Over View of Hybrid Excitation of Synchronous Generator for Wind Turbines

Heshw Nassradin M.A.[1] & Ghamgeen I. Rashed [2]

[1]Electrical Engineering Department – University of Sulaimani, heshwnassradin@gmail.com

[2] Electrical Engineering Department – University of wuhan, ghamgeen@whu.edu.cn

Abstract:

The generation of energy from wind power is sustainable and environment-friendly, since its use does not require any external energy sources such as coal, oil or gas and does not contribute to global warming. The principle of extraction is based on converting the kinetic energy of air currents into mechanical rotating energy, and that in turn into electricity. Synchronous Generators are one of the most common types of generators used it wind turbines. A hybrid excitation of synchronous generators for wind turbines will be discussed in this report, which combines the two main types of synchronous generators; electrically excited and permanent magnet synchronous generators.

Keyword: Wind Turbine, Hybrid Excitation, Synchronous Generator.

1. Introduction:

The continuously rising energy demand of the modern society and its implications on climate change have led to a significant number of technological efforts and a place to renewable energies. Figure 1. Shows the numbers of yearly capital investment into renewable energies (large scale hydro-power and traditional biomass are not included) from 2004 to 2009. A prominent source of renewable energy is wind energy, which has concerned a lot of attention in the current years. By the end of 2009, the global capacity of wind energy power plants has gotten 158 GWatt.

There are certain demands and conditions put on the electrical machines and drives that are used to produce electricity. For example, the mechanical energy from renewables injected into electrical machines is neither predictable nor controllable. And this challenge has led to a number of technical developments in both induction machines and lasting magnet synchronous generators. These technological developments and their economic feasibility has been continuously shaping the wind energy market.

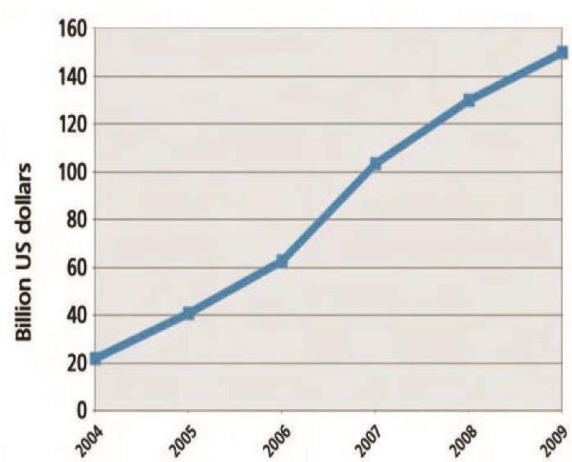

Fig 1. Source power range from 2004 – 2009 in $ [1]

In this paper, the principles of wound rotor synchronous machines (WRSM) and permanent magnet synchronous machines (PMSM) will be discussed, along with their advantages and disadvantages, and hybrid excitation synchronous generators, which combine the advantages of both WRSM and PMSM.

2. Wind Turbines

Wind turbines can be categorized according to two different principles; their aerodynamic occupation and their design. In terms of the aerodynamic recital, wind turbines are subdivided into drag-based and lift-based. Drag based wind turbines utilize the drag power of wind and are identified as low speediness turbines. And lift based turbines, which employ the lift force of wind as well, are identified as high speediness turbines and are able of absorbing advanced quantity of wind energy in comparison to drag based turbines, which is why they are most commonly used as a solution today. [1]

Sort of Wind turbine

Wind turbines can be isolated into two kinds based by the pivot in which the turbine turns.

1- Horizontal Axis Wind Turbines are commonly used:

Even horizontal axis wind turbines (HAWT) have the principle rotor shaft and electrical generator at the highest point of a pinnacle, and should be pointed into the wind. Most have a gearbox, which transforms the lethargic pivot of the edges into a speedier turn that is more reasonable to drive an electrical generator. Since a pinnacle produces choppiness behind it, the turbine is generally pointed upwind of the pinnacle. Turbine edges are made firm to keep the sharp edges from being driven into the pinnacle by high wind. Also, the edges are set an extensive distance before the pinnacle and are some of the time shifted up a modest quantity. Downwind machines have been worked, notwithstanding the issue of disturbance, since they needn't bother with an extra instrument for keeping them in accordance with the wind, and on the grounds that in high breezes the edges can be permitted to twist which diminishes their cleared zone and subsequently their breeze opposition. Since cyclic (that is monotonous) choppiness may prompt exhaustion disappointments most HAWTs are upwind machines.

2-Vertical-Axis Wind turbines are less oftentimes utilized.

Vertical axis wind turbines (or VAWTs) have the primary rotor shaft masterminded vertically. Key preferences of this plan are that the turbine shouldn't be pointed into the wind to be compelling. This is a favorable position on locales where the wind heading is exceptionally factor. VAWTs can use twists from changing headings. With a vertical pivot, the generator and gearbox can be put close to the ground, so the pinnacle doesn't have to help it, and it is more available for upkeep. Disadvantages are that a few plans produce throbbing force. Drag might be made when the edge pivots into the wind.

The main types of wind turbine generators and their subdivisions are listed as follows:

1. AC Asynchronous (Induction) Generators:
    - Squirrel Cage Induction Generator (SCIG)
    - Wound Rotor Induction Generator (WRIG)
    - Doubly-Fed Induction Generator (DFIG)
2. AC Synchronous Generators
    - Electrically Excited Synchronous Generator (EESG)
    - Permanent Magnet Synchronous Generator (PMSG)

2.1. Synchronous generators:

Synchronous generators are mostly preferable for direct drive applications with low rotational speed and high torque rating conditions. The topologies utilizing synchronous generators require full scale power conversion and have higher expected efficiency and energy yield. The aspiration of abandoning gearboxes and their efficiency and maintenance drawbacks is one of the ideas that led to the utilization of synchronous generators in wind turbines. [2]

One of the relatively recent technological advancements in wind turbines is the hybrid excitation of synchronous generators, which is subject to numerous scientific study and literature. The several terms that are used to label electrical machines that utilize two excitation flux sources are:

- Hybrid excitation synchronous machines
- Double excitation synchronous machines
- Dual excitation synchronous machines
- Combined excitation synchronous machines
- Permanent magnet synchronous machines with auxiliary exciting windings

2.2. Wound Rotor and Permanent Magnet Synchronous Machines:

As the name suggests, Wound Rotor Synchronous Machines (WRSM) have windings around the slots of their rotors. They have a robust design but also require a power supply system at the rotor. They offer a simple flux control by acting on the excitation current [3]. However, the presence of rotor windings leads to higher copper losses and therefore a drop in efficiency.

Permanent Magnet Synchronous Machines (PMSM) are more common due to their high power and torque-to-weight ratio and have a noticeably higher efficiency as compared to WRSMs. The permanent magnet allows them to have a constant magnetic flux [4] and no copper loses. They see many industrial applications, such as power generation, due to their broad power range [4]. Furthermore, they come with low maintenance cost due to the lack of slip rings and brushes. However, complicated control algorithms and high-price are major drawbacks, especially in high power applications [5]. See Table 1. for a summary of this section.

Generator		Efficiency	Reliability	Cost		
				Investment	Maintenance	Power Converter
Squirrel Cage Induction Generator		Low	High	Low	Low	-/+++
Wound rotor Induction Generator		Low	Low	Low	High	N/A
Doubly Fed Induction Generator		Low	Low	Low	High	Medium
Electrically Excited Synchronous Generator	Direct Drive	Medium	Low	High	High	High
	Geared	Medium	Low	Medium	High	High
Permanent Magnet Synchronous Generator	Direct Drive	High	High	High	Low	High
	Geared	High	High	Medium	Low	High

Table 1. Comparison of generator topologies (+: Low, ++: Medium, +++: High, -: N/A).

2.3. Hybrid Excitation Synchronous Generators:

A few half hybrid excitation synchronous generators have been accounted for in the logical and specialized writing [6] [7]. According to the combination of the flux, they are divided into the following groups:

1) series hybrid excitation.

2) parallel hybrid excitation.

2.3.1. Series Hybrid Excitation Synchronous Generators:

In this group, excitation coils and the permanent magnets are connected in series together [Fig. 2]. The flux created by the excitation coils passes through the permanent magnets. These types of machines come with their own drawbacks; risk of demagnetization and high averseness of the excitation coil's magnetic circuit, which can be attributed to the magnetic properties of the permanent magnet (their permeability is close to that of air).

In figure 2 there are two machines that have a place with this group [6]. In Figure. 2(a) both the excitation coils and permanent magnets are located in the stator, which implies the presence of sliding contacts in the machine [6]. Whereas in Figure. 2(b) both of them are located in the stator, avoiding sliding contacts. In terms of simplicity, the rotor in this structure resembles the rotors in switched reluctance machines [8].

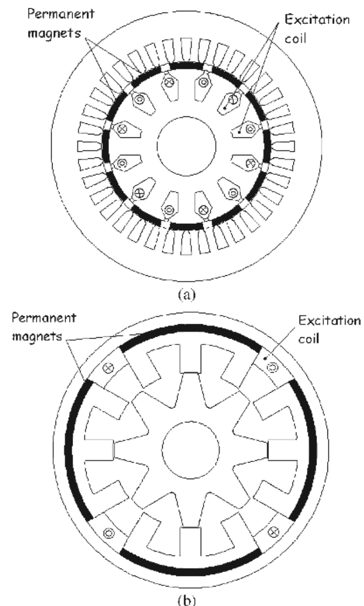

Fig2. Series Hybrid Excitation Synchronous

2.3.2. Parallel Hybrid Excitation Synchronous Generators:

In these machines, the excitation flux made by the permanent magnet, besides the excitation coil both have various directions. The magnetic flux from the excitation coil doesn't go through the permanent magnet. In comparison to series hybrid excitation synchronous machines, a wide variety of structures can be realized with this group.

Figure 3. and Figure 4. show a number of constructions dependent on this rule. In both Figure 3. (a) and 3. (b) both sources are put in the rotor, which combines two excitation flux sources. Although this may have its own advantages, it comes with drawbacks as well. For example, the machine in Figure 3(b) needs an outer yoke to channel wound field, and it lead to the increasing the weight of the machine.

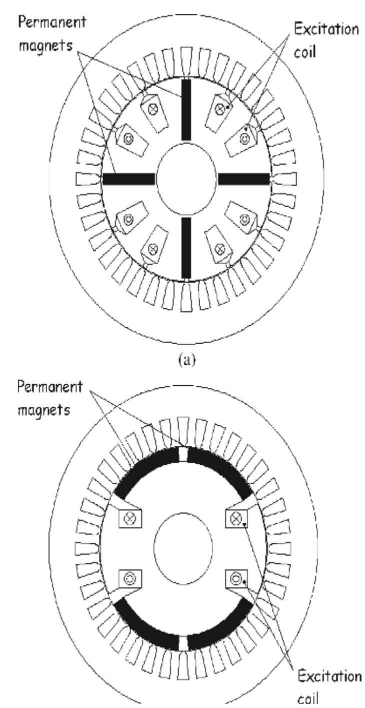

Fig 1: Parallel Hybrid Excitation Synchronous

In Figure 4. (a) the excitation coils and the permanent magnets are placed in the stator, but in Figure 4. (b) only the excitation coil is located in the stator, while the permanent magnet is located in the rotor. All of the previous mentioned structures are of the radial flux machine type, but the hybrid excitation principle is not only constrained to this type. And we have axial flux parallel hybrid excitation machines [9]

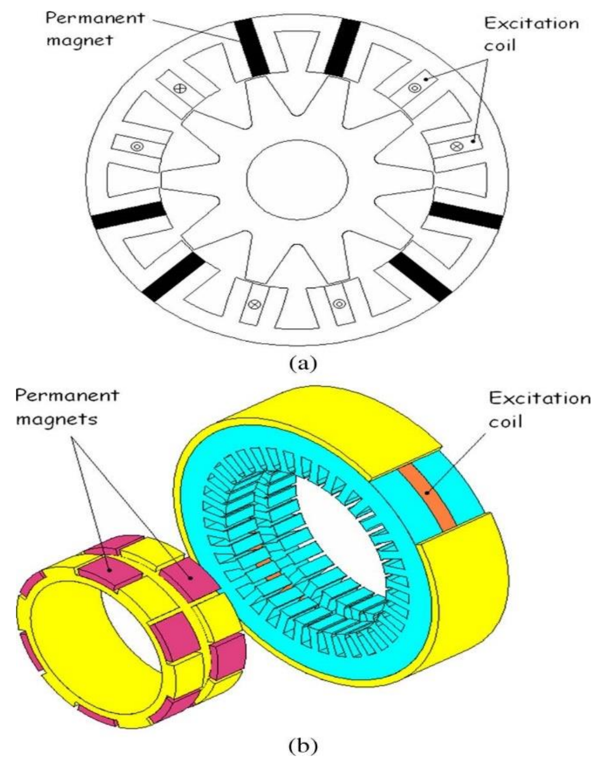

Figure.4(when Parallel excitation coils are in the stator)

literature:

In this paper there are so many kinds of electrical generators that are used in wind turbines. In the past the idea of using hybrid excitation to effectively control the output voltage emerged. The half and half term come from the work of both PM and DC energized field winding excitations. By thusly, it is conceivable to control the heap point and force factor, and an uncontrolled diode rectifier can be utilized. Moreover, the measure of required magnet lessens, which assists with decreasing in general expense [2]. From this paper briefly talk about A synchronous generator dependent on a hybrid excitation, including lasting magnets and field coil, is considered. The constructions of rotor magnetic circuit permitting one to extend the scope of generator voltage change are clarified and contrasted and the standard mixture rotor, the consequences of hypothetical investigation and trial test are introduced. [11]

In this paper an examination of Hybrid Excitation Synchronous Generator (HESG) geographies for an immediate drive wind turbine is researched. Through an improvement interaction, the geographies of HESG are looked at with respect to the expense and the complete misfortunes. The improvements are performed at the ostensible on-load working purpose of the generator. Furthermore, thought about during a trial working pattern of the immediate drive wind turbine. The productivity improvement underlines the interest of the plan by enhancement. [12]. This paper presents a novel excitation coordinated wind power generator (ESWPG) with a greatest force following plan. The excitation simultaneous generator and servo engine rotor speed tracks the lattice recurrence and stage utilizing the proposed coaxial arrangement and stage following advances. The generator yield would thus be able to be straightforwardly associated with the framework network without an extra force converter. The proposed most extreme force following plan administers the exciter current to accomplish stable voltage, greatest force following, and reducing servo engine power utilization [13].

This paper presents Various sorts of perpetual magnet generators for wind power application have been subject of examination during most recent twenty years. In this postulation various geographies of electrical generators have been examined for limited scope vertical pivot wind turbine application. A two-phase acceptance generator is proposed as an elective arrangement as for the expense of such a framework. Be that as it may, a greatest accentuation in the report has been put on the plan of Permanent Magnet Synchronous Generator (PMSG) reasonable for a limited scale Vertical Axis Wind Turbine (VAWT)The qualities of PMSG makes it exceptionally viable for variable speed Wind Energy Conversion System (WECS) with no pitch instrument, the standards of wind streamlined features is gone before by a survey on wind turbine attributes and difficulties with accentuation on VAWT s. Further different geographies of electrical machines with center around PMSG s including Permanent Magnet configurations, different windings and warm conduct is introduced. Generally, the fixed speed wind frameworks are planned so that it has its ideal breeze speed equivalent to site mean breeze speed. Hindrances are low efficiency of wind energy framework in other breeze conditions beside the mean breeze speed, and extreme elements execution. [1].

This report shows the appropriateness of a class of electric machines for vehicle foothold applications is examined. These machines, which are known as crossover excitation coordinated machines, join perpetual magnet (PM) excitation with wound field excitation. The objective behind the standard of cross breed excitation is to consolidate the upsides of PM energized machines and wound field simultaneous machines. It is demonstrated that these machines have great motion debilitating ability contrasted and PM machines, and that they establish an energy-effective answer for vehicle drive [8]. This paper depicts the best in class of cross hybrid excitation synchronous machines. Diverse half and half energized synchronous constructions from logical and specialized writing are portrayed and investigated. Favorable circumstances and disadvantages of the various designs are talked about. Diverse technique for characterization of these constructions will likewise be examined. The commitment of the crossover excitation rule for motoring and creating mode is nitty gritty and the various models for the plan of these constructions are introduced [14].

This paper presents another construction for a hybrid excitation, flux-switching synchronous machine. The disposition of this machine is its worldwide excitation winding segment that makes a 3D excitation transition way to control the worldwide air hole motion. A 3D limited component examination and a correlation with exploratory outcomes are both given. This model makes it conceivable to: show the excitation transition way, investigate the motion guideline ability of another construction, and recognize the impact of material qualities. The trial execution of this machine in a DC generator is introduced and contrasted and reproduction yield [5].

These machines, which are identified as hybrid excitation synchronous machines, consolidate perpetual magnet excitation with wound field excitation. Half and half excitation coordinated machines consolidate perpetual magnet excitation with wound field excitation. Parallel Hybrid Excitation Synchronous Machines for equal crossover excitation simultaneous machines, the excitation motion made by PMs and excitation curls have various directions. [3]

2.4. Conclusion:

Wind energy has been a promising source of renewable energy and the continuous efforts of research and development has already led to higher production rate, better reliability and maintainability and an increase in its cost-effectiveness. The DFIGs are currently widespread in medium and large wind turbines, while permanent magnet generators may only see competition in small wind turbines. Nevertheless, the market is moving from fixed speed, geared and brushed generators towards the direction of variable speed, gearless and brushless generator machine technologies, while still improving in aspects of decreasing weight, failure rates and cost. This paper has provided a general overview of different types and structures of hybrid excitation of synchronous generators for wind turbines and a comparison of their relative advantages and drawbacks. But in summary, the choice of a complex wind turbine system is largely determined by the capital and operations costs, due to the fact that the wind market is foundationally cost sensitive.

2.5. References:

[1] Nima Madani ’Design of a Permanent Magnet Synchronous Generator for a Vertical Axis Wind Turbine, Royal Institute of Technology, XR-EE-EME 2011:013

[2] AYSEL AKGEMC˙I ‘HYBRID EXCITED SYNCHRONOUS GENERATOR DESIGN AND COMPARISON OF DIRECT DRIVE WIND TURBINES’

[3] Y. Amara, L. Vido, M. Gabsi, E. Hoang, A. Hamid Ben Ahmed, and M. Lecrivain, “Hybrid excitation synchronous machines: Energy efficient solution for vehicles propulsion,” IEEE Trans. Veh. Technol., vol. 58, no. 5, pp. 2137–2149, 2009.

[4] K. Kamiev, J. Nerg, J. Pyrhonen, V. Zaboin, and J. Tapia, “Feasibility of an armature-reaction-compensated permanent magnet synchronous generator in island operation,” IEEE Trans. Industrial Electronics, to be published.

[5] A. Ammar, A. Berbecea, F. Gillon, and P. Brochet, “Influence of the ratio of hybridization on the performances of synchronous generator with Hybrid Excitation,” in International Conference on Electrical Machines (ICEM), 2012 XXth, 2012, pp. 2921–2926.

[6] G. Henneberger, J. R. Hadji-Minaglou, and R. C. Ciorba, “Design and test of permanent magnet synchronous motor with auxiliary excitation winding for electric vehicle application,” in Proc. Eur. Power Electron. Chapter Symp., Lausanne, Switzerland, Oct. 1994, pp. 645–649.

[7] C. C. Chan et al., “Novel permanent magnet motor drives for electric vehicles,” IEEE Trans. Ind. Electron., vol. 43, no. 2, pp. 331–339, Apr. 1996.

[8] Yacine Amara, Member, IEEE, Lionel Vido, Mohamed Gabsi, Emmanuel Hoang, A. Hamid Ben Ahmed, and Michel Lécrivain, “Hybrid Excitation Synchronous Machines Energy-Efficient Solution for

Vehicles Propulsion”

[9] M. Aydin, S. Huang, and T. A. Lipo, “A new axial flux surface mounted permanent magnet machine capable of field control,” in Conf. Rec. IEEE IAS Annu. Meeting, 2002, vol. 2, pp. 1250–1257.

[10] M. Aydin, S. Huang, and T. A. Lipo, “A new axial flux surface mounted permanent magnet machine capable of field control,” in Conf. Rec. IEEE IAS Annu. Meeting, 2002, vol. 2, pp. 1250–1257.

[11] Andrzej Popenda , and Sławomir Chwalba, “The synchronous generator based on a hybrid excitation with the extended range of voltage adjustment” Czestochowa University of Technology, Department of Electrical Engineering, Al. Armii Krajowej 17,42-200 Czestochowa, Poland.

[12] Maxime Ployard, Fréderic Gillon Aymen Ammar, Daniel Laloy Lionel Vido “Hybrid Excitation Topologies of Synchronous Generator for Direct Drive Wind Turbine” Conference Paper · September 2016

DOI: 10.1109/ECCE.2016.7855173

[13] Tzuen-Lih Chern, Ping-Lung Pan, Yu-Lun Chern, Wei-Ting Chern, Whei-Min Lin, Member,

“Excitation Synchronous Wind Power Generators With Maximum Power Tracking Scheme” IEEE,

Chih-Chiang Cheng, Jyh-Horng Chou, Senior Member, IEEE, and Long-Chen Chen

[14] Sami Hliou“Overview of Hybrid Excitation Synchronous Machines Technology” Member, IEEE, Yacine Amara, Member, IEEE, Emmanuel Hoang, Michel Lecrivain, Mohamed Gabsi, Member, IEEE