WIND ENERGY CONVERSION SYSTEM

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ABSTRACT: Wind power capacity has experienced tremendous growth in the past decade, thanks to wind power's environmental benefits, technological advance, and government incentives. This paper presents wind energy conversion systems, and their social and environmental benefits. The paper provides, a review of the interconnection issues of distributed resources including wind power with electric power systems.

KEYWORDS: Wind power, Wind generators and Control options.

1. INTRODUCTION

Electricity generation using wind energy has been well recognized as environmentally friendly, socially beneficial, and economically competitive for many applications. Because of crucial fossil energy resources shortage and environmental issues the wind energy is very important resource for electricity production.

WECS Technology

A WECS is a structure that transforms the kinetic energy of the incoming air stream into electrical energy. This conversion takes place in two steps, as follows. The extraction device, named wind turbine rotor turns under the wind stream action, thus harvesting a mechanical power. The rotor drives a rotating electrical machine, the generator, which outputs electrical power.

Wind turbines are classified into two general types: horizontal axis and vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground (Fig 1). A vertical axis machine has its blades rotating on an axis perpendicular to the ground (Fig 2). Today, the vast majority of manufactured wind turbines are horizontal axis with two or three blades, operating either down-wind or up-wind.

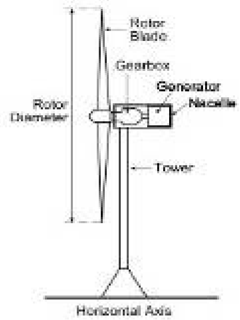

Fig.1

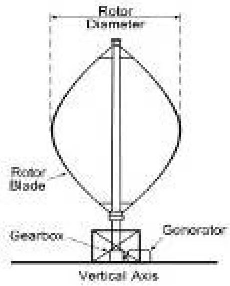

Fig.2

Fig.1 Horizontal axis wind turbine
Fig.2 Vertical Axis wind turbine

PARTS OF WIND TURBINE

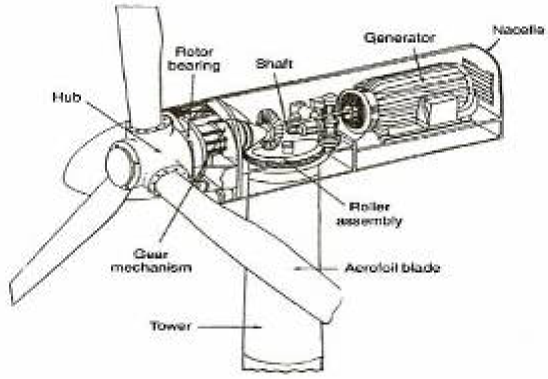

Figure 3. Main elements of a horizontal axis wind turbine

Figure 3 illustrates the major components placement in horizontal axis wind turbine.

A typical wind turbine consists of the following components:

BLADE- An important part of a wind turbine that extracts wind energy.

HUB- Blades are fixed to a hub which is a central solid part of the turbine.

GEAR BOX- Two types of gear box used in wind turbine-

1. Parallel shaft-It is used in small turbines, design is simple, maintenance is easy, high mass material and offset shaft.
2. Planetary shaft- It is used in large turbines, complex design, low mass material and in line arrangements.

BRAKES-Two independent brakes sets or incorporated on the rotor low speed shaft and high speed shaft

The low speed shaft is Hydraulic operated .The high speed shaft is self-adjusted and spring loaded.

NACELLE- The nacelle houses the generator, the gearbox, the hydraulic system and yawing mechanism.

GENERATOR- The conversion of mechanical power of wind turbine into the electrical power can be accomplished by one of the following type of the electrical machine-

1. Synchronous machine

2. Induction machine

TOWER- Towers are made from tubular steel, concrete or steel lattice. Because wind speed is getting higher with the height, taller towers enable turbines to capture more energy and this way generates more electricity.

WIND TURBINE GENERATOR

At the present time and in the near future, generators for wind turbines will be synchronous generators, permanent magnet synchronous generators, and induction generators, including the squirrel cage type and wound rotor type. For small to medium power wind turbines, permanent magnet generators and squirrel cage induction generators are often used because of their reliability and cost advantages. Induction generators, permanent magnet synchronous generators and wound field synchronous generators are currently used in various high power wind turbines. Interconnection apparatuses are devices to achieve power control, soft start and interconnection functions. Very often, power electronic converters are used as such devices. Most modern turbine inverters are forced commutated PWM inverters to provide a fixed voltage and fixed frequency output with a high power quality. Both voltage source voltage controlled inverters and voltage source current controlled inverters have been applied in wind turbines. For certain high power wind turbines, effective power control can be achieved with double PWM (pulse width modulation) converters which provide a bi-directional power flow between the turbine generator and the utility grid.

POWER GENERATION SYSTEM

The electrical power generation structure contains both electromagnetic and electrical subsystems. Besides the electrical generator and power electronics converter it generally contains an electrical transformer to ensure the grid voltage compatibility.

FIXED-SPEED WECS

Fixed-speed WECS operate at constant speed. That means that, regardless of the wind speed, the wind turbine rotor speed is fixed and determined by the grid frequency. Fixed-speed WECS are typically equipped with squirrel-cage induction generators (SCIG), soft starter and capacitor bank and they are connected directly to the grid, as shown in Figure (4).

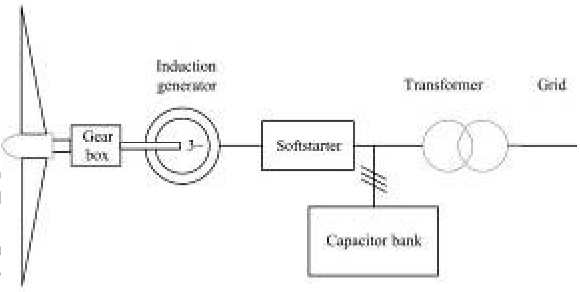

Figure 4. General structure of a fixed-speed WECS

SCIG are preferred because they are mechanically simple, have high efficiency and low maintenance cost. SCIG-based WECS are designed to achieve maximum power efficiency at a unique wind speed. In order to increase the power efficiency Fixed-speed WECS have the advantage of being simple, robust and reliable, with simple and inexpensive electric systems and well proven operation. On the other hand, due to the fixed-speed operation, the mechanical stress is important.

An evolution of the fixed-speed SCIG-based WECS are the limited variable speed WECS. They are equipped with a wound-rotor induction generator (WRIG) with variable external rotor resistance; see Figure 5. The unique feature of this WECS is that it has a variable additional rotor resistance, controlled by power electronics. Thus, the total (internal plus external) rotor resistance is adjustable, further controlling the slip of the generator and therefore the slope of the mechanical characteristic.

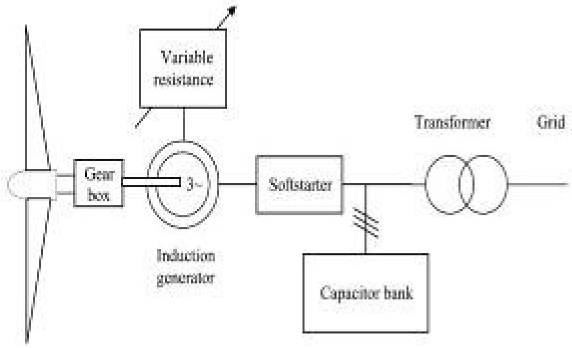

Figure 5. General structure of a limited variable-speed WECS

VARIABLE SPEED WECS

Variable-speed wind turbines are currently the most used WECS. The variable speed operation is possible due to the power electronic converters interface, allowing a full (or partial) decoupling from the grid.

The doubly-fed-induction-generator (DFIG) based WECS (Figure 6), also known as improved variable-speed WECS, is presently the most used by the wind turbine industry.

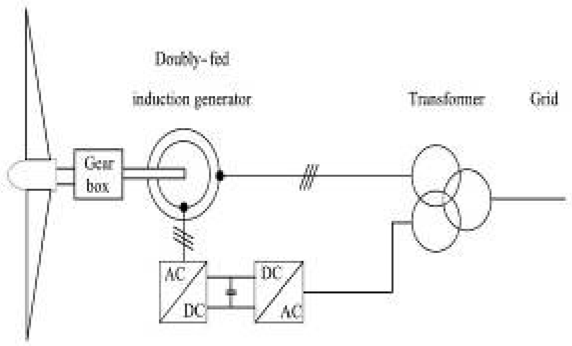

Figure 6. General structure of an improved variable-speed WECS

The DFIG is a WRIG with the stator windings connected directly to the three phase, constant-frequency grid and the rotor windings connected to a back-to-back (AC–AC) voltage source converter. Thus, the term "doubly-fed" comes from the fact that the stator voltage is applied from the grid and the rotor voltage is impressed by the power converter. This system allows variable-speed operation over a large, but still restricted, range, with the generator behavior being governed by the power electronics converter and its controllers. The power electronics converter comprises of two IGBT converters, namely the rotor side and the grid side converter, connected with a direct current (DC) link. The rotor side converter controls the generator in terms of active and reactive power, while the grid side converter controls the DC-link voltage and ensures operation at a large power factor. The stator outputs power into the grid all the time. The rotor, depending on the operation point, is feeding power into the grid when the slip is negative (over synchronous operation) and it absorbs power from the grid when the slip is positive (sub-synchronous operation). In both cases, the power flow in the rotor is approximately proportional to the slip. DFIG-based WECS are highly controllable, allowing maximum power extraction over a large range of wind speeds.

Full variable-speed WECS are very flexible in terms of which type of generator is used. As presented in Figure 4, it can be equipped with either an induction (SCIG) or a synchronous generator. The synchronous generator can be either a wound-rotor synchronous generator (WRSG) or a permanent-magnet synchronous generator (PMSG). The back-to-back power inverter is rated to the generator power and its operation is similar to that in DFIG-based WECS. Its rotor-side ensures the rotational speed being adjusted within a large range, whereas its grid-side transfers the active power to the grid and attempts to cancel the reactive power consumption. The PMSG is a good option to be used in WECS, due to its self-excitation property, which allows operation at high power factor and efficiency. PMSG does not require energy supply for excitation, as it is supplied by the permanent magnets. The stator of a PMSG is wound and the rotor has a permanent magnet pole system. The salient pole of PMSG operates at low speeds, and thus the gearbox (Figure 7) can be removed. This is a big advantage of PMSG-based WECS as the gearbox is a sensitive device in wind power systems. The same thing can be achieved using direct driven multi pole PMSG with large diameter. The synchronous nature of PMSG may cause problems during start-up, synchronization and voltage regulation and they need a cooling system, since the magnetic materials are sensitive to temperature and they can lose their magnetic properties if exposed to high temperatures.

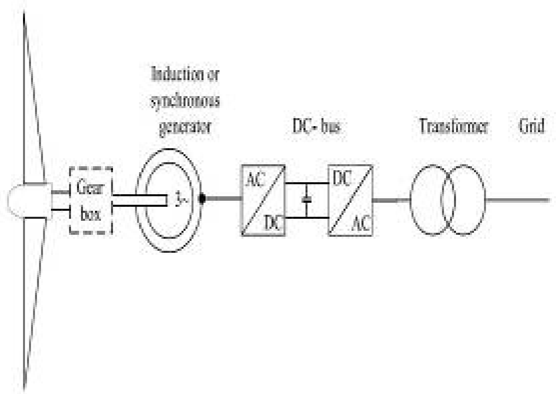

Figure 7. General structure of a full variable-speed WECS

CONTROL OPTIONS

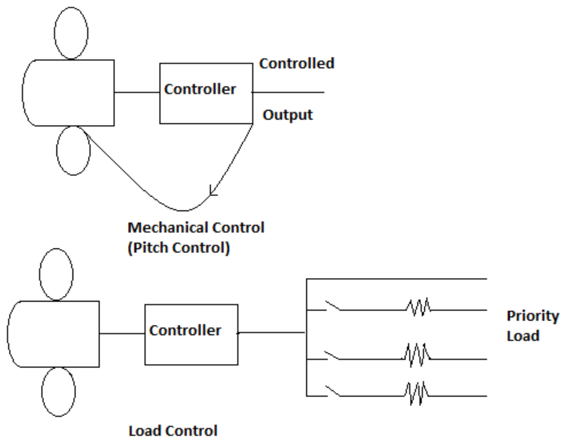

Figure 8. Mechanical control & Load control

Mechanical Control of the turbine blade:
As the wind speed changes the pitch of the blades or blade tip is adjusted to control the frequency of the turbine rotation.
The drawback of this method is that power in the wind is wasted and control method can be expensive and unreliable.
Load control: As the wind speed changes the electrical load is changed by rapid switching, so the turbine frequency is controlled. This method makes greater use of power in the wind because the blade pitch s kept at the optimum angle.

CONCLUSION

Energy crisis calls for a large penetration of renewable energy resources, among which wind energy is a promising one. Voltage and frequency regulation is vital to meet the grid code. This paper has covered many key issues to compose the proposed wind energy system, including the system architecture, control objective, and component design.

Specifically:

1. A family of wind energy system with integrated active power transfer, reactive power compensation, and voltage-conversion capabilities was proposed. Compared with the previous applications which utilize only the active power transfer and voltage-conversion functionalities, reactive power compensation capability is fully investigated.
2. The proposed family of wind energy system was demonstrated in the presence of squirrel-cage induction generators, by far the most demanding case in terms of voltage fluctuation and reactive power demand. Under the SST interface, the WF was rendered free of distribution power transformer and mandatory passive and active static power compensators.
3. Variable-speed WECS is a highly nonlinear time variant system excited by stochastic inputs which significantly affect its reliability and leads to non-negligible variations in the dynamic behaviour of the system over its operating range. This is the reason why the control of variable-speed wind turbines is still in the phase of searching technical solutions suitable to be widely implemented in the wind turbine industry.

However, there are still lots of issues needed to be addressed and thus opens the possible research opportunities:
1. The high voltage and high power system operation is still not fulfilled yet, although there is no technique limitation in this topic.
2. Fault operating condition is not studied yet, which is a key issue in wind energy system. Similar issues, such as how to realize the fault-ride through of the traditional wind energy system, can also be studied in the SST-interfaced wind system.

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