Development of ANFIS Based Controller for Variable Speed Induction Generator

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1 Introduction

Induction generators which may be operated in grid or self-excited mode, are found to be successful machines for wind energy conversion. Self-excited modes is gaining importance due to its ability to convert the wind energy into electrical energy for large variations in operating speed [1]. However, it has been found that these machines exhibits a poor voltage regulation. Steady-state analysis of self-excited induction generator reveals that such generators are not capable to maintain the terminal voltage and frequency in the absence of expensive controllers. There have many way to control the terminal voltage through excitation control using series compensation. In this paper, the adaptive neuron-fuzzy interference (ANFIS) control is proposed for proper reactive compensation under different operating conditions for wind turbine.

The scope of this study is to design, implement in the prototype and test dc-dc converter control circuit which input is a variable voltage for a wind-energy conversion system that is suitable for grid-connected wind turbine. The control circuit not only can be implemented for the wind generator but also hybrid system couple with photovoltaic systems. Many researchers have been done nowadays to design the speed controller of induction generator, but in fact, the contribution of this research is to design artificial intelligent for push-pull dc-dc converter to improve the response of the system.

Successful implementation of the control could pave a way for cheaper cost with high performance of the implementation speed controller to control the speed of the induction generator. Due to desirable feature and specifications of the induction generator, it can be seen in many green house power applications, including the power systems. As the result, it is very significant to develop ANFIS control to stimulate the input voltage of the dc-dc converter; therefore, increase the performance of the speed controller for induction generator.

2 System Description

Total system of power generation from wind turbine is divided into 5 steps. Block Diagram of the complete system is shown in Fig. 1.

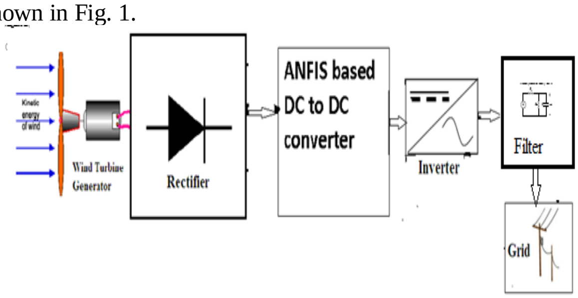

Fig. 1. Total Block Diagram of the System.

This research involved the design of a high-voltage dc-dc converter capable of converting 12 volt dc into 240 volt ac and delivering 300 watt of power. The design is based on a push-pull topology utilizing power switches, a custom center-tapped transformer, and an all analog feedback control systems. The design comprised the front-end of a dc-ac sine wave inverter and was implemented using a custom proto circuit board and tested. The control circuitry worked as expected by using ANFIS controller. A generic block diagram of how one of these converters works with feedback loop can be seen in Fig. 2.

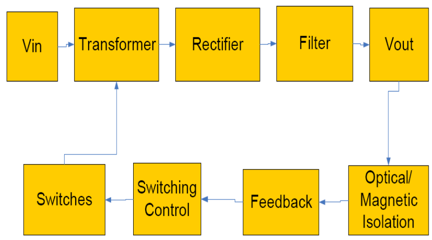

Fig. 2. Block diagram of generic dc-dc converter.

From the block diagram, it is easy to see that the switches control the current that gets fed into the transformer. From there, the transformer creates a magnetic field which induces a voltage on the secondary side of the transformer. This voltage then, turns on a part of the rectifying circuit and charges a capacitor. Here, the signal is passed through an LC filter to remove ripples, forming the output of the dc converter. The output is continuously monitored by the switching controller to adjust the duty cycle of the switches. This feedback loop is normally isolated through optical or magnetic when using an isolated topology.

2.1 Push-Pull DC-DC Converter

The push-pull topology is an ideal choice for this dc-dc converter for multiple reasons. The most important reason is the isolation between the source and output provided by the magnetic in the transformer [2]. Another deciding factor is the simplicity of the switching over a full bridge design. By only having to turn on one switch at a time, timing issues become less critical. The other important factor is that the push-pull topology is commonly used at this power level. This makes the study on the topology more reliable and achievable. The ANFIS controller is implemented to the voltage control of push-pull converter. The result obtained in section 3.1 proves that implementation of ANFIS controller system can observe enhancement in the dynamic response of the system.

2.2 ANFIS-Based Equivalent Control

An adaptive networks architecture which functionally equivalent to fuzzy inference system was proposes by Jang [3]. It is method for tuning an existing rule base of fuzzy with a learning algorithm based on a collection of training data found in artificial neural network. Furthermore, ANFIS has much less tuneable parameters than conventional artificial neural network; the advantage of ANFIS is that each rule produces one value rather a distribution.

To develop ANFIS-based inverse model, the input layer has two nodes which consists of output and input. One Bell membership function is used for all input nodes since it suitable membership function for function approximation purpose.

The main aim of ANFIS is to optimize the ANFIS parameters. There are two steps in the ANFIS design. Firstly, the design of the premise parameters, while the other is consequent parameters training. There are many methods for designing the premise parameter such as grid partition, fuzzy c-means clustering and subtractive clustering. In this study, hybrid learning algorithm is used to train the ANFIS model. It combines the back propagation gradient decent and least squares methods.

3 Result and Discussion

3.1 Results

To describe the controller, plant model was taken from system description in Section 2. By applying the controller and collecting the data from the system, ANFIS controller is developed to control the duty cycle of the converter. The result shows that, when the input changes, then the ANFIS controller will change the duty cycle accordingly to the output voltage.

The evolution of training error is present and it shows that network error is convergent at 500 epochs. The root mean squared error (RMSE) of the network is equal to 0.05 at the end training process; there is evolution of the membership function. After ANFIS train the data and ANSIF block set up the membership function. The data inhere in the simulation to control the output voltage and compare with voltage reference. The ANFIS input is voltage error and ANFIS output is duty cycle.

Results also shows that, duty cycle was varying between 0.49 to 0.23. In converter control, the operation of single phase inverter is discussed. Push-pull converter control the voltage and feed the constant voltage to the inverter. The inverter convert 240V dc into 240 ac with 50 Hz and ready to used. The harmonic component magnitude and phase are shown in Table 1.

Table 1. Fundamental and Harmonics of The Inverter

Harmonics	Magnitude (V)	Angle (degree)
DC	145	-90
Fundamental	550.28	171.2
2	17.46	172.2
3	11.58	174.9
4	8.703	176.5
5	6.884	176.5
6	6.892	176.7
7	4.918	178.9
8	4.328	178.1
9	3.085	178.6

3.2 Discussion

The input is fed by 12V dc from the diode rectifier and the 12V will step up by the transformer from 12V dc to 240V ac. The voltage coming out of the dc-dc converter will compare with voltage reference, and the error will send to the input ANFIS controller. ANFIS controller will send command to the duty cycle from the output of ANFIS controller and the duty cycle will change to the max which is 0.49 and will not excess more than 0.49. Otherwise the transformer will damage. After changing the duty cycle by ANFIS controller, the duty cycle give the correct pulsing to the switches, and the current will cross the transformer and the diode rectifier deliver the current to the inductor , then to the LC filter which have the desired output voltage.

When the input voltage is low, the ANFIS controller force the duty cycle to increase till reach the desired output. Whereas, when the input voltage is high, ANFIS controller command the duty cycle to decrease till reach the desired output voltage. Voltage reference compares the output voltage coming from the push-pull converter and will send the error to the ANFIS input. Furthermore, the ANFIS output will send the desired duty cycle after calculating the error and duty cycle will reset the command coming from the output voltage. At 12V input it takes more time to reach the steady state, whereas at 24V input, it more smooth and quickly to reach the steady state.

4 Conclusion

In this paper, wind turbine power conversion project, that need for 12-24 dc volt to 240 ac volt converters was presented, especially when a requirement is pure sine wave. Complete project was split into some part such as rectifier, dc-dc boost converter and sine wave inverter. For the desired power rating of 300W, a push-pull inverter topology seems to work best with an efficiency rating of 85% at 350W.

Part of the goals for this paper was to produce a pure sine wave dc or ac inverter that would give output at 50 Hz, 240 volts root mean square with 250 watt output, would be cheap to manufacture, and fairly efficient in the method in which it produced. Based on the result achieve from simulation and experimental, it can be said that goals and objective were met.

For variable speed induction generator, ANFIS based control system is developed that keeps the output ac voltage of induction generator at constant magnitude and frequency even the speed of the wind turbine is varied. Here, single phase induction generator output voltage is rectified then dc-dc boost conversion is done using PWM inverter that convert

to constant frequency ac voltage.

Acknowledgement

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