A Review on Fuzzy Logic Control for Solar PV Fed Modular Multilevel Inverter towards Water Pumping Applications

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ABSTRACT

Now-a-days Renewable energy sources have arisen as a viable alternative to fill the ever-increasing need for power. This is due to the fact that renewable energy sources are less damaging to the environment and can be found abundantly in nature. Because there is an abundance of solar power available, the photovoltaic (PV) system is becoming increasingly popular in the field of alternative energy sources. This is due to the fact that PV systems produce electricity directly from sunlight. A method known as the Maximum Power Point Tracking Technique is applied in photovoltaic (PV) arrays in order to extract the maximum amount of power possible from the modules. When it is necessary to transport a significant amount of power from a PV Array to the power grid, there are a number of power quality problems that need to be addressed. These concerns must be solved before the power can be moved. The challenges with the actual and reactive power flow are of special concern. When solar arrays are linked to the electrical grid, there will almost certainly be issues with the quality of the electricity produced. The purpose of this study is to address these issues and manage the flow of power by presenting a novel control strategy that has the latter as its primary focus. It is composed of a Fuzzy-GA based Cascaded Controller fed Flexible AC Transmission System device that is known as the Unified Power Flow Controller. This allows for efficient management of actual and reactive power flow in grid-connected solar systems. The output of the Fuzzy Logic Controller will be a control vector, and the Genetic Algorithm method will be applied in order to fine-tune this vector.

Keyword: Flexible AC transmission system (FACTS), Photo voltaic (PV)system ,Unified power flow controller(UPFC)

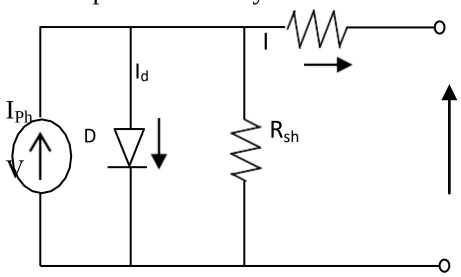
1. INTRODUCTION

In the previous five years, photovoltaic (PV) energy has expanded at an average annual rate of 60%, surpassing one-third of total wind energy installed capacity, and is soon becoming a major element of the energy mix in various regions and power networks. This expansion has also prompted the development of traditional PV power converters from single-phase grid-tied inverters to more complicated topologies in order to boost efficiency, power extraction from modules, and reliability without increasing costs. Solar PV energy conversion systems have grown dramatically, from a total power of around 1.2 GW in1992 to 136 GW in 2013 [1]. Cost reduction, increasing efficiency of PV modules, the hunt for alternative clean energy sources, growing environmental consciousness, and favorable politicallegislation from local governments are the elements driving this phenomenal rise.

When compared to stand-alone systems, grid- connected PV systems account for more than 99% of PV installed capacity. Grid-connected photovoltaic systems do not require storage batteries since all of theelectricity generated by the PV plant is uploaded to the grid for direct transmission, distribution, and consumption. The generated PV power decreases the usage of other energy sources that feed the grid, such as hydro or fossil fuels, whose savings operate as energy storage in the system, offering the same function of power regulation and backup that a battery would provide in a stand-alone system.

When it comes to incorporating renewable energy sources into the existing electrical infrastructure, power electronics technology is absolutely essential. In recent years, power electronics has been subject to a great deal of change, and this can primarily be attributed to two factors. The first of these is the creation of fast semiconductor switches that are able to switch quickly and are able to withstand high power levels. The development of real-time computer controllers that are able to perform complex and cutting-edge control algorithms is the second factor. A typical component of Distributed Generation systems that are based on renewable energy or micro sources is the power electronics interfaces that are required to transform the output voltages of the energy sources to grid-ready voltages [2]. As the need for electricity in the world increases, photovoltaic (PV) power that is supplied to the utility grid is gaining more and more attention [3]. Few photovoltaic (PV) systems have been deployed on the grid as of yet because of the relatively high cost of doing so in comparison to other conventional forms of energy generation, such as oil, gas, coal, nuclear power, hydroelectricity, and wind. It has been shown that solid-state inverters are the technology that makes it possible to link photovoltaic (PV) systems to the electrical grid [4].

There are two distinct categories for solar systems that are connected to the grid: distributed and centralized. Grid-connected distributed photovoltaic systems are installed to offer



electricity to a customer who is also linked to the grid or to the electric network directly. Benefits of these systems include low distribution losses in the electric network because the system is installed at the point of use; no additional land is required; mounting costs can be reduced if the system is mounted on an existing structure; and the PV array itself can be used as cladding or roofing material, as in building-integrated PV. These benefits come as a result of the fact that the system is installed at the point of use. The normal range for residential systems is between 1 and 4 kW, but the range for rooftop systems on public and commercial buildings is anywhere from 10kW to several MW.

Centralized photovoltaic (PV) systems that are linked to the grid can function as central power stations. The electricity that is supplied by such a system is not connected to any one particular energy consumer, and the system itself is not placed on the electrical network for any purpose other than to serve as a source of bulk power. More than one megawatt of power may often be handled by centralized systems, which are typically installed on the ground. The ability to reduce the costs of installation and operation through bulk purchase, as well as the cost efficiency of photovoltaic components and system balancing when implemented on a large scale, are among the economic benefits offered by these systems. In addition, the liability that is associated with centralized PV systems may be greater than that which is associated with distributed PV systems. This is due to the fact that maintenance systems that include monitoring equipment may account for a lower fraction of the total cost of the system [5].

2. PV CELL MODEL

Solar energy powers PV systems. PV cells are the foundation of PV systems. PV Cells made of semiconducting material turn sunlight into direct electricity. Modules ranging from 50 to 200 watts are formed using PV cells. Modules, inverters, batteries, electrical components, and mounting systems are the components that make up a PV system. Modular photovoltaic systems have the potential to generate anything from a few watts to tens of megawatts. Silicon photovoltaics dominate. Modules made of thin films other than silicon are quite popular. Thin films have a lower cost per unit of capacity compared to silicon modules, but they have a lower efficiency.

PV advantages. Large manufacturers can construct modules for scale. Modular PV. Solar power may make advantage of either direct or diffuse sunlight. Solar photovoltaic, in contrast to concentrated solar power, may produce electricity even on cloudy days. Because of this capacity, deployment beyond CSP may occur anywhere in the world [6].

The fundamental photovoltaic cell is seen in Figure 1.

Figure 1. Basic PV Cell Model

The source of the current, known as photocurrent, is directly related to the quantity of light that is concentrated on the cell. According to: the amount of irradiation from the sun and the temperature both have an effect on the amount of current that is produced by the current source.

Where K1 is the temperature coefficient of the short-circuit current of the cell, Isc is the short-circuit current of the cell at 25 °C, T is the temperature of the cell, and G is the solar irradiance in W/m2. The I-V characteristic of a PV cell is described as follows, with Id representing the current that is flowing through the diode and I representing the output current: Where V is the solar cell's output voltage, Rs is the series resistance, and Rsh is the shunt resistance.

3. GRID CONNECTED PV SYSTEM

The photovoltaic (PV) system that is linked to the gridnot only creates active electricity, but it also functionsas a reactive power compensator, particularly during peak hours, which are times when the primary grid requires more reactive power than its usual use. Voltage fluctuations are a possible problem that mightarise during the integration of solar power into the gridbecause of the intermittent nature of solar electricity. Intermittency in power is caused primarily by two phenomena known as ramping (the fast output fluctuations that occur when clouds pass overhead) and "cloud edge effect." Both of these phenomena are responsible for the rapid output variations that occur as clouds pass overhead (where the edge of a cloud acts like a lens, when the sun is behind it).

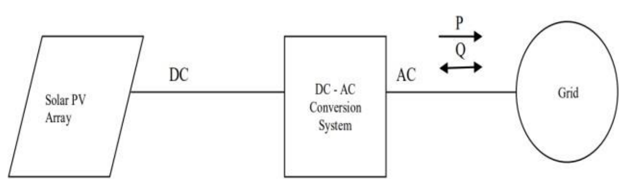


Figure 2. Grid Connected PV System

Conventional photovoltaic (PV) systems typically consist of photovoltaic cells that are organised into the shape of a single module, a string of modules that are linked in series, or an array of modules that are connected in parallel. Using these configurations, the PV cells are able to generate a dc current, and the degree of sensitivity of this current is determined, in large part, by the quantity of solar irradiation, the temperature, and the voltage that are present at the terminals of the PV system. This direct current (dc) electricity has to be transformed using a photovoltaic (PV) inverter before it can be fed to the grid as an alternative source of energy. Some of the additional components that are included are a grid connection filter, a grid monitor or interaction unit (for synchronisation, measurements, anti-island detection, and other purposes), and a low-frequency transformer (although the inclusion of these components may be optional depending on local regulations, the converter topology, and the modulation that is used to control it). Another option involves the installation of a dc–dc power stage anywhere in the middle of the line that connects the solar modules to the grid-connected inverter. This may be done anywhere along the way. This extra step, which is optional, allows the operational point of the PV system to be detached from the control that the PV inverter has over the grid. In addition to these capabilities, it may also be able to offer galvanic isolation, change the maximum power point tracking (MPPT) function, and raise the dc output voltage of the PV system if it is necessary for it to do so [7].

There has been consistent growth in the photovoltaic power conversion stage as a consequence of a rise in the capacity of PV systems that have been installed. This is a direct result of the aforementioned situation. This is a direct consequence of the previous action. Solar photovoltaic (PV) power converters have undergone consistent development to become incredibly dependable, space-saving, and effective. Because of this, it is now possible to create the greatest amount of useful electricity from the sun in a variety of various contexts, such as in residential, commercial, and industrial settings [8, 9]. Figure 2 provides a visual representation of the primary elements that make up a photovoltaic (PV) system that is linked to the grid but does not incorporate any kind of energy storage solution. Either the voltage at which the array operates can be manually altered by the operator, or the voltage at which the array operates can be predetermined by the inverter using a maximum power point tracking system. This allows the voltage at which the array operates to be controlled in one of two ways. The operator can choose any of these two viable courses of action. The inverter operates in phase with the grid (it has a power factor of one), and it is normally sending as much power as it can to the electric power grid taking into consideration the amount of sunlight that is present at the time as well as the temperature conditions that are present at the time in question. The inverter plays the part of a current source; it generates a sinusoidal output current, but it does not in any way, shape, or form change the voltage that is existing at its terminals. This is because the inverter does not have any voltage-changing capabilities.

4. FUZZY LOGIC CONTROLLER

The key components of the Fuzzy Logic Controller are the defuzzifier at the output terminal, the Fuzzy at the input terminal, the rule base or knowledge base, and the inference engine. The Fuzzy is located at the input terminal. Figure 4 provides a visual representation of these component parts. The input variables and the output variables count as necessary variables within the context of the fuzzy logic control system. Both sets of variables are included in the phrase "needed variables." The inputs to the fuzzy logic controller are the aspects of the process, such as its variables or parameters that need to be regulated.

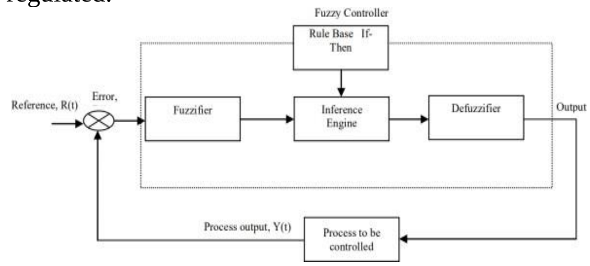


Figure 4. Basic Fuzzy Logic Controller

As input variables, we have selected error and the rate at which error is changing. As output variables, we have chosen the change in current and the change in voltage. The term "error," E(t), refers to the disparity that exists between the desired output or reference, R(t), and the variable that represents the outcome of the process, Y(t).

$$E(t) = R(t) - Y(t) \quad (5)$$

$$\Delta E(t) = E(t) - E(t-1) \quad (6)$$

In equations (5) and (6), respectively, the present error,denoted by E(t), as well as the change in error, denoted by the function E(t), are outlined. It is the job of the membership functions to inject a little bit of randomness into the variables that are being entered. The controller is able to reduce the error signal in a more expedient manner by employing triangular and trapezoidal membership functions, while simultaneously boosting the system's capacity to respond to transients. This is possible because the controller is able to use triangle membership functions. The rule-based or knowledge-based section of the fuzzy logic controller is the most important component of this kind of controller. This element of the controller, which consists of a list of fuzzy rules, can also be thought of as the knowledge-based portion. If the If-Then requirements are adhered to, the inference technique will, as a consequence, result in the development of a fuzzy output set. The fuzzy controller is able to display intelligent behavior and is capable of making judgements that are equivalent to those made by people when these rules are applied to it.

The linguistic names NL (Negative Large), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PL (Positive Large) (Positive Large) will be used for the membership functions, respectively. NL, NM, NS, and ZE make up the membership classification. The outcomes of the creation of rules using 49 rule bases [27] are displayed in Table 1. The rules are specified in linguistic variables that tie input signals to control signals.

Table 1: The existing body of knowledge A table containing 49 rules

E	Δe

	NL	NM	NS	ZE	PS	PM	PL
NL	ZE	PS	PM	PL	PL	PL	PL
NM	NS	ZE	PS	PM	PM	PL	PL
NS	NM	NS	ZE	PS	PS	PM	PL
ZE	NM	NM	NS	ZE	PS	PM	PM
PS	NL	NM	NS	NS	ZE	PS	PM
PM	NL	NL	NM	NM	NS	ZE	PS
PL	NL	NL	NL	NL	NM	NS	ZE

5. SEVEN LEVEL INVERTER TOPOLOGY

Fig. 1 shows a cascaded capacitor selection circuit and full-bridge power converter in a seven-level inverter. The seven-level inverter's positive and negative half cycles may be separated. Assuming ideal power electronic switches and diodes simplifies analysis. In the capacitor selection circuit, capacitors C1 and C2 have constant voltages of Vdc /3 and 2Vdc /3. The seven-level inverter's output current is positive in the utility's positive half cycle since the solar power production system's output current is sinusoidal and in phase with it. The solar power generating system will manage its output current to be sinusoidal and in phase with the utility voltage. Figure 7 shows the seven-level inverter's four modes throughout the utility's positive half cycle.

Mode 1: The seven-level inverter's output voltage matches the capacitor selection circuit's. The seven-level inverter outputs Vdc/3. Mode 2: The seven-level inverter's output voltage matches its input voltage. Fig. 7(a) shows the technique. Since the capacitor selection switches SS1 and SS2 are off, D1 discharges C1. The capacitor selection circuit outputs Vdc/3. The full-bridge power converter activates S1 and S4 outputs.

Figure 7(b) illustrates mode 2. Mode 2 defaults. The capacitor selection circuit outputs 2Vdc/3 because C2 is discharged through SS2 and D2 when SS1 is off and SS2 is on. The full-bridge power converter activates S1 and S4 outputs. The seven-level inverter now outputs 2Vdc/3...

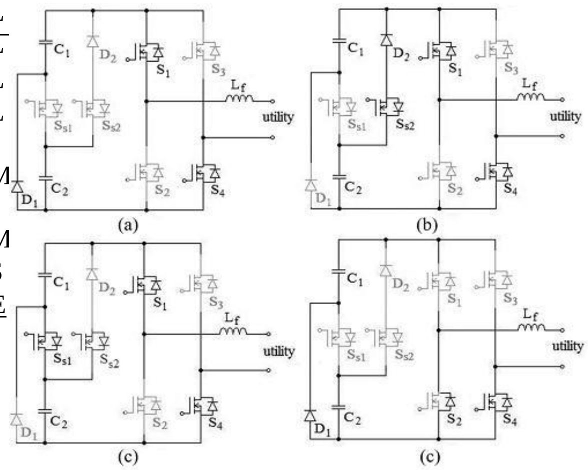


Fig. 7. In the positive half cycle, the seven-level inverter operates in modes 1–4.

Mode 3: The capacitor selection circuit, SS1, is active (Fig. 7(c)). SS2 cannot affect current flow because D2 has a reverse bias while SS1 is active. To prevent switching, SS2 can be ON or OFF. The capacitor selection circuit outputs Vdc and discharges C1 and C2 in series. The full-bridge power converter activates S1 and S4 outputs. The seven-level inverter now outputs Vdc.

Figure 7(d) shows mode 4 operation. The capacitor selection circuit's SS1 and SS2 switches are off. The capacitor selection circuit generates Vdc minus three. Only

The full-bridge power converter's S4 is active. The seven-level inverter's positive output current travels via the filter inductor, causing S2's anti-parallel diode to be switched ON to continually conduct the current. The seven-level inverter is now outputting no voltage.

The seven-level inverter's positive half-cycle output voltage has four levels: Vdc, 2Vdc/3, Vdc/3, and 0. The seven-level inverter outputs negative current during the negative half cycle. Figure 8 shows four modes of operation for the seven-level inverter.

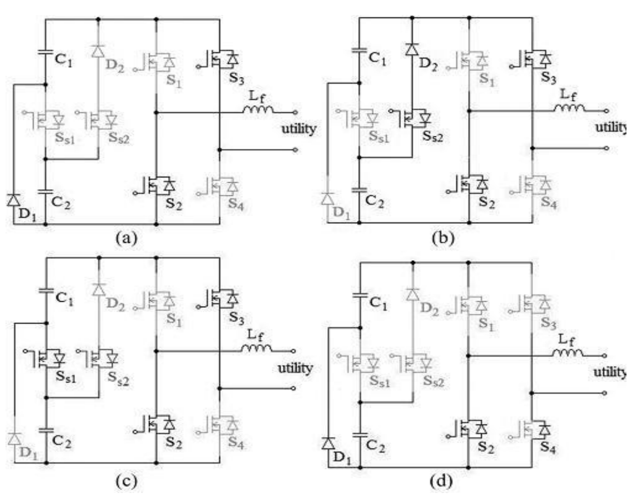


Fig. 8. In the negative half cycle, the seven-level inverter

operates in modes 5–8.

6. PROPOSED SYSTEM

The inner loop and the outer loop make up the cascaded fuzzy-logic controller, and they are both connected to each other. There are two fuzzy controllers located inside of each loop, and these controllers are accountable for the evolution of error signals. The final outputs of the cascaded controller are what are employed to create the pulse width modulation (PWM) signals that are then utilized to run the power electronic switches that are a part of the power converter. These final outputs serve as the voltage references for the three-phase system. The output of the fuzzy logic controller is a regulated vector so that the level of controllability of the power electronic switches may be improved. The genetic algorithm is then used to make additional adjustments to this vector.

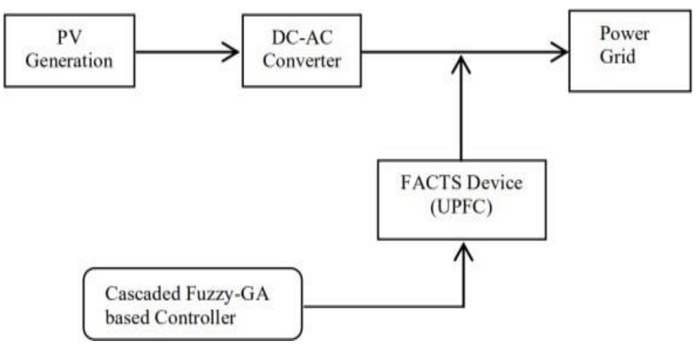


Figure 6. Grid Connected PV system with Proposed Controller and FACTS device

In Figure 6, we see a solar power setup that has been connected to the local power grid by utilizing an inverter to carry out the process of converting direct current to alternating current. This is just one part of the whole conversion process. A FACT S Device known as the Unified electricity Flow Controller (UPFC), which is linked in between the inverter and the utility grid, is responsible for the regulation and management of the flow of electricity from photovoltaic (PV) systems to utility grids. The Unified Power Flow Controller, which is also referred to as the UPFC, is composed of two voltage-source converters that have the ability to turn off by themselves. These converters are attached to a power transmission system through the use of coupling transformers. In addition, they share a capacitor for the dc link. The creation and absorption of reactive power is the sole responsibility of each converter, and this power is not transferred over the DC connection. The direct current connection functions as a channel via which the active power of one converter can be transferred to another converter. The injected voltage as well as the line current are what determine the active and reactive powers that are injected by the series converter. The independent interchange of reactive power between the ac system and the converters in the series and shunt configurations is the responsibility of both of these converters. The UPFC possesses the capability to provide simultaneous control of all of the fundamental parameters of the power system, including transmission voltage, impedance, and phase angle. This is made possible by the UPFC's multi-controller architecture. The user is able to achieve a wide variety of control objectives since the controller is capable of performing operations such as reactive shunt compensation, series compensation, and phase shifting. The goal of coupling the Unified Power Flow Controller (UPFC) to the Proposed Cascaded Fuzzy-GA based Controller is to improve controllability and minimize the effect of difficulties that develop on both the grid side and the producing side of the system..

7. CONCLUSION

The structure that has been designed and is being deployed as a result of this study will make solar generating systems that are linked to the grid perform more effectively. In the course of the study that has been carried out in order to improve the power transfer efficiency of the photovoltaic system and to extract the maximum amount of power from the solar array, a wide variety of distinct controllers have been proposed as potential solutions. It has been established that, when compared to the traditional control structures, the performance provided by the cascaded control structure is superior to that of the traditional control structures. However, due to the non-linear characteristics of the structure, determining the parameters for a cascaded control structure may be rather challenging. This is especially the case when the application in question pertains to the field of electric power systems. As a consequence of this, a novel topology has been proposed for the aim of establishing an optimal design technique for the cascaded fuzzy controller that is utilized in power conversion system. This has been done in an effort to improve the design process. As its output, the suggested controller would create a controlled Vector. This Vector will have undergone optimization through the application of the genetic algorithm strategy. The cascaded control approach that was provided may be utilized in a wide number of settings, some of which include those relevant to renewable energy, energy storage systems, variable-speed drives, and FACTS devices that are utilized in power systems.

REFERENCES

[1] International Energy Agency, "PVPS report snapshot of global PV 1992-2013," Rep. IEAPVPS T1-24: 2014.

[2] Carrasco J. M., *et al.*, "Power-electronic systems for the grid integration of renewable energy sources: a survey," *IEEE Trans Industrial Electronics*, vol/issue: 53(4), pp.1002-1016, 2006.

[3] Benner J. P. and Kazmerski L., “Photovoltaics gaining greater visibility,” *IEEE Spectrum,* vol/issue: 36(9), pp. 34-42, 1999.

[4] S. B. Kjaer, *et al.*, “A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules,” *IEEE Trans Industry Applications,* vol/issue: 41(5), pp. 1292-1306, 2005.

[5] Sheikh N. and K. Dundar F., “A comprehensive assessment of solar photo- voltaic technologies: literature review,” in *Proceedings of the technology management in the energy smart world, PICMET,* 2011.

[6] Marks N. D., *et al.*, “Photovoltaic power systems: are view of topologies, converters and controls,” in *22nd Australian universities power engineering conference (AUPEC), 26– 29, Sept 2012*, pp. 1–6, 2012.

[7] S. Kumari J. and Saibabu Ch., “Maximum Power Point Tracking Algorithms for Grid-Connected Photovoltaic Energy Conversion System,” *International Journal of Power Electronics and Drive System (IJPEDS),* vol/issue: 3(4), pp. 424-437, 2014.

[8] Teodorescu R., *et al.*, “Grid Converters for Photovoltaic andWind Power Systems,” Piscataway, NJ, IEEE Press/Wiley, 2011.

[9] Carrasco J. M., *et al*., “Power-electronic systems for thegrid integration of renewable energy sources: A survey,” *IEEE Trans. Ind. Electronics,* vol/issue: 53(4), pp. 1002-1016, 2006.

[10] Abella M. and Chenlo F., “Choosing the right inverter forgrid connected PV systems,” *Renewable Energy World,* vol/issue: 7(2), pp. 132-147, 2004.

[11] Klumpner C., *et al.*, “Alternate ASDs: evaluation of theconverter topologies suited for integrated motor drives,” *IEEE Industry Applications Magazine*, vol/issue: 12(2), pp.71-83, 2006.

[12] Kazmierkowski M., *et al.*, “Control in Power Electronics- Selected Problems,” Academic Press, 2002.

[13] Blasko V. and Kaura V., “A novel control to actively damp resonance in input LC filter of a three-phase voltagesource converter,” *IEEE Trans. on Industry Applications*, vol/issue:33(2), pp. 542-550, 1997.

[14] Agirman I. and Blasko V., “A novel control method of a VSC without AC line voltage sensors,” *IEEE Trans. on Industry Applications,* vol/issue: 39(2), pp. 519-524, 2003.

[15] Song S. H., *et al.*, “Implementation and control of grid connected AC-DC-AC power converter for variable speed wind energy conversion system,” in *Proc. of APEC '03*, vol.1, pp. 154-158, 2003.

[16] Teodorescu R., *et al.*, “Flexible development and test systemfor 11kW wind turbine,” in *Proc. of PESC'03,* vol. 1, pp. 67-72, 2003.

[17] Zeng Q., *et al.*, “SVPWM-based current controller with gridharmonic compensation for three-phase grid-connected VSI,” in *Proc. of PESC04*, vol. 4, pp. 3494-3500, 2004.

[18] Teodorescu R. and Blaabjerg F., “Flexible control of small wind turbines with grid failure detection operating in stand-alone and grid-connected mode,” *IEEE Trans. on Power Electronics*, vol/issue: 19(5), pp. 1323-1332, 2004.

[19] Malinowski M., *et al.*, “Virtual-flux-based direct power control of three-phase PWM rectifiers,” *IEEE Trans. on Industry Applications,* vol/issue: 37(4), pp. 1019-1027, 2001.

[20] Malinowski M., *et al.*, “A comparative study of control techniques for PWM rectifiers in AC adjustable speed drives,” *IEEE Trans. on Power Electronics*, vol/issue: 18(6),pp. 1390-1396, 2003.

[21] Prodanovic M. and Green T. C., “Control of power quality in inverter based distributed generation,” in *Proc. of IECON'02*, vol. 2, pp. 1185-1189, 2002.

[22] Prodanovic M. and Green T., “Control and filter design of three-phase inverters for high power quality grid connection,” *IEEE Trans. on Power Electronics,* vol/issue: 18(1), pp. 373-380, 2003.

[23] Candusso D., *et al.*, “Modelling, control and simulation of a fuel cell based power supply system with energy management,” in *Proc. of IECON'02,* vol. 2, pp. 1294-1299,2002.

[24] Malinowski M., *et al.*, “Simple direct power control of three phase PWM rectifier using space-vector modulation (DPC-SVM),” *IEEE Trans. on Industrial Electronics*, vol/issue: 51(2), pp. 447-454, 2004.

[25] Xu L. and Cartwright P., “Direct active and reactive power control of dfig for wind energy generation,” *IEEE Trans. on Energy Conversion,* vol/issue: 21(3), pp. 750-758,2006.

[26] X. Yan, *et al*., “An Improved Genetic Algorithm and Its Application,” *TELKOMNIKA Indonesian Journal ofElectrical Engineering*, vol/issue: 10(5), pp. 1081-1086, 2012.

[27] H. Reddy, “Power Control using Fuzzy Logic Controller in DFIG Wind Farm,” *IJST,* vol/issue: 2(11), pp. 47-51,2014.