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REVIEW ON WIND ENERGY SYSTEM BASED MICRO GRID FOR REMOTE APPLICATION

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Abstract - In this paper a comprehensive review of a micro grid based on wind energy system has been discussed in detail. An in depth review of the different configuration of generators with their relative merits and demerits also have been considered in this paper. The classification of the generators for Micro Grid suitable for remote area application, their control strategies and Grid interface strategies also has been discussed in detail.

Keywords— Renewable energy, Wind Energy system, Micro Grid

I. INTRODUCTION

The increasing rate of the depletion of conventional energy sources along with increase in the demand of electrical energy have given rise to an increased emphasis on renewable energy sources. Amongst the various renewable energy sources such as Wind Energy, Solar Energy, Biomass etc., wind energy is one of the most promising energy source in Indian context. Due to short gestation periods for installing wind turbines, reliability and performance of wind energy machines, it's a favored choice for power capacity addition in India.
Power contribution by different energy sources in India is shown in table 1.1.

FUEL	MW	PERCENTAGE
Total Thermal (coal, gas and oil)	153847.99	67.40
Hydro (Renewable)	39,623.40	17.36
Nuclear	4,780.00	2.09
RES*	29,989.21	13.14
Total	2,28,240.60	100.00

Table 1.1 - Power Contribution by different sources in India

Renewable Energy Sources (RES) includes Small Hydro Project, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power and Wind Energy. Power contribution by different RES sources in India is shown in table 1.2.

SOURCE	TOTAL INSTALLED CAPACITY (MW)	PERCENTAGE
Wind Power	20,149.50	67.19
Solar Power (SPV)	2,180.00	7.27
Small Hydro Power	3,763.15	12.54
Biomass Power	1,284.60	4.28
Bagasse Cogeneration	2,512.88	8.38
Waste to Power	99.08	0.33
Total	**29,989.21**	**100.00**

Table 1.2 - Power Contribution by different RES sources in India

1.1 An Overview of Wind Power Generation in India

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. Although a relative newcomer to the wind industry compared with Denmark or USA, India has the fifth largest installed wind power capacity in the world. The worldwide installed capacity of wind power reached 197 GW by the end of 2010. China (44,733 MW), US (40,180 MW), Germany (27,215 MW) and Spain (20,676 MW) are ahead of India. However, it is pertinent to note that India recorded highest growth rate in 2009-10 in terms of new wind capacity as compared to other four countries.

The wind generation is increased from 13.06 GW in year 2010 to 20.15 GW in year 2013.Fig. 1 shows the bar representation of wind power generation in India by year.

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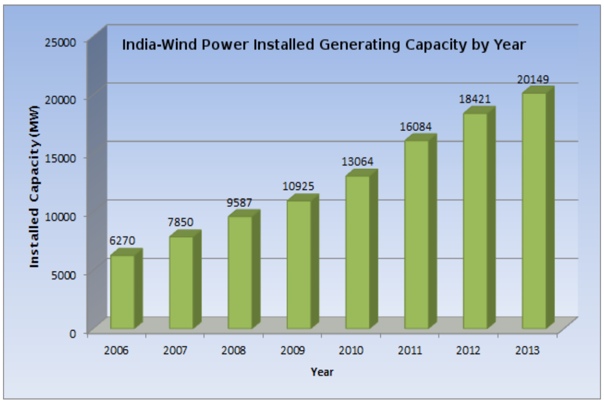

Fig 1.1- Bar Representation of Wind Power Generation in India by Year

The distribution of installed capacity in India is as under: Tamil Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka(2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's Energy need.

II. GENERATORS IN WECS

In conversion of wind power to electrical power generator has a vital role. This led to development of different generators which are used for different configurations of wind energy conversion systems. A classification of most common electric generators in large WECS is presented in the below Fig. 2.1.

Depending on their construction and operating principle, the wind generators are divided in two main groups: induction generators (IG) and synchronous generators (SG). Both induction and synchronous generators have wound rotors, which are fed by slip rings through brushes or by a brush less electromagnetic exciter. The wound- rotor induction generator, also known as the doubly fed induction generator (DFIG) is most commonly used generator in the WECS. The wound rotor synchronous generator (WRSG) is also found in practical WECS with high number of poles operating at low rotor speeds. Squirrel- cage induction generators (SCIG) are widely employed in wind energy systems where the rotor bars are shorted internally. In permanent magnet synchronous generator (PMSG), the rotor magnetic flux is generated by permanent magnets.

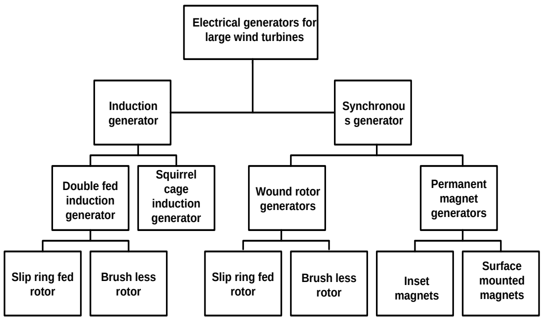

Fig.2.1- Classification of commonly used electric generators used in WECS

Depending on how the permanent magnet is mounted on the rotor, the PMSG can be classified in to surface mounted and inset PMSGs. In surface mounted PMSG the permanent magnets are placed on the rotor surface. Two magnets are evenly mounted on the rotor surface separated by non-ferrite materials between two adjacent magnets. The main advantage of the surface mounted is its simplicity and low construction cost when compared to the inset PMSG. This type of configuration is known as a non-salient pole PMSG. In inset PMSG permanent magnets are inset in to the rotor surface. The saliency is created by the different permeability of the rotor core material and magnets. This type of configuration is known as salient pole PMSG. This type of PMSG can operate at high speeds. Permanent magnet machines are characterized as having large air gaps, which reduce flux linkage even in machines with multi magnetic poles. As a result, low rotational speed generators can be manufactured with relatively small sizes with respect to its power rating. Moreover, gearbox can be omitted due to low rotational speed in PMSG wind generation system resulting in low cost. PMSG wind generation system can supply more reactive power to the network than that of DFIG.

CLASSIFICATION OF WECS

As already mentioned different configurations of WECS are evolved to make WECS more reliable. The different configurations are evolved based on the type of control, wind turbine used and they are classified as follows

Classification based on the WT.

- Horizontal axis wind turbine
- Vertical axis wind turbine

Classification based on the aerodynamic power control

- Stall controlled WECS.(blade position is fixed)
- Pitch controlled WECS. (blades are turned out of the wind)
- Active stall controlled WECS.(blade angle is adjusted)

Classification according to the speed control of WECS

The classification is done according to the collection of maximum wind power at wind speeds i.e. if the available WECS is able to draw only at one particular speed then we name it as fixed speed. If not it is able to draw maximum power at different speeds using different techniques then it is named as the variable speed WECS.

a. Fixed speed WECS.
b. Variable speed WECS.
   i. Limited variable speed.
   ii. Variable speed with partial scale frequency converter.
   iii. Variable speed with full scale frequency converter.

III. CONTROL STRATEGIES

The synchronous generators can be controlled by number of methods to achieve different objectives.

- For instance, the d-axis stator current of generators can be set to zero during the operation to achieve a linear relationship between the stator current and electromagnetic torque. This type of control is ZDC control
- Another one is the generator can be controlled to produce maximum torque with a minimum stator current this type of control is maximum torque per ampere (MTPA) control.
- Another approach is to operate the system with unity power factor called unity power factor control.

INDUCTION GENERATOR

An induction generator is a type of electrical generator that is mechanically and electrically similar to an induction motor. To excite the generator, external reactive supply is required, which can be supplied from the electrical grid or from the externally connected capacitor bank.

CLASSIFICATION OF INDUCTION GENERATORS

✓ CLASSIFICATION BASED ON EXCITATION PROCESS
   ✓ Grid connected induction generator
   ✓ Self-excited induction generator

✓ CLASSIFICATION BASED ON PRIME MOVERS
   ✓ Constant speed constant frequency
   ✓ Variable speed constant frequency
   ✓ Variable speed variable frequency

✓ CLASSIFICATION BASED ON ROTOR CONSTRUCTION
   ✓ Wound rotor induction generator
   ✓ Squirrel cage induction generator

In standalone induction generators, the magnetizing flux is established by a capacitor bank connected to the machine and in case of grid connected, it draws magnetizing current from the grid. A detailed study of the performance of the induction generator operating in various modes during steady-state and various transient conditions is important for the optimum utilization of the renewable resources, which may be scarce or intermittent. The steady-state performance is important for ensuring good quality power and assessing the suitability of the configuration for a particular application, while the transient condition performance helps in determining the insulation strength, suitability of winding, shaft strength, value of capacitor, and devising the protection strategy.

Parameter	Induction generator	Doubly fed induction generator	Synchronous generator	Permanent magnet Synchronous generator
Application	Medium voltage, fixed speed	Low and Medium voltage, variable speed	Low voltage, fixed and variable speed	Medium and high voltage, variable speed
Gear box	Needed	Needed	Elimination possible	Not needed
Speed range	Full	Limited	Full	Full
Efficiency	Low	Higher	High	Higher
Reactive Power Compensation	Complete, need auxiliary reactive power	Complete	Complete	Complete
Converter	Full rated	Fractional rated (~25%)	Full rated	Full rated
Complexity	Brushless, low maintenance	Slip ring and brushes	With brushes/ Brushless, heavy	Permanent magnet, heavy
Cost	Low	Low	Medium	High

Table 3.1- Comparison of Various Electrical Generators

POWER ELECTRONIC INTERFACE

In its simplest form, wind power generation system is a combination of wind turbine, an electrical generator and a power electronic interface. Selection of a power electronic interfacing device not only depends on the wind turbine, but also on the power system operation, when it is connected to the grid.

Fig.4 represents a generalized power electronic interface inserted between renewable energy system and grid / load. The renewable energy system sends power at variable voltage and frequency through the power electronic interface, which processes the power and provides output at required voltage and frequency to be supplied to the grid / load.

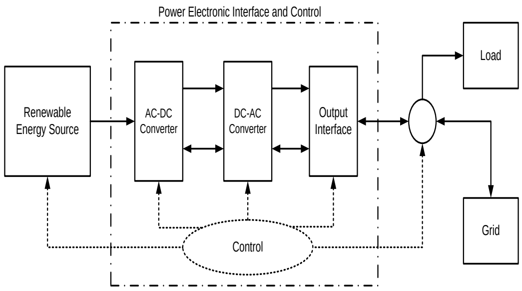

Fig.3.1- Generalized diagram of power electronic interface

Power electronic interface topologies available with wind power generation systems are -

- Voltage fed converter
- Rectifier-inverter converter
- Rectifier-chopper converter
- Rectifier-boost converter

IV. CONCLUSIONS

By considering all the analysis discussed in the previous sections configuration of the WECS is justified as follows. Variable speed wind turbines have shown better performance related to voltage fluctuation in comparison to fixed speed wind turbines. The reason is that variable speed operation of the rotor has the advantage that the sharp power variations are not transmitted to the grid due to the presence of interfacing converters. This made to choose variable speed wind turbines.

Controlling of the WECS involves the control of the wind energy system, generator control, and reactive power control. In a typical WECS the wind energy system employs pitch angle control system to avoid the power fluctuations and optimal torque control for MPPT. The generator is controlled by the generator side rectifier which employs maximum torque per ampere method for achieving maximum torque for the generator. The grid side inverter controls the grid voltage and the dc link voltage. A chopper can be employed at the dc link to provide fault ride through capability for the WECS.

Recently, the induction generators have been widely employed to operate as wind-turbine generators and small hydroelectric generators of an isolated power system. Stand-alone generator systems are used in a wide variety of situations such as remote area power supplies, lighting, transportation, life support systems, and communications.

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