Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

An Adaptive Control Strategy For Wind Energy Conversion System Using Neuro-Fuzzy Logic Controller

Reeshma V V[1] ,Rajalakshmi C R[2]
[1,2] *Department of EEE, Vivekanandha College of Engineering for Women,*

Abstract—This paper proposes a new adaptive control strategy for converting a wind energy system.The generator used is permanent magnet synchronous generator. The converter for dc conversion is pulse width modulated current source converter. The proposed PMSG is highly efficient and reliable. Power generated by PMSG is modified according to the wind velocity and load profile by the converter. The adaptive control for pulse width modulated current source converter uses neuro-fuzzy logic controller. Neuro-fuzzy controller uses neural network learning techniques to tune membership function while keeping semantics of fuzzy logic controller intact. The proposed controller is self- tuned and adapt to changes in wind speed. Space vector modulation is used for modulating the output of the PWM-CSC. Finally a model reference is used to reduce the power system fault due to short circuit.

Keywords- PMSG, Neuro fuzzy controller, PI controller.

I.INTRODUCTION

Many challenges exist for efficient and safe operation of wind turbine due to difficulty in modelling the dynamic characteristics and turbulent condition in which they operate. Adaptive control techniques are promising new area of wind turbine research. Modern wind power applications require efficient and flexible technologies that adapt to changes in load and generation. These challenges can be met by a combination of non-conventional energy conversion systems and improved adaptive control strategies.

Most of the wind turbines used doubly fed induction generators in the past for on land emplacement due to economic advantage. The PMSG choice allows direct-drive systems that avoid gearbox use. This solution is very advantageous as it leads to low maintenance constraints. However, in such design, the generator is completely decoupled from the grid by a voltage source full power converter (AC/DC/AC) connected to the stator. Conventional current source converter is an auto sequentially commutated inverter. That is thyristor is used as a switching device and large capacitors are used as dc link. If GTO converter operates in the manner of PWM dc link inductor size can be reduced significantly and the converter input side filter can also be small. Inverter output filter capacitor is to absorb the switching voltage spike and to provide a path for the current harmonics.

The classical theory is based on mathematical model that consider physical plant under consideration. The essence of fuzzy control is to build a model of human expert who is capable of controlling the plant. The transformation of expert's knowledge in terms of control rules to fuzzy framework has not been formalized and arbitrary choices concerning, for example, the shape of membership functions have to be made. The quality of fuzzy controller can be affected by membership functions. Thus methods for tuning of fuzzy logic controllers are needed. In this paper, neural networks are used in a novel way to solve the problem of tuning a fuzzy logic controller. The neuro fuzzy controller uses neural network learning techniques to tune the membership functions while keeping the semantics of the fuzzy logic controller intact. This paper proposes a new adaptive control strategy for a wind energy conversion system based on a permanent magnet synchronous generator and a pulse-width modulated current source converter. The proposed conversion system is a good alternative due to its high efficiency and reliability

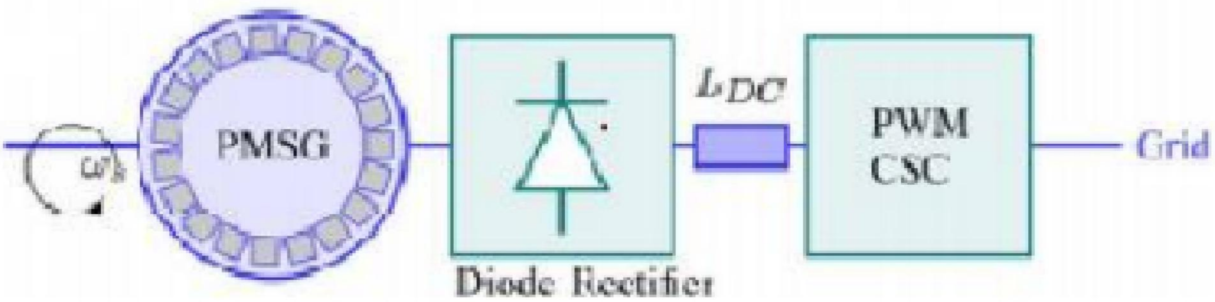


Fig.1.Proposed energy conversion system with PWM-CSC

II.RELATED WORKS

The proposed energy conversion system is based on PMSG. This type of machine has three main features which are relevant for wind power applications: there are no significant losses generated in the rotor; magnetization provided by the permanent magnets allows soft start; and there is no consumption of reactive power. The first characteristic implies an improvement in efficiency while the second and third effect the power electronic converter which does not require bidirectional power capability. Hence, a full bridge diode rectifier is enough for the AC/DC conversion. In addition, PMSGs allow smaller, flexible and lighter designs as well as lower maintenance and operating costs. A gear box is not required if it is designed appropriately with a high number of poles. PWM-CSC technology has been applied successfully in a wide range of applications such as motor drives, power quality conditioners and HVDC transmission for offshore wind generation.

Unlike the line commutated converter a PWM-CSC is based on forced commutation and consequently it is able to control active and reactive power. In addition, it has an inherent short-circuit protection capability. A PWM-CSC requires semiconductor devices with reverse voltage blocking capability. This can be added to a standard insulated-gate bipolar transistor (IGBT) using a diode connected in series. Another alternative is the new type of semiconductor devices such as reverse blocking IGBTs (RB-IGBT) or integrated gate commutated thyristors (IGCTs). The latter alternative is promising for PWM-CSCs. The DC current is directly controlled by the converter. This feature is especially important for low wind velocities when voltage in the machine is greatly reduced. While a voltage source converter requires a constant voltage on the DC side, a PWMCSC is able to adapt its voltage according to the wind velocity. Efficiency is improved due to this capability.

A hierarchical control is proposed for integration of the wind turbine into the grid as depicted in Fig. 2. First, the maximum tracking point algorithm is modified in terms of the DC current in the PWM-CSC. Therefore, the reference for this current is modified dynamically according to the wind velocity. Next, an adaptive PI control is designed in order to track this reference. Finally, a model reference control is included in order to reduce the over-voltages resulting from a fault in the grid. Space vector modulation (SVM) is used to modulate the current of the converter.

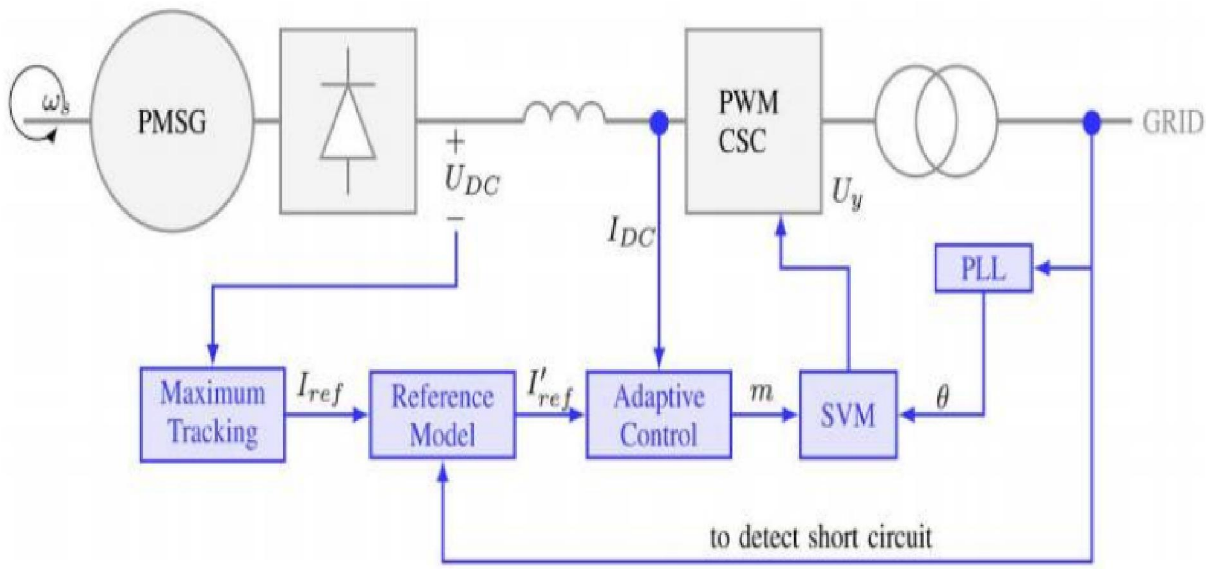


Fig.2. Proposed strategy for adaptive control of energy conversion system based on PWM-CSC

Maximum power tracking. The power generated by wind turbine is directly proportional to the cube of wind velocity

$$P = \frac{1}{2}\rho \cdot A \cdot C_p(\lambda, \beta) \cdot V^3$$

Maximum power transference is achieved by optimal value of λ. Rotational speed ω is proportional to wind velocity and power is proportional to cube of rotational speed.

$$P_{pu} = \frac{P(t)}{P_{nom}} = \left(\frac{\omega_s(t)}{\omega_{nom}}\right)^3 = w^3_{s(pu)}$$

On rotor reference frame model of PMSG is given as

$$u_{s(d)} = R_s \cdot i_{s(d)} + L_s \cdot \frac{d}{dt} i_{s(d)} - L_s \cdot \omega_s \cdot i_{s(q)}$$
$$u_{s(q)} = R_s \cdot i_{s(q)} + L_s \cdot \frac{d}{dt} i_{s(q)} + L_s \cdot \omega_s \cdot i_{s(d)} + \psi_m \cdot \omega_s$$

SPACE VECTOR MODULATION.

Space vector modulation is an algorithm for control of pulse width modulation. It is used for the creation of alternating current waveforms. To implement space vector modulation a reference signal Vref is sampled with frequency fs. The reference signal may be generated from three separate phase reference using αβλ transform. The reference vector is then synthesized using a combination of the two adjacent active switching vectors and one or both of the zero vectors. Various strategies of selection will affect the harmonic content and the switching losses. Space vector modulation (SVM) is used to modulate the current of the current source converter.

III. PROPOSED CONTROLLER

Classical control theory is based on the mathematical models that describe the physical plant under consideration. The essence of fuzzy control is to build a model of human expert who is capable of controlling the plant without thinking in terms of mathematical model. The transformation of expert's knowledge in terms of control rules to fuzzy frame work has not been formalized and arbitrary choices concerning, for example, the shape of membership functions have to be made. The quality of fuzzy controller can be drastically affected by the choice of membership functions. Thus, methods for tuning the fuzzy logic controllers are needed. In this paper, neural networks are used in a novel way to solve the problem of tuning a fuzzy logic controller. The neuro fuzzy controller uses the neural network learning techniques to tune the membership functions while keeping the semantics of the fuzzy logic controller intact.

The main idea of fuzzy logic control (FLC) is to build a model of a human control expert who is capable of controlling the plant without thinking in terms of a mathematical model. The control expert specifies his control actions in the form of linguistic rules. These control rules are translated into the framework of fuzzy set theory providing a calculus which can simulate the behavior of the control expert. The specification of good linguistic rules depends on the knowledge of the control expert, but the translation of these rules into fuzzy set theory framework is not formalized and arbitrary choices concerning, for example, the shape of membership functions have to be made.

The quality of fuzzy logic controller can be drastically affected by the choice of membership functions. Thus, methods for tuning fuzzy logic controllers are necessary. Neural networks offer the possibility of solving the problem of tuning. Although a neural network is able to learn from the given data, the trained neural network is generally understood as a black box. Neither it is possible to extract structural information from the trained neural network nor can we integrate special information into the neural network in order to simplify the learning procedure. On the other hand, a fuzzy logic controller is designed to work with the structured knowledge in the form of rules and nearly everything in the fuzzy system remains highly transparent and easily interpretable. However, there exists no formal framework for the choice of various design parameters and optimization of these parameters generally is done by trial and error. A combination of neural networks and fuzzy logic offers the possibility of solving tuning problems and design difficulties of fuzzy logic. The resulting network will be more transparent and can be easily recognized in the form of fuzzy logic control rules or semantics. This new approach combines the well-established advantages of both the methods and avoids the drawbacks of both.

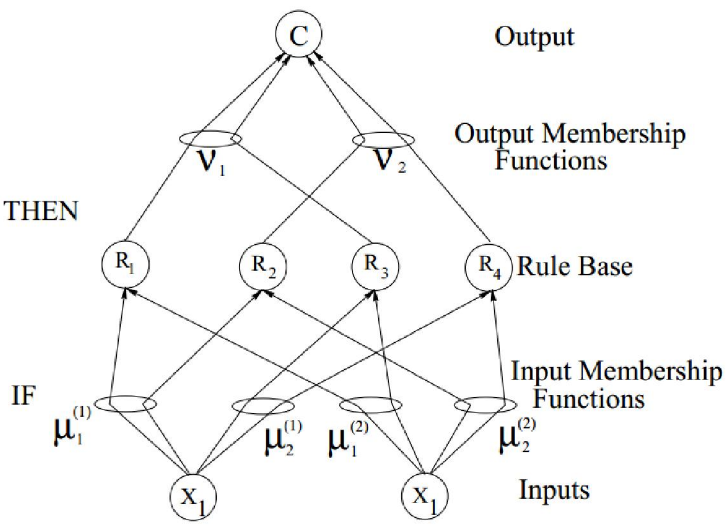
We consider a multi-input, single-output dynamic system whose states at any instant can be defined by "n" variables X1, X2,...,Xn. The control action that derives the system to a desired state can be described by a well-known concept of "if-then" rules, where input variables are first transformed into their respective linguistic variables, also called fuzzification. Then, conjunction of these rules, called inferencing process, determines the linguistic value for the output. This linguistic value of the output also called fuzzified output is then converted to a crisp value by using defuzzification scheme. All rules in this architecture are evaluated in parallel to generate the final output fuzzy set, which is then defuzzified to get the crisp output value. The conjunction of fuzzified inputs is usually done by either min or product operation (weuse product operation) and for generating the output max or sum operation is generally used. For defuzzification, we have used simplified reasoning method, also known as modified center of area method. For simplicity, triangular fuzzy sets will be used for both input and output.[5] The whole working and analysis of fuzzy controller is dependent on the following constraints on fuzzification, defuzzification and the knowledge base of an FLC, which give a linear approximation of most FLC.

FLC implementations.

CONSTRAINT 1: The fuzzification process uses the triangular membership function.

CONSTRAINT 2: The width of a fuzzy set extends to the peak value of each adjacent fuzzy set and vice versa. The sum of the membership values over the interval between two adjacent sets will be one. Therefore, the sum of all membership values over the universe of discourse at any instant for a control variable will always be equal to one. This constraint is commonly referred to as fuzzy partitioning.

CONSTRAINT 3: The defuzzification method used is the modified center of area method. This method is similar to obtaining a weighted average of all possible output values. An example of a very simple neuro fuzzy controller with just four rules is depicted in Figure 1. This architecture can be readily understood as a "neural-like" architecture. At the same time, it can be easily interpreted as a fuzzy logic controller. The modules X_1 and X_2 represent the input 4 variables that describe the state of the system to be controlled. These modules deliver crisp input values to the respective membership modules (μ-modules) which contain definitions of membership functions and basically fuzzify the input. Now, both the inputs are in the form of linguistic variables and membership associated with the respective linguistic variables. The μ-modules are further connected to R-modules which represent the rule base of the controller, also known as the knowledge base. Each μ-module gives to its connected R-modules, the membership value $\mu(x_i)$ of the input variable X_i associated with that particular linguistic variable or the input fuzzy set. The R-modules use either min-operation or product-operation to generate conjunction of their respective inputs and pass this calculated value forward to one of ν-modules. The ν-modules basically represent the output fuzzy sets or store the definition of output linguistic variables. If there are more than two rules affecting one output variable then either their sum or the max is taken and the fuzzy set is either clipped or multiplied by that resultant value. These ν-modules pass on the changed output fuzzy sets to C-module where the defuzzification process is used to get the final crisp value of the output.



IV. CONCLUSION

An adaptive control for a PWM-CSC-based energy conversion system particularly designed for wind power applications was presented. Both the control and the type of converter increase the flexibility of the wind turbine. They are able to operate in critical conditions such as short circuit and fast changes in wind velocity. Measurements of wind velocity or rotational speed are not required. A reference model is used to improve the transient behavior of the control after critical faults. For systems with time invariant behavior, the adaptive controller also behaves as a fixed controller. Therefore, it can be seen that the adaptive controller method can be used as a technique for self-tuning the controller based on the desired response.

REFERENCES

[1].Eduardo Giraldo,Alejandro Garces, "*An adptivecontrol strategy for a wind energy conversion system based on a PWM-CSC and PMSG*" IEEE transaction on power systems,vol.29,no.3,May 20.

[2] Doon-Choon Lee, Dong Hee Kim, Dae-Woong Chung, "*Control of PWM current source converter and inverter system for high performance induction motor drives*", IEEE transaction 1996.

[3] Alan Mullane, G.Lightbody, R.Yakamini, "*Adaptive control of Variable speed wind turbines*" Rev. Energ. Ren.: Power Engineering (2001)101 -110.

[4]S. Benelghali, M.E.H. Benbouzid and J.F. Charpent, "*Comparison of PMSG and DFIG for Marine Current Turbine Applications*" XIX International Conference on Electrical Machines ICEM 2010, Rome.

[5]Gurpreet S. Sandhu and Kuldip S. Rattan, "*Design of a Neuro Fuzzy Controller*" Department of Electrical Engineering Wright State University Dayton, Ohio.

[6]J.Carrasco, L.Franquelo, J.Bialasiewicz, E Galvan, R.Guisado, M.Prats, J.Leon, and N.MorenoAlfonso, "*Power-electronic systems for the grid integration of renewable energy sources: A survey*," IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016, 2006.

[7] L. Wang and M. N. Thi, "*Stability enhancement of a PMSG-based offshore wind farm fed to a multi machine system through an LCC-HVDC link*," IEEE Trans. Power Syst., to be published.

[8] H. Geng, G. Yang, D. Xu, and B. Wu, "*Unified power control for PMSG-based WECS operating under different grid conditions*," IEEE Trans. Energy Convers., vol. 26, no. 3, pp. 822–830, 2011.

[9]R.Blasco-Gimenez, S.Ano-Villalba, J.RodriguezDerle, S. BernalPerez, and F.Morant, "*Diode-based hvdc link for the connection of large offshore wind farms*," Trans. Energy Convers.,vol.26, no.2, pp. 615–626, 2011

[10] J. Dai, "*Current source converters for megawatt wind energy conversion systems*," Ph.D. . Dissertation, Ryerson University, Toronto, ON, Canada, 2010

