Indian Journal of Science and Technology, Vol 8(17), DOI: 10.17485/ijst/2015/v8i17/64966, August 2015
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Comparison of PI and FLC for AC/DC Converter using SEPIC in Renewable Energy System

B. Hariharasubramaniam* **and M. Preethi Pauline Mary**

Satyabama University, Solinganallur, Chennai - 600119, Tamil Nadu, India; questhari@hotmail.com, preethi.drives@gmail.com

Abstract

This paper proposes a unique synchronization mechanism system for meritoriously monitoring an AC-to-DC converter in renewable energy system. The green energy system using DFIG is used in this project. SEIG techniques used in AC-DC converter to produce low DC voltage and SEPIC techniques increases the DC voltage at DC – DC converter to Dc load (LED). Power factor and THD of the system are amended using above techniques. The enactment of the project is implemented using MATLAB with PI and Fuzzy controller. The circuit model is designed with microcontroller.

Keywords: DFIG, LED (DC load), SEIG, SEPIC

1. Introduction

Nowadays fast consumption of fossil fuel energy starts to reduce, the extensive growing concepts on environmental protection have led to enormous researches and developments on various renewable energies. Currently, wind energy is one of the most promising renewable-energy resources in the world today. To effectively capture available energy from time-varying wind, Variable-Speed Wind Turbines (VSWTs) are generally used. Induction Generators (IGs) have become one of the most widely employed candidates for different Wind-Energy Conversion Systems (WECSs) [1] Self-excited induction generator, digital signal processor, switched excitation capacitors, AC-to-DC converter, renewable-energy systems[2-4]. Three different types of IG for WECSs can be utilized: 1. Squirrel-Cage Induction Generator (SCIG) with its stator windings directly connected to a power grid or fed to a power grid through static converters[5,6], 2. Doubly-Fed Induction Generator (DFIG) with its stator windings directly connected to a power grid and its rotor windings connected to the stator windings through an AC-to-DC controlled or uncontrolled rectifier, a DC link, a DC-to-AC inverter, and a step-up transformer [7,8], and 3. wound-rotor induction generator with its rotor windings connected to a variable resistance using a power switch based on Pulse-Width Modulation (PWM) modulation. Voltage regulation is the major concern of using SEIGs for variable-speed operations. However, due to the fast development of power electronics, various voltage regulators have been developed. Distinct voltage regulators for SEIGs acted as reactive-power controllers were based on switched capacitors, variable inductor, or saturated reactor, which employed relay/contactors or semiconductor switches [9-14]. On the other hand, power-electronics converters were also proposed to effectively control the output quantities of SEIGs. The performance of several compensation schemes for reactive power and harmonic compensation of SEIGs was presented in[15], while a hybrid compensation method using a Silicon-Controlled Rectifier (SCR) interfaced to a Permanent-Magnet Generator (PMG)-based variable-speed control scheme was also proposed. A WECS interconnected to a utility through an asynchronous link consisting of adiode-bridge rectifier and a line-commutated inverter was proposed in[16]. A rule-based Fuzzy-Logic Controller (FLC) to control the output power of a PWM-based inverter was presented and the objective was to track and extract maximum power

*Author for correspondence

from a WECS [17]. The performance of an IG-based system was improved through a voltage-source based PWM inverter and the electronic converter to achieve better system behaviour on voltage regulation, frequency stabilization, and reactive power compensation[18]. A generic simulation approach for a controlled power converter using a DSP was proposed in[19]. The software program for simulating a feedback control scheme was incorporated in the software code of the DSP-controlled power conversion system while the solution of the state equation was computed by an appropriate numerical method[19]. An AC-to-DC converter with active-power filtering and power-factor correction was proposed[20], Hitherto the increasing demand and peak loads lead to an increase of required grid capacity and preventing larger investments [21] the conventional type PI controllers normally do not have appropriate compensation from the inverters for the grid connected applications[22], and the converter with its AC-side inductors and capacitors to eliminate current harmonic consisted of six diodes. Previous research works did not study the coordination control between the switched excitation-capacitor bank and the AC-to-DC controlled converter for SEIGs yet. This paper proposes a PIC-based control scheme using the rotor speed of the studied SEIG as a feedback signal to achieve coordinate control of the switched excitation capacitor bank and the AC-to-DC controlled converter and DC-DC converterwhich are both connected to the stator windings of thestudied SEIG. Three rotor-speed operating ranges of theSEIG are selected to activate the switching functions for theexcitation-capacitor bank and the controlled AC-to-DC converter. Experimental results obtained for different loads from a laboratory 2.2-kW (3-hp) induction machine driven by a brushless DC motor and Led bank are also performed and compared with simulatedresults to validate the effectiveness of the proposed control scheme. The output is compared with various control techniques such as, PI controller and Fuzzy control schemes.

2. Configuration of Proposed System

Theconfigurationofthestudiedsystemisshownin Figure 1. the heart of the system is a PIC16F84 chip, it consist of two ports one port consist of 8 bit and another port consist of 5 bit .with this PIC controller we can control or provide switching pulses for the MOSFET's.

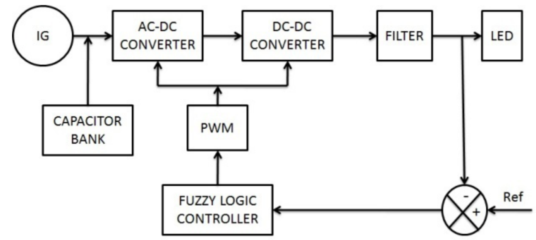

Figure 1. Functional block diagram.

The functional block diagram is shown in Figure 1, Low power 3 phase AC suply is generated with the help of three phase induction generator a capacitor bank is used to excidation of induction generator. The generated low power AC supply is converted in to DC power supply with the help of controlled rectifier this low power dc is given to the controlled DC-DC converter (SEPIC). This converter can be used as step up and step down purpose. In this project we use this SEPIC converter for step up purpose alone. The step uped DC voltage is given to the filter unit to eleminte the ripples. Since we are using a closed loop system,This output voltage is monitered to maintain constant voltage at the load side. The output voltage is given as a feedback to the controll unit (PIC Controller). This PIC controller will give switching pulses of the MOSFET's of the SEPIC and controlled rectifier.

3. Designed System

The system is designe for openloop,closed loop with PI controller and closed loop system with FLC controller is explained in detailed below

The above shown Figure 2 is the open loop system of the proposed system A three phase AC voltage is obtained from SEIG is given to the the rectifier, here 3 ph AC is converted in to DC using this rectifier. PWM pulses for the MOSFET's are given by PIC controller. Low voltage DC supply is given to the dC-DC converter (SEPIC), With the help of this converter DC voltage is step-up this

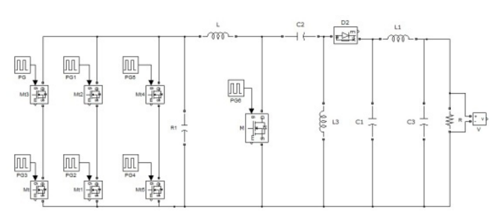

Figure 2. Circuit diagram of Open Loop System.

DC voltage is given through filters and pure DC voltage is given to the load (LED & Motor).

3.1 Results of Open Loop Control

The output voltage of 48 volts is without disturbance, When the disturbance occured in the source side there is some light variation in the load side, Controller not able to regain it's original state or possition, since we are using open loop system the output voltage will not come back to its original voltage of 48 volts is shown in the Figure 3.

The output current of 1 Amps is without disturbance, When the disturbance occured in the source side there is some light variation in the load side, Controller not able to regain it's original state or possition, since we are using open loop system the output current will not come back to its original current of 1 Amps is shown in the Figure 4.

The output power of 48 Watts is without disturbance, when the disturbance occured in the source side there is some light variation in the load side, Controller not able to regain it's original state or possition, since we are using open loop system the output power will not come back to its original power of 48 Watts is shown in the Figure 5.

The circuit diagram of PI controller is as shown in Figure 6, A three phase AC voltage is obtained from SEIG is given to the the controlled rectifier, here 3 ph AC is converted in to controlled DC using this controlled rectifier. PWM pulses for the MOSFET's are given by PIC controller.low voltage DC supply is given to the dC-DC converter (SEPIC),With the help of this converter DC voltage is

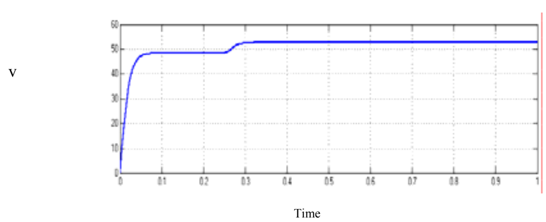

Figure 3. Output voltage waveform with open loop control with disturbance.

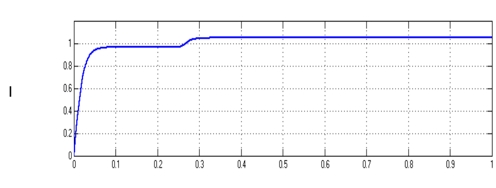

Figure 4. Output current waveform with open loop control with disturbance.

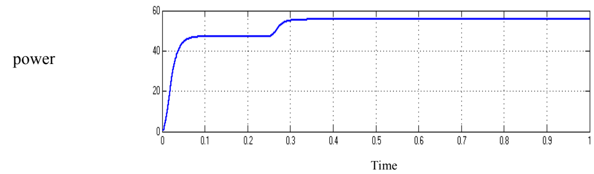

Figure 5. Output power waveform with open loop control with disturbance.

step-up this DC voltage is given through filters and pure DC voltage is given to the load (LED & Motor). The voltage is taken as feedback and compared with referance voltage and the difference is given to the PI controller, the output of the PI controller is given as the input to the PIC controller, This controller will generate the trigerring pulses of the MOSFET's of controlled rectifier and SEPIC convertes.

3.2 Results of PI Control

A 3 Ph AC voltage is obtained from SEIG is shown in the Figure 9, A low voltage of 10 volts is shown in the waveform.

A controlled rectifier voltage is shown in the Figure 5, A controled DC voltage of 20 volts is obtained and the DC voltage is with Disturbance of 2.5 volts as shown in the Figure 8.

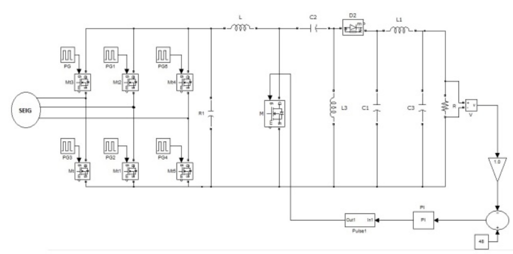

Figure 6. Circuit diagram of PI controller.

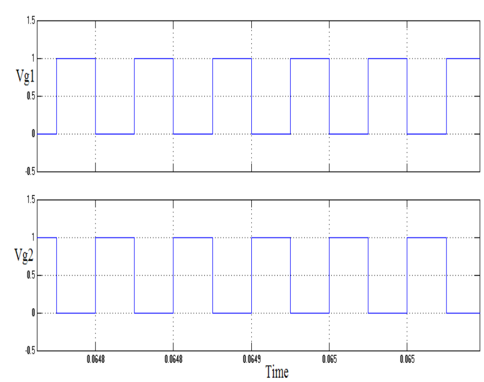

Figure 7. PWM pulses to MOSFET.

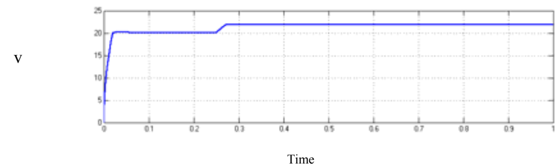

Figure 8. Rectified voltage.

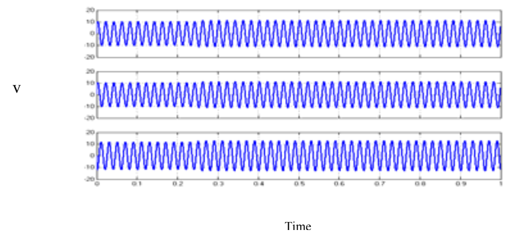

Figure 9. Input voltage.

The output voltage of 48 volts is without disturbance, When the disturbance occured in the source side there is some light variation in the load side for a certain period of time,Time taken by the controller to regain it's original state or possition is called as setteling time, since we are using closed loop system the output voltage is automatically it will come back to its original voltage of 48 volts is shown in the Figure 10.

The output current of 1 Amps is without disturbance, When the disturbance occured in the source side there is some light variation in the load side for a certain period of time, Time taken by the controller to regain it's original state or possitionis called as setteling time, since we are using closed loop system the output current is automatically it will come back to its original current of 1Amps is shown in the Figure 11.

The output power of 48 Watts is without disturbance, When the disturbance occured in the source side there is some light variation in the load side for a certain period of time,Time taken by the controller to regain it's original state or possition is called as setteling time, since we are using closed loop system the output power is automatically it will come back to its original power of 48 watts is shown in the Figure 12.

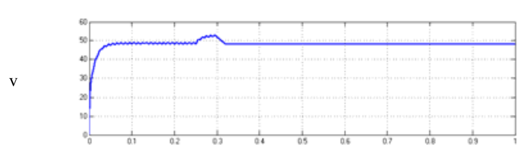

Figure 10. Output voltage waveform with PI controller.

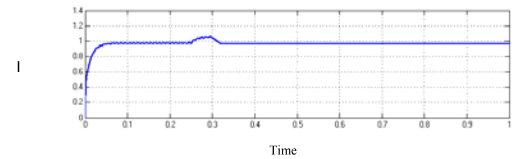

Figure 11. Output current waveform with PI controller.

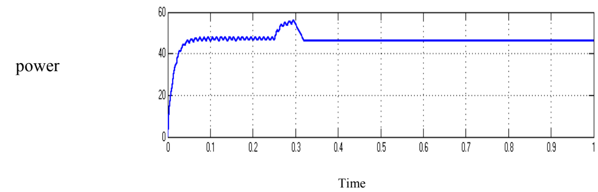

Figure 12. Output power waveform with PI controller.

The circuit diagram of FLCcontroller is as shown in Figure 13, A three phase AC voltage is obtained from SEIG is given to the the controlled rectifier, here 3 ph AC is converted in to controlled DC using this controlled rectifier.PWM pulses for the MOSFET's are given by PIC controller. low voltage DC supply is given to the dC-DC converter (SEPIC), With the help of this converter DC voltage is step-up this DC voltage is given through filters and pure DC voltage is given to the load (LED & Motor). The voltage is taken as feedback and compared with referance voltage and the difference is given to the FLC controller, the output of the FLC controller is given as the input to the PIC controller. This controller will generate the trigerring pulses of the MOSFET's of controlled rectifier and SEPIC convertes.

3.3 Results of FLC Control

The output Voltage of 48 voltsis without disturbance, When the disturbance occured in the source side there is some light variation in the load side, since we are using closed loop FLC system the output voltage is automatically

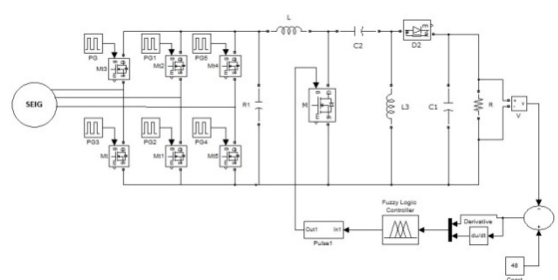

Figure 13. Circuit diagram of FLC.

it will come back to its original Voltage of 48 volts is shown in the Figure 14.

The output current of 0.9 Amps is without disturbance, When the disturbance occured in the source side there is some light variation in the load side, since we are using closed loop FLC system the output current is automatically it will come back to its original current of 0.9 Amps is shown in the Figure 15.

The output power of 40 Watts is without disturbance, When the disturbance occured in the source side there is some light variation in the load side, since we are using closed loop FLC system the output power is automatically it will come back to its original power of 40 watts is shown in the Figure 16.

The hardware implementation which is implemented in the laboratory is shown in the Figure 17.

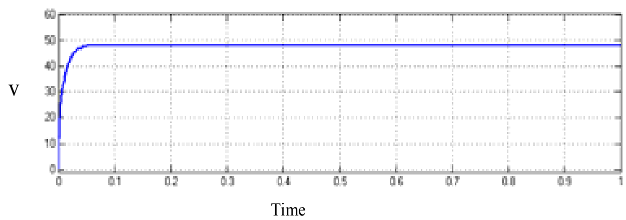

Figure 14. Output voltage waveform with FLC.

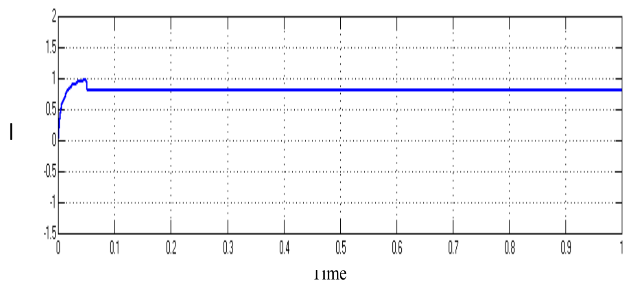

Figure 15. Output current waveform with FLC.

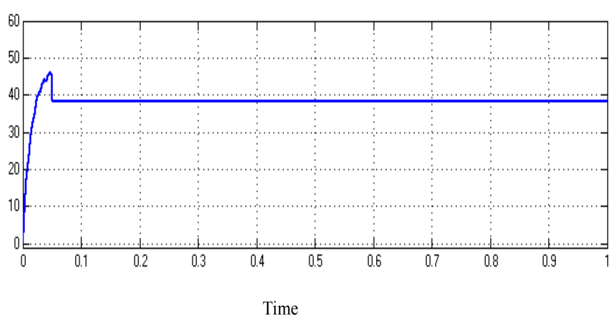

Figure16. Output power waveform with FLC.

Table 1. Comparison table

Controllers	Rise time (s)	Settling time (s)	Steady state error (v)
PI controller	0.06	0.35	0.3
FLC	0.02	Negligible	0.015

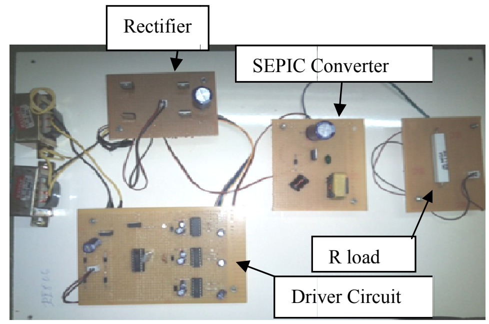

Figure 17. Hardware snap taken in laboratory.

4. Conclusion

This paper has presented a comparative design and implementation of SEPIC converter using different control techniques PI and FLC for the different load conditions for the renewable energy system (wind energy) had been conducted in the laboratory and the results are tabulated below. When compared to PI controller FLC is better, fast and accurate with negligible less than 0.1 seconds.

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