Wind Turbine System Connected To A Permanent Magnet Synchronous Generator : A Review

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Abstract- *In today's world electricity generation using renewable sources are more popular. It includes sunlight, wind, biomass, rain, tides, waves and geothermal heat etc. This paper presents a review of wind turbine system for extracting wind power and convert the kinetic energy of wind to electrical energy using different types of generators and the main focus is on permanent magnet synchronous generator (PMSG) with various controlling techniques.*

Keywords- Doubly fed induction generator (DFIG), Maximum power point tracking (MPPT), Permanent magnet synchronous generator (PMSG), and Wind turbine generator (WTG).

I. INTRODUCTION

This a Wind power has an important role in the future energy in many regions across the world. Where wind energy is one of the most important permanent clean energy sources. For extracting power from such system, a systematic arrangement is needed in which it consists of wind turbine, generators, power electronics equipment's and load.

Wind turbine is a device that converts kinetic energy into electrical energy. It is manufactured in a wide range of vertical and horizontal axis types. Generally the smallest turbines are used as battery charging for auxiliary power for boats or caravans or to power traffic warning sign. Large turbines can be used for making contributions to domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms.

In electricity generation, generator is a device that converts mechanical power into electrical power. In variable speed wind energy system used generators are squirrel cage induction generators, doubly fed induction generator, wound rotor induction generator and permanent magnet synchronous generator. Permanent magnet synchronous generator is more suitable for energy conversion system because of self-excitation property, operation at high power factor, low cost and small size compared to all other generators. It is a synchronous generator where the excitation field is provided by a permanent magnet instead of coil.

II. LITERATURE SURVEY

Power generation by renewable energy sources is becoming more popular and economical than the traditional generation system to supply reliable power in areas not served by conventional power grids. The demand of global energy in 2040 will expand to be about 30% higher than in 2010[1].

In the last fifteen years the penetration of the wind turbine power generation is dramatically increased world-wide [2]. The wind turbine system is one of the most known and used source of renewable energy. It has not only a several environmental and economic advantages, but also, it can be installed in all regions. The wind turbine system produces the electrical energy from the wind speed after converting it to mechanical energy by the generator. Meanwhile, we can find several types of generators such as the permanent magnet synchronous generator (PMSG) [3] [4], squirrel-cage induction generator (SCIG) [5] [6], doubly fed induction generator (DFIG) [7] [8] [9] [10], and wound rotor induction generator (WRIG). While, the PMSG generator is known by its reliability, efficiency, low cost and small size compared to SCIG, DFIG and WRIG.

The wind energy control system that is under consideration is a direct-drive system i.e. without gearbox and includes a wind turbine, multi-pole permanent magnet synchronous generator (PMSG) and pulse-width modulation (PWM) based fully controlled power converter with buck boost converter in the DC bus as shown in fig.1. The use of buck-to-buck pulse width modulation full power converter insures that the generator currents and the grid currents are sinusoidal. Moreover, the generator side converter is controlled to achieve maximum power extraction. In partial load region, WECS is controlled by means of MPPT algorithm which maximizes the energy captured by the turbine from the wind's kinetic energy. Many literature shows various kind of maximum power point tracking algorithm, which globally can be classified into two categories, based on whether direct wind speed measurement is taken as input or not: a) Sensor-less

MPPT Control, b) With Sensor MPPT control While dealing with a direct-drive system using PMSG generator, a sensor-less MPPT control is found to be suitable for variable wind speed conditions, as the wind speed is a constantly changing parameter, and measuring it with some sensor will give unstable reading, which will make it difficult to perform the further control calculations. So this paper presents various control techniques that are used in wind turbine control algorithms in variable speed wind turbine system with drive-less PMSG [11].

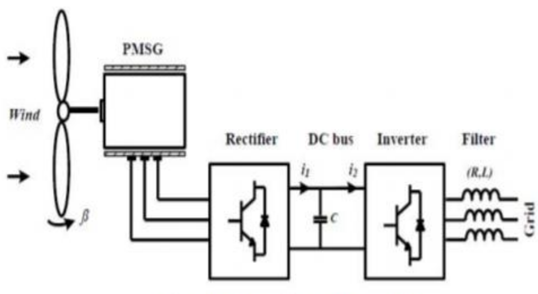


Fig 1- Wind Turbine Systems [11]

Fig. 2 shows the small wind turbine market segmentation: the maximum number of manufacturers in Europe corresponds to stand alone wind applications with a maximum wind turbine size of 20 kW, but the average wind penetration rate is maximum in the pumping field. It is possible to observe that the maximum wind turbine size increases in the case of wind diesel system with battery, and the maximum wind turbine size increases in case of grid connection. The field of small generation was dominated by the use of asynchronous generators directly connected to the grid/load and more recently by Permanent Magnet Synchronous Generators (PMSG) with a diode rectifier, boost converter and inverter [12].

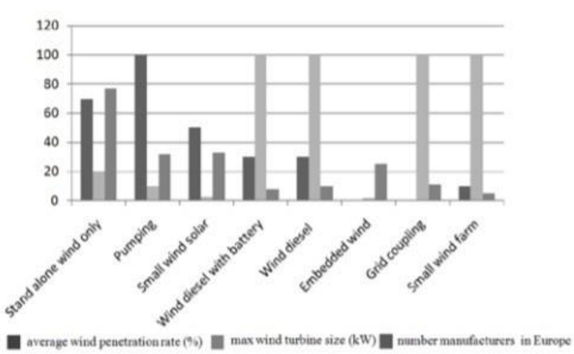


Fig 2 small wind market segmentation

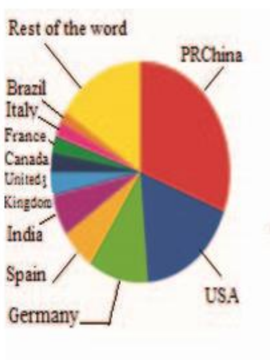
Further here is a complete overview about the main control issues in small wind turbine systems. The overall system is analyzed both on wind source-side and on grid-side, focusing on the main power converters configurations. Looking at the source-side, it results that the most critical issues are: sensor less operation of the generator and power limitation. Sensor less operation can be based on a Phase Locked Loop, but special care is required in the design since when the converter starts to switch it produces a voltage at the point of connection of the PMSG and the phase lock loop gets synchronized with it, as a consequence an error in the rotor position occurs and it should be estimated and properly compensated. About power limitation, it is highlighted that two systems for limiting the power in excess, one mechanical (the pitch controller) and the other one electrical (the braking chopper), may interact. In fact in small power wind turbine systems their time constants can be similar and the controller should be proper designed. Looking at the grid-side, an innovative concept of “universal” wind turbine is expressed. It relies on ensuring that the wind turbine system can work grid-connected but also with the possibility to switch to island-operation and even support local loads during grid voltage variation. A proper grid-side converter control design, together with a coordinated static transfer switch which operates the connection and disconnection to/from the grid, can fulfill this aim [12].

Wind turbine generator are usually equipped with mechanical sensors to measure wind speed and rotor for system controlling, monitoring, and protection. The use of mechanical sensors increases the cost and hardware complexity and reduces the reliability of wind turbine generator systems. So here presents a mechanical sensorless maximum power tracking control for wind turbines directly driving PMSG .In the proposed algorithm, the PMSG rotor position is estimated from the measured stator voltages currents by using a sliding mode observer. The wind turbine shaft speed is estimated from PMSG back electromotive force using a model adaptive reference system observer. A back propagation artificial neutral network is designed to generate the optimal shaft speed reference in real time by using the estimated turbine shaft speed and the measured PMSG electric power. A control system developed for PMSG wind turbine to continuously track the optimal shaft speed reference to generate the maximum electrical power without using any wind speed or rotor position sensors [5].

As wind power generation undergoes rapid growth, new technical challenges emerge like dynamic stability and power quality. The transient stability of variable speed wind turbines with PMSG/full power converter topology has been used and the controllers used in converters are PI controllers. Pulse width modulation by space vector modulation associated with sliding mode is used for controlling the converters.

The sliding mode control strategy presents attractive features such as robustness to parametric uncertainties of the wind turbines and the electrical machines as well as to electrical grid disturbances. Sliding mode controllers are particularly interested in systems with variable structure, such as switching power converters, guarantees the choice of the most appropriate space vectors. Their aim is to let the system slide along a predefined sliding surface by changing the systems structure. And considering not only wind speed disturbances, but also a pitch control malfunction. And the current THD for wind power system with multilevel converter is much lower than 5% limit imposed by IEEE 519 standard [13].

The dynamic modelling and control approach of a wind farm with variable speed direct- driven PMSG WTGs for dynamics studies in DG systems has been presented. The proposed wind farm modelling approach groups all WTGs that experiences similar wind velocities into an equivalent aggregated WTG model. The simplified modelling is developed using the state-space averaging technique. In addition, a three-level control scheme is designed [14].
According to the recent data, cumulative capacity of installed wind turbine in 2015 is shown in fig 3.



Country	MW	% SHARE
PR CHINA	114.609	31.0
USA	65.879	17.8
Germany	39.165	10.6
Spain	22.987	6.2
India	22.465	6.1
United Kingdom	12.440	3.4
Canada	9.694	2.6
France	9.285	2.5
Italy	8.663	2.3
Brazil	5.939	1.6
Rest of the world	58.473	15.8
Total Top 10	311.124	84.2
World Total	369.597	100

Fig. 3 Cumulative capacity of installed wind turbine in 2015 [15]

A dynamic modelling and simulation of a small wind turbine connected to PMSG and to the AC load as shown in fig.4. [16]

fig.4

In this paper PMSG is controlled by a zero d-axis current control scheme is applied, where the d-axis stator current of the generator is set to zero is shown in fig.5. [16]

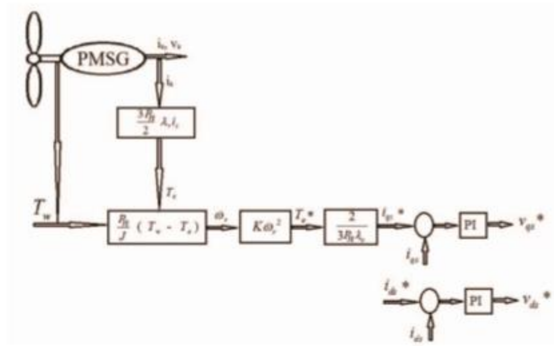


Fig.5. ZDC control scheme of the PMSG generator.

III. CONCLUSION

In this paper an overall review of wind turbine system with direct-driven PMSG generator connected to the distribution grid/AC load is carried out. And different controlling strategies for PMSG generator is reviewed. Mainly the whole study is based on PMSG generator because it is known by its reliability, efficiency, low cost and small size compared to the other generators.

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