (Ps) and responsive power (Qs) is accomplished and additionally rotor speed of the generator is controlled, subsequently control variable can be controlled.

To enhance the participation of DFIG WTS for voltage regulation, by enabling load balancing and reactive power support to the grid. For this purpose, derives the optimal power coefficient of the wind turbine system that allows reactive or unbalanced power compensation and optimal power injection simultaneously. Furthermore, as the interaction between the different sequence components of the current in both the stator and the rotor causes oscillating torque leading to mechanical strain on the drive-train, the unbalanced power is compensated by the GSC. The RSC is controlled to adjust the active and reactive power of the stator. The optimal power coefficient is derived based on the steady-state power capability of the DFIG-GSC.

For regulating reactive power in DFIG wind farm, a certain number of DFIG wind turbines are selected according to the up and down limitations to inject the demanded reactive power into the grid.In DFIG wind farm thus can not only generate active power, but also generate or absorb the reactive power to stabilize the grid voltage. The reactive power is mainly controlled in two modes, i.e. power factor control and voltage control. Both the two modes take the point of common coupling (PCC) as the reference point. The voltage or power factor at Point of Common Coupling is detected and it is compared with the reference to calculate the reactive power demanded by the grid. Based on the demanded reactive power and the reactive power the number of DFIGs involved is determined.

## IV. Conclusion

The DFIG framework has a greater number of focal points however high cost than settled speed acceptance generators without converters. Likewise the controllability and execution of DFIG wind turbines are phenomenal. They catch more wind vitality, display a higher dependability adapt framework, and excellent power provided to the matrix. In Modern twist ranches, with an ostensible turbine control up to a few MWs, are a regular instance of DFIG application. Different applications incorporate DFIG frameworks are, flywheel vitality stockpiling framework, remain along diesel frameworks, pumped capacity control plants, or turning converters sustaining a railroad lattice from a consistent recurrence utility matrix.

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