Analysis and comparisons of different type of WECS- A literature Review

Sushant Gaur[1], Ravinder Choudhary[2], Kamal Kumar Sharma[3]

[1]Student, M. Tech, ESSEAR, Ambala

[2]Assistant Professor, Dept. of EE, E-Max group of Institutions, Ambala

[3]Professor, Dept. of ECE, E-Max group of Institutions, Ambala

Abstract— **With very rapid development of wind power technologies and significant growth of wind power capacity installed worldwide, various wind turbine concepts have been developed. The wind energy conversion system is required to be more cost-competitive, so that comparisons of different wind generator systems are necessary. A literature review of different types wind energy conversion systems is presented. First, the modern wind turbines are described with respect to both their control features and drive train types, and their advantages and disadvantages are described. Then, the quantitative comparison and market penetration of different wind generator systems are presented. The promising permanent magnet generator types are also investigated. After that the ongoing trends of wind generator systems and related comparison criteria are discussed.**

Keywords— **Doubly-fed induction generator (DFIG), protection, wind power generation, wind energy conversion system, renewable energy sources**.

I. Introduction

India has tremendous energy needs and an increasing difficulty in meeting those needs through traditional means of power generation. On July 30th and 31st, 2012 the world's largest blackout, The Great Indian Outage, stretching from New Delhi to Kolkata occurred. This blackout, due to failure of the northern power grid, caused nearly 700 million people twice the population of the United States to be without electricity. Because of the of decreasing sources of conventional energy we cannot depend on them for long period. For economic as well as environmental reasons India needs to shift to non-polluting renewable sources of energy to meet future demand for electricity. Renewable energy is the most attractive investment because it will provide long-term economic growth for India. A favorable renewable energy policy could create millions of new jobs and an economic stimulus of at least US$1 trillion, and perhaps much more if all indirect economic (ripple) effects are included.

WECS is one of the most attractive options among all the RES. According to MNRE's achievent report, The cumulative installed capacity of Grid Interactive Wind Energy in India by the end of September 2011 was 14989MW (of which 833MW was installed during 2011-2012 against a target of 2400MW). Aerogenerators and hybrid systems contributed 1.20MW during 2011-12 to yield cumulative off-grid wind capacity of 15.55MW. In 2008, India shared 6.58% of total wind energy installed capacity around the world, according to World Wind Energy Report-2008. According to GSR-2011, the world witnessed highest renewable energy installations through wind energy. Total installed capacity of wind energy reached 198GW by the end of 2010. India ranked third in the world in annual capacity additions and fifth in terms of total wind energy installed capacity. India has been able to fast pace its growth in wind energy installations and bring down costs of power production. The GSR 2011 reported on-shore wind power (1.5-3.5MW; Rotor diameter 60-100m) at 5-9 cents/kWh and off shore wind power (1.5-5MW; Rotor diameter 75-120m) at 10-20 cents/kWh. But India's onshore wind power cost reached 6-9cents/kWh in 2008 itself (Indian Renewable Energy Status Report-2010). It is clear that the Indian market for the electrical power produced by wind turbine generators has been increasing steadily, which directly pushes the wind technology into a more competitive area.

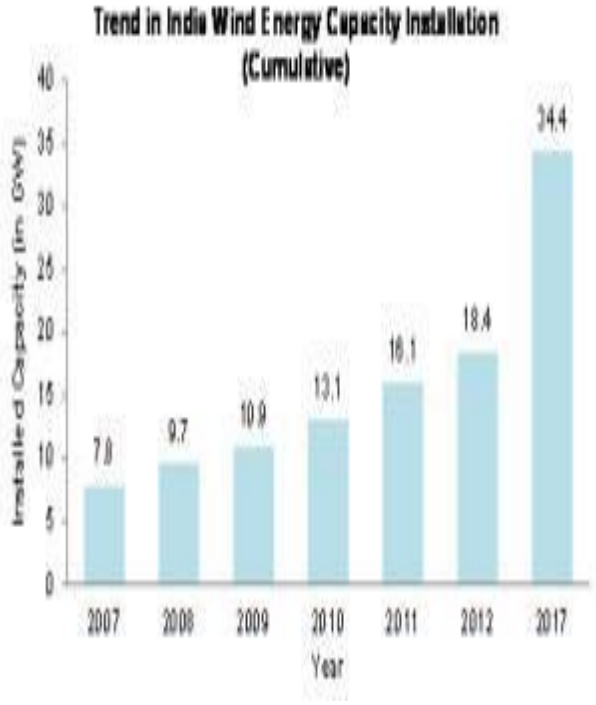
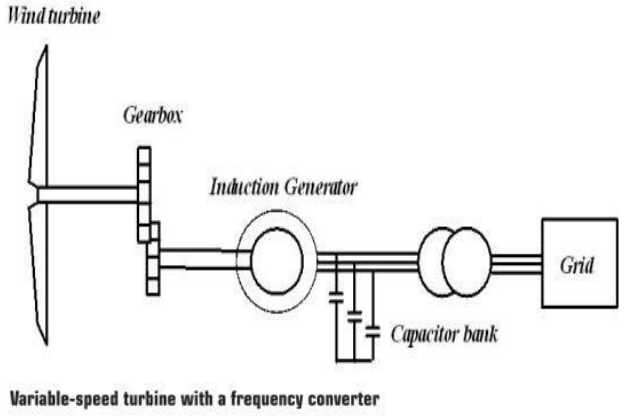


Fig-1 Trend of wind energy installation in India.

The purpose of this paper is to provide an overall perspective on various types of existing wind generator systems and possible generator configurations, and some comparisons of different wind generator systems in literatures and in the market. Finally, the trends and developments of wind generator systems are presented, and suitable comparison criteria of different wind generator systems are also discussed.

II. WIND TURBINE CONCEPTS AND GENERATOR TYPES

Referring to the rotation speed, wind turbine concepts can be classified into fixed speed, limited variable speed and variable speed. For variable speed wind turbines, based on the rating of power converter related to the generator capacity, they can be further classified into wind generator systems with a partial scale and a full-scale power electronic converter. In addition, considering the drive train components, the wind turbine concepts can be classified into geared drive and direct-drive wind turbines. In geared-drive wind turbines, one conventional configuration is a multiple-stage gear with a high-speed generator; the other one is the multibrid concept which has a single stage gear and a low-speed generator [1].



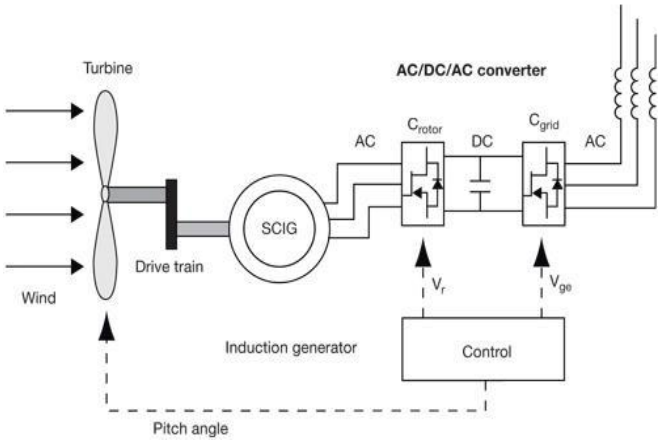


Fig-2 Fixed and variable speed WECS.

III. COMPARISON OF DIFFERENT WECS

Some comparisons of different wind generator system have been conducted by some researchers [1-7].

Grauers [3] has presented a quantitative comparison the variable speed direct-drive concept of the RFPM generator system with a forced-commutated rectifier and the commercial product of the fixed-speed concept with SCIG. Some main parameter comparisons for two rated power levels of 500 kW and 3 MW are respectively, shown in Table 1.

Generators concepts	PMSG	SCIG	PMSG	SCIG
Rated power, kW	500	500	3000	3000
Outer diameter of generator, m	2.7	1.5	5	2.5
Length of system (incl. high-speed shaft in SCIG)	1.2	3	2	6
Average efficiency, %	90.7	88.4	91.6	90.0

Table -1 Comparison of the direct-drive PMSG and the fixed speed concept of SCIG system [3].

Some comparisons between the direct-drive PMSG and the geared-drive traditional SCIG of commercial 500 kW wind turbines have been performed by Annon. [7].

From the paper [8] it is observed that the annual energy production of the direct-drive PMSG is higher than at of the geared-drive conventional SCIG. Although the wind turbine rotor diameter of the direct-drive PMSG is greater than that of the geared-drive SCIG, the total weight of the rotor and nacelle is lower; it seems realistic to conclude that the total weight of the two alternative systems will be of the same order. A 1.5 MW direct-drive wind turbine system with EESG has been compared with the DFIG system with a multi-stage gearbox by Siegfriedsen and Bo¨hmeke [1] and Bo¨hmeke et al. [8]. They concluded that the direct-drive system would be more expensive and heavier than the DFIG wind turbines. In addition, the comparison between the direct-drive PMSG and EESG shows the cost for active material of PMSG is lower.

IV. MARKET PENETRATION OF DIFFERENT WIND TURBINE CONCEPTS

Various types of wind turbines have been on the market with different power levels. In order to present the trends of different wind generator systems on the market, Table 2 shows some wind turbines with a rated power over 2 MW from different manufactures, such as Vestas, Gamesa, GE wind, Repower, Nordex and so on, where the wind turbine concept, generator type, rated power and turbine rotor speed are obtained from manufacturers' websites [9-12].

Wind turbine concept	Generator type	Power/rotor diameter/ speed	Manufacturer
variable speed multiple-stage concept with partial-scale power converter	DFIG	4.5 MW/120 m /14.9 rpm	Vestas
2 MW/90 m/19 rpm		Gamesa	
3.6 MW/104 m/		GE Wind	

15.3 rpm			
5 MW/126 m/12.1 rpm		Repower	
2.5 MW/90 m/ 14.85 rpm		Nordex	
3 MW/100 m/ 14.25 rpm		Ecotecnia	
limited variable speed with multiple-stage gearbox	WRIG	2 MW/88 m/17 rpm	Suzl on
variable speed multiple-stage gearbox with full-scale power converter	SCIG	3.6 MW/107 m/13 rpm	GE wind
variable speed single-stage gearbox with full-scale power converter	PMSG	5 MW/116 m/14.8 rpm	Mult ibird

Table 2 Large wind turbine concepts on the market over 2 MW.

V. TRENDS DISCUSSION

With rapid development of wind turbine technologies, future trends in the wind turbine industry will probably be focused on the gradual improvement of already known technologies, which can be summarized as follows [13-16].

- The power level of a single wind turbine will continue to increase, because this reduces the cost of placing wind turbines, especially for offshore wind farms.
- Offshore wind energy is more attractive, because of higher wind speed and more space than on shore wind energy.
- An increasing trend is to remove dispersed single wind turbine in favour of concentrated wind turbines in large wind farms.
- An increasing trend in the penetration of wind power into the power system.

VI. CONCLUSIONS

The paper provides an overview of different wind turbine concepts and possible generator types. The basic configurations and characteristics of various wind generator systems based on contemporary wind turbine concepts are described with their advantages and disadvantages. The promising direct-drive PM machines, such as AFPM, RFPM and TFPM machines, have been surveyed. A detailed analysis has been performed based on the survey of the quantitative comparison of different wind generator systems as well as their market penetration. The developing trends of wind generator systems have been presented, and some comparison criteria have
also been discussed. The multiple-stage geared drive DFIG concept is still dominant in the current market. Additionally, the market shows interest in the direct-drive or gear drive concepts with a full-scale power electronic converter. Current developments of wind turbine concepts are mostly related to offshore wind energy; variable speed concepts with power electronics will continue to dominate and be very promising technologies for large wind farms. The performance of PMs is improving and the cost of PMs is decreasing in recent years, which make variable speed direct-drive PM machines with a full-scale power converter more attractive for offshore wind power generations. With the increasing levels of wind turbine penetration in modern power systems, grid connection issues have posed several new challenges to wind turbine design and development. The future success of different wind turbine concepts will strongly depend on their ability of complying with both market expectations and the
requirements of grid utility companies.

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