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A Proposed Methodology for Intelligent Control of Six Phase PMSG in a Grid Connected Wind Energy Conversion System

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Abstract: ***The renewable energy resources are need of the hour where the requirements of the power plant increase every year in India. The implementation of the generator plant is a large process as it is time consuming and it also needs huge financial support from the government. In recent era, the distribution side power generation becomes more important as it requires less cost and time compared to huge power plant as it requires large distance travel of power. Wind energy generation is one of the renewable resources where it can generate power at distribution level. This is because of permanent magnet synchronous machine. In this paper a brief survey is conducted for the proposed methodology of intelligent control of six phase permanent magnet synchronous generator (PMSG) in a grid connected wind energy conversion system.***
Index Terms: Direct & Quadrature Axis (DQ), Multiphase Machines, MPPT, PI & PID Controller, Permanent Magnet Synchronous Generator (PMSG), Six Phase Synchronous Generator (SPSG).

I. INTRODUCTION

Permanent magnet synchronous machines are compact and it can be modelled for low power with good efficiency. But the problem is, it can run at high speeds compared to synchronous and induction machines. So, the frequency of the permanent magnet synchronous machine (PMSM) is more. It means, there is a need for converters which is helpful in converting the high frequency AC to fundamental 50Hz/60Hz power supply. Although three-phase electric machines are still leading in number in industrial applications, machines with more than three phases can provide bulk power in some applications, such as lower per-phase current rating, current ripple, torque pulsation, dc-link voltage ripple and higher reliability which are particularly smart for high power applications, especially on ships and aircraft like dedicated applications.

The weight of the machine has to be reduced as well as it has to perform with better efficiency and the vector control has to perform well in any transient conditions. Six phase synchronous generator (SPSG) possess several advantages over conventional three phase machine. It increases the inverter output power efficiency. SPSG also improves the reliability of the system. Vector control decouples field flux and armature flux so that they can be able to control both current and speed. Thus, implementation of vector control in Six phase synchronous generator is efficient to obtain zero steady state error since the steady state currents errors are DQ quantity currents.

The usage of wind power generation if it has to be doubled then we need two machines and two turbine and two converters practically. But in the case of six-phase permanent magnet synchronous machine, the two machines are connected in parallel using the star-delta-star transformer connection. This connection reduces the usage of multiple power converters in the conversion side. This may improve the efficiency by reducing the switching losses and cost.

Intelligent Control of Six Phase PMSG in Grid Connected Wind Energy Conversion System with Multi-Phase machines provides several advantages such as: reduction of amplitude of pulsating torque and increased pulsating frequency; reduction of current per phase for the same rated voltage; lowering the dc-link current harmonics; reducing the stator copper loss; improving reliability and give additional degree of freedom [1]-[3]. Permanent magnet synchronous generators known to have higher power density, higher efficiency, more stable and secure during normal operation. Off shore wind energy system needs to be more reliable and lighter than on shore wind energy system.

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Therefore, Multiphase PMSG's have become attractive for large off shore wind farm. Multiphase machines drive, motors, have been used as in electric vehicles (EV), hybrid electric vehicles, aerospace, ship propulsion and high-power applications in which the requirements are not cost oppressive when compared to the overall system [1]-[4]. [2] gives thorough survey related to Multiphase drives in various subcategories and including the application of Multiphase machines for electric generation. In [5] parallel connection of converters in modular way is investigated to allow the use of classical converters. The application of multiphase PMSG for wind is also shown in [6] that the two three phase windings are controlled independently.

II. PROPOSED WORK

The main objectives of the proposed work are:

A. To construct six phase synchronous machine connected with wind turbine
B. Design and modeling of converter with MPPT control of wind power
C. To connect the wind power to grid using the DQ control strategy
D. To replace PI with hybrid adaptive neuro fuzzy inference system (ANFIS-PI) and fractional order proportional integral derivative (FOPID) controller
E. Compare the system response of the conventional controller with new adaptive neuro fuzzy inference system (ANFIS) hybrid controllers

III. LITERATURE SURVEY

The literature survey is conducted for the following two topics:
1) Multi-phase machines
2) Intelligent controllers in machine drives

A. Multi-Phase Machines

Schiferl RF in 1983, presented a detailed circuit representation of a six-phase synchronous machine wherein mutual leakage couplings between the two sets of three phase stator windings are included. With sinusoidal inputs the main modes of power transfer of a six-phase machine are examined. The mutual leakage inductances with winding displacement angle relationship and pitch for a number of practical six phase winding configurations are derived. The operating load conditions, winding displacement angle, pitch, converter commutating reactance and rotor impedance with AC-DC stator connections are characterized in this article and a novel application of the six-phase machine in an uninterruptible power supply scheme is proposed.

Sudhoff SD in 1993, discussed the average value characteristics of 6-phase synchronous machine system with dual line commutated converter.

Vetter W in 1994 has proposed the damper winding current of synchronous machine with a solid iron rotor. The model's component elements are determined by finite element method.

Singh G K in 2003, the stability of the multiphase induction machine is analyzed. The eigenvalue stability criterion is used in this article. In 2011 he has modeled and analyzed the six-phase synchronous generator for standalone renewable energy generation. And in the same year the fabrication of the same six- phase machine is made and tested experimentally. The transient analysis of isolated six-phase synchronous generator is made for different dynamic and loading conditions. Balanced and unbalanced loading condition with resistive, inductive and resistive-inductive is made and analyzed.

Cursino Brandao Jacobina in 2014 presented two-configuration system for six-phase synchronous system. One is with three phase series converters and three single-phase half bidirectional series converters. The other configuration is with full bidirectional converter. This configuration doesn't use the transformer for the step up. So, the power losses are less.

Vukosavic S N in 2005 has introduced the vector control of six-phase induction motor. Special attention is paid to the current control issue, from the point of view of the minimum number of current controllers. Experiments are conducted with number of operating regimes, including acceleration, deceleration, reversing and step loading/unloading transients.

Martin Jones in 2006 has proposed the two-motor drive system. Two topologies are used here. First one is the two asymmetrical connected in series and other uses one six phase and a two-phase ac machine. Performance wise the two asymmetrical machines performs better. Then there is a problem with the connection of neutral point for this drive system.

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Emil Levi in 2006 has presented a novel concept called multi motor drives on multiphase motors. Independent control of the motors can be achieved by connecting it in series combination. There is a problem when connecting the three-phase machine and six- phase machines in series due to the power flow from three-phase machine to six phase machine copper loss increases.

Lazhari Nezli in 2010, has presented the vector control of double star synchronous machine fed by three-level inverters controlled by PWM hysteresis strategy. The regulation of the chopper is made for rotor current control. There is an added note on the replacement for the PI regulator with recent control that can perform still more better.

Mario J Duran in 2010, presented a two series connected three-phase inverter and a grid side neutral point clamped multilevel inverter. Compared with back-to-back NPC converter this topology does not require the medium voltage generator. It has several advantages like improved power quality, increased efficiency, easier grid code compliance and smaller cables.

Paul Sandulescu in 2014, presented three models. First model has problem with triplen harmonics. Second have problem with optimal value predictions. The third model utilizes the DC link better and prevents zero sequence voltage in inverter saturation. And main thing to note in this article is the performance depends on the parameters of the machine. So, machine design is necessary for the better performance. So, these are all not done for the multi-machine systems.

Niewierowicz T in 2003 has discussed that the order of equivalent circuit increases the optimization index used in the identification procedure is enhanced in a clear fashion. To correctly reproduce the standstill frequency response data, this analysis is important for determining the number of rotor branches. The optimization is done by hybrid genetic algorithm (GA).

Rafael Escarela-Perez in 2004 has studied the variation of synchronous machine parameters due to saturation. A hybrid genetic algorithm, capable of finding global extrema is then applied to obtain the parameters of two equivalent circuit structures for the d-axis. Synchronous machine short-circuits and the results obtained have been compared to those calculated by a transient finite element program.

Saeedeh Hamidifar in 2014, aims to develop a new synchronous machine model incorporating an accurate saturation model. The algorithm used in this article to represent magnetic saturation calculates the coefficients in several real function expressions for the saturation characteristics of a synchronous machine. It is also tested in various operating conditions.

Niewierowicz T in 2003 has discussed that the order of equivalent circuit increases the optimization index used in the identification procedure is enhanced in a clear fashion. To correctly reproduce the standstill frequency response data, this analysis is important for determining the number of rotor branches. The optimization is done by hybrid genetic algorithm.

Arjona MA in 2012 has presented the parameter estimation of the synchronous generator using standstill step voltage test. The hybrid genetic algorithm is used as the solution method. The three-phase short circuit test is used to find the betterment of the responses.

B. Intelligent Controllers in Machine Drives

In the last few years, electro-energetic systems are often subject to disturbances that can cause serious problem; their reliability is defined by operating limits and behavior subject disturbances [23-25]. These disturbances lead to additional constraints, mechanical, thermal or electrical to those of the steady state and give the instability of the power system. Quite recently, considerable attention has been paid to cope with its problems. Two means of improving stability: classical means such us transformer with taps adjustable, shifting phase transformer; modern means such as using a controller in the generator with an additional signal control in the exciter system of the generator or using a controller in line-side with additional control signal in the systems FACTS devices. Due to previous dilemma, the power systems require more and more advanced devices and techniques. Current research on power system improvement is focused on different techniques such as HVDC, FACTS and Power system stability (PSS) [26-30]. Several publications have appeared in recent years documenting the PSS's. [31] shows a variety of approaches such as PID and lead lag compensators which have been devoted to the study of optimization algorithm. One of the first examples of PSO is presented in [32].

The results obtained in [33-39] suggest the sequential linear programing such as genetic algorithm (GA), chaotic algorithm, bacteria foraging and H∞. A key limitation of this research is that their simple structure, lead to an accurate model and its non-optimal damping in different cases of power system. However, the issues of the adaptive of the PSS such as neural networks (NN) are discussed in [16-19], wavelet neural networks (WNN) controller [40-41], self-tuning PID controllers [42-43], sliding mode and fuzzy controller [44-47]. Nevertheless, there are still some interesting and relevant problems to be addressed using adaptive control law. The problem with this approach is that, it requires offline training. Hence, an appropriate PSS have indicated in view of the drawbacks.

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IV. METHODOLOGY

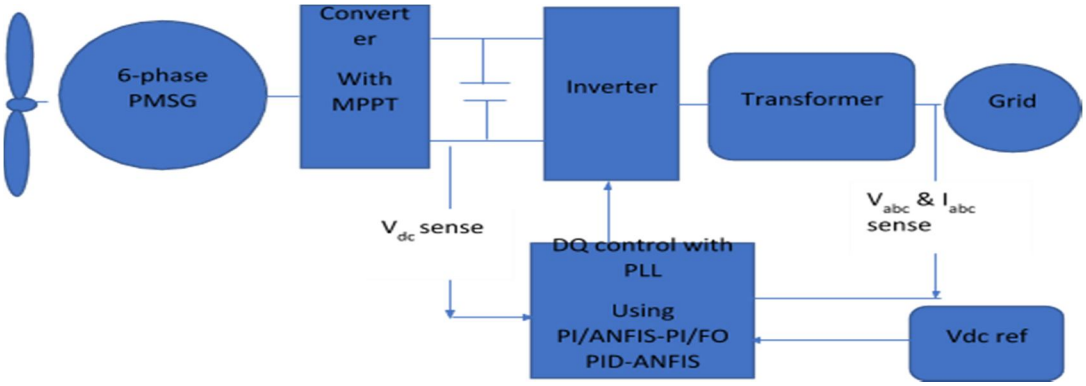


Fig.4.1: Six Phase Synchronous Machine

The modeling of Six Phase Synchronous Machine is as follows:

1) Parameter Estimation for six phase synchronous machine
2) Vector control of the Six phase synchronous machine as power generation
3) Hybrid wind power generation with six phase synchronous machine and solar power generation
4) Modeling of the six-phase synchronous machine in MALTAB Simulink
5) Identification of the parameters of the machine by using optimization techniques by maximization of power output
6) Implementation of vector control in six-phase synchronous machine by using the optimal parameters
7) Then connecting the hybrid power generation system like PV and load with appropriate synchronization techniques
8) Analyzing the results with hybrid power generation system

V. CONCLUSION

Literature review of intelligent control of six phase PMSG in a grid connected wind energy conversion system is carried out. Proposed methodology involves simulation of six phase synchronous machine connected with wind turbine. Initially design of converters and controls for MPPT is to be done. Later simulation of DQ control strategy is to be implemented. Then, Simulation model of FOPID with ANFIS hybrid and PI with ANFIS hybrid blocks is to be built. Further the results of various controller implementation can be compared thereby improving the system efficiency.

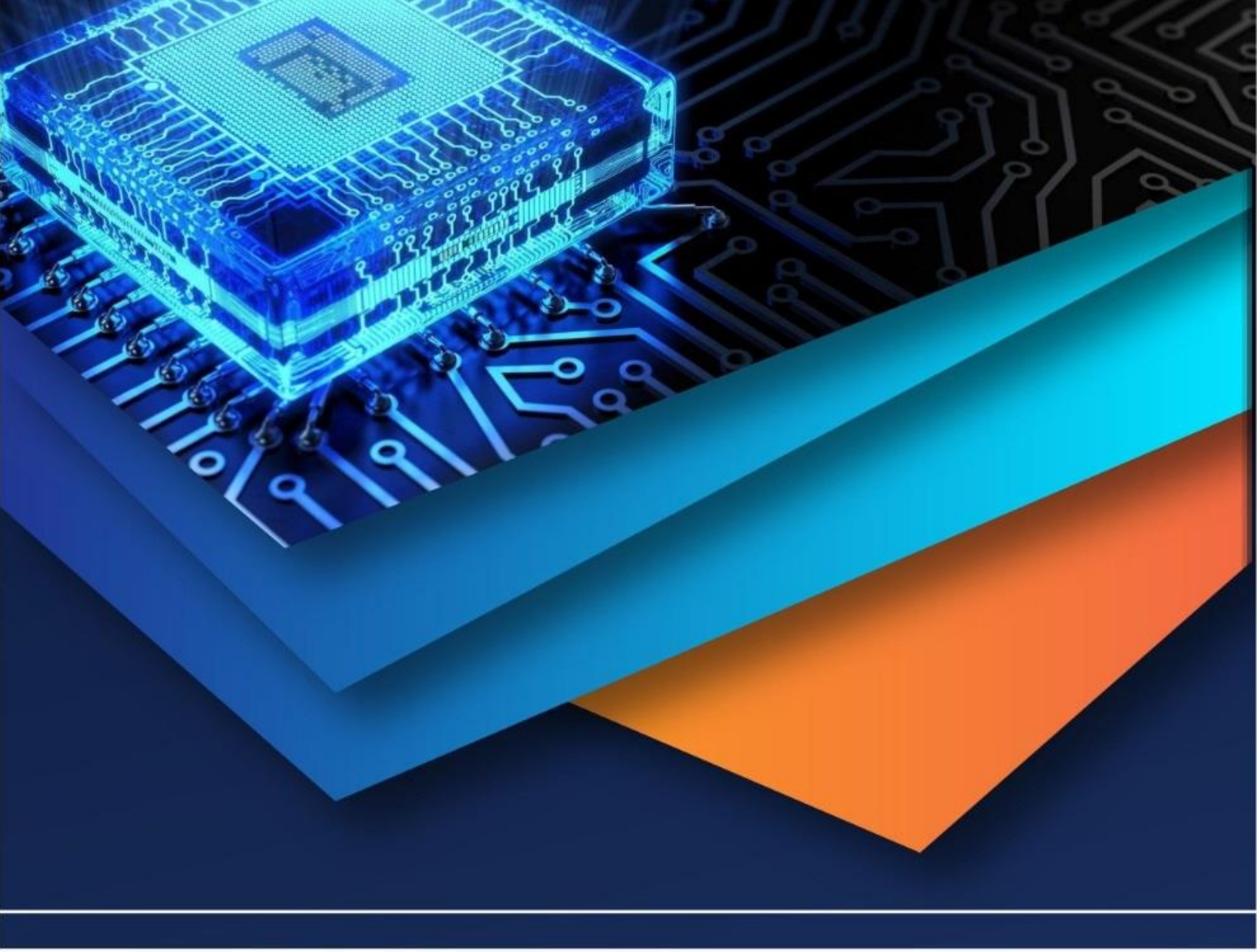
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