Active Power Control For A Single-Phase Grid-Connected PV System

Dalia H Al_Maamoury, Muhamad Bin Mansor, Ali Assim Al_Obaidi

Abstract: - This research presents a simulation modelling for the development of active power control for photovoltaic single-phase inverter grid-connected system. The inverter system model and its control strategies are carried out in MATLAB/SIMULINK environment, utilizing SPWM with bipolar switching scheme signals for switching inverter devices (IGBTs) to generate (50Hz) pure sine wave. Fuzzy logic controller is used to regulate the active power flow for both modes of operations namely isolated and grid-connected mode according to the load power demand. The inverter provides power not only to the local loads but also feeds the available excess power to the grid. The simulation was carried out to facilitate the real PV power transfer to the local loads and grid. With the excellent results of 2.07% in the total harmonic distortion (THD) of output voltage, suggests that the proposed control system exhibits a good performance. The simulation results waveforms such as AC output voltages, current and system power flow are presented to validate the efficacy of the control system.

Index Terms: - Fuzzy logic, grid, active power, SPWM, single-phase

1 INTRODUCTION

Alternative energy is one of the requirements of our modern era because of depletion of conventional sources of energy on the surface of the globe. The conventional sources of energy affects the environment by emission of carbon dioxide () which causes global warming. Many options of alternative energy sources for electricity generation have been adopted in order to provide clean energy like wind energy, solar energy, biomass, ocean and nuclear etc. One of the solar energy options is the photovoltaic system. Solar energy has many advantages such as robustness, availability and environmental-friendly. Grid-connected PV inverters are required to excerpt energy from the PV modules and feed it into the utility grid while guaranteeing that power quality tracks specific grid interconnection criteria like IEEE-1547 [1]. Photovoltaic (PV) energy is one of the important renewable energy sources, In order to transport this kind of energy to the electric utility, an interface such as inverter is necessary. The heart of the PV system is the inverter as it inverts the DC voltage from the solar panels into an AC voltage which can be used for numerous loads and the interconnection into the grid [2]. A traditional approach of grid synchronization for grid linked DC/AC inverter is to duplicate the grid voltage. This is so that output current reference has the phase that is the same as the grid voltage [3]. Unbalanced load will effect on inverter output power. Hence, the control of power flows when the system has different loads power demand, this control plays an important role in achieves system stability and improvement the system performance in renewable energy applications, especially in PV. Fuzzy logic control is the proposed method in this resurge to manage the system power flow according to the load power demand and boost the performance of the single phase grid-connected PV system.

- Dalia H Al_Maamoury pursuing master'sdegree program in electric power engineering in Universiti Tenaga Nasional, Malaysia, PH-0107778197.
- E-mail: Daliahamza_84@yahoo.com

There are many advantages of FL which comprise aspects that provide advantages to the control system. Firstly, is that the FL is easy to understand as there has numerous mathematical expression that are very simple and easy to comprehend. Its approach of "naturalness" and not complexity leads to the fact that FL is extremely interesting to study. Secondly, the FL can be created on besides taking into account the experience of experts; in other words means when in contrast to neural networks, which consider trainingdata and produce opaque, impenetrable models, on the people's experience who know the system can depend on FL. It is based on natural language and the foundations of fuzzy logic are parallel to that of human communication [4]. This paper describes a simulation modeling for the single-phase grid-connected DC/AC inverter for PV system. The inverter system model and the control strategies are carried out on MATLAB/SIMULINK environment. Utilizingfuzzy logic controller to manage power flow for the systemat three defferent loads profile. The inverter not only provides power to the local loads, but also feeds the grid with the available excess power. The fuzzy logic controller regulates real power for both modes of operations, namely isolated and grid-connected modes.

2 GRIDCONNECTED PV SYSTEM

The DC voltage source simulator has (347 V) and capacity power (5200W), then it is connected to the inverter DC/AC with LC filter. The detail of inverter system simulation model is shown in Figure 1. It consists of DC voltage source act as PV array, a full-bridge inverter is connected to the load, and then to the grid the connection to the grid is made possible by (AC/AC converter) act as the switch to isolate or connect the grid according to the load power demand and later this arrangement is controlled through a controller. This paper is developedcontroller for active power flow by use fuzzy logic controller to be utilized in (BIPV) for homes and businesses to manage the active power flow. During the period of overproduction from the generating source, power is routed into the power grid, there by being sold to the local powecompany.

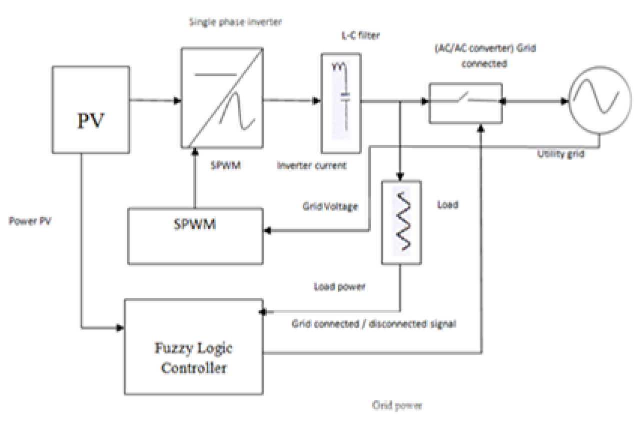

Fig.1. Block diagram of fuzzy controller for a grid connected PV

3 SINGLE-PHASE INVERTERS

A single-phase inverter in the full bridge topology is as shown in Figure.2which consists of four switching devices, two of them on each leg. The full-bridge inverter can produce an output power twice that of the half-bridge inverter with the same input voltage. The operations of single phase full bridge inverter can be divided into two conditions. Normally the switches $S_{11}$and $S_{22}$are turned on and kept on for one half period and $S_{12}$and $S_{21}$are turned off. At this condition, the output voltage across the load is equal to *Vdc.* When $S_{12}$and $S_{21}$are turned on, the switches $S_{11}$and switches $S_{22}$are turned off, then at this time the output voltage is equal to *–Vdc.* The output voltage will change alternately from positive half period and negative half period. To prevent short circuit across DC supply occurred, the switches S_{11} and S_{22}must be in 'on' state while $S_{12}$and S_{21}must be in 'off' state. In order to prevent short circuit occurred, dead time mechanism has been used in gate driver circuit.

$$Vd/2\ (S_{11}-S_{12}) = V_{an}+V_{n0}=V_{(a0)} \qquad (1)$$

$$Vd/2\ (S_{21}-S_{22}) = V_{bn}+V_{n0}=V_{(b0)} \qquad (2)$$

$$V_{ab}=V_{a0}+V_{bn} \qquad (3)$$

$$M_{11}= (2(V_{an}+V_{n0}))/V_d \qquad (4)$$

$$M_{21}= (2(V_{bn}+V_{n0}))/V_d \qquad (5)$$

Equations 4 and5 give the general expression for the modulationsignals for single-phase DC-AC inverter[5].

4 SIMULATION MODEL

A simulation was conducted for 0.16 seconds in MATLAB/SIMULINK to validate the effectiveness of the control system. It is show in Figure 3.

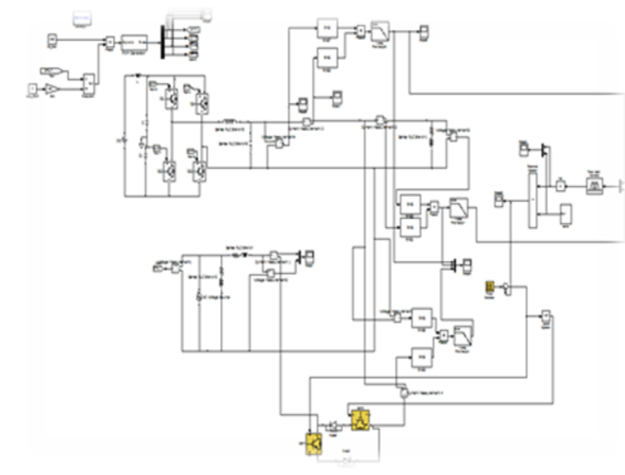

Fig 3. Inverter system simulation model

By applying different loads,the inverter is evaluated with three load profiles:

- **(i)** 5200 W (equal to PV capacity)
- **(ii)** 7700 kW (higher than PV capacity)
- **(iii)** 2700W (less than PV capacity)

The fuzzy logic controller is use to regulate the power flow system according to the load power demand the dynamic of the system power balance (generation and absorption) and the power flow can be observed whether the inverter dispatches excess power to the grid or drawn power from the grid. The output real power signals from the DC voltage source inverter and load real power are fed to the fuzzy logic conntroller, after that the output fuzzy signal is compare with a triangular wave of 9 kHz to generate pulse width(PWM) fed toAC-AC Converter (AC chopper) use as the switch between the grid and the load to decide the choice of an insulat or connect the grid according to the load power demand.

5 BASIC OPERATION OF AC/ACCONVERTER (ACCHOPPER)USING FUZZY CONTROL

AC chopper or (PWM) AC chopper was selected for design to obtain a variable AC voltage from a fixed AC source as show in Figure 4.

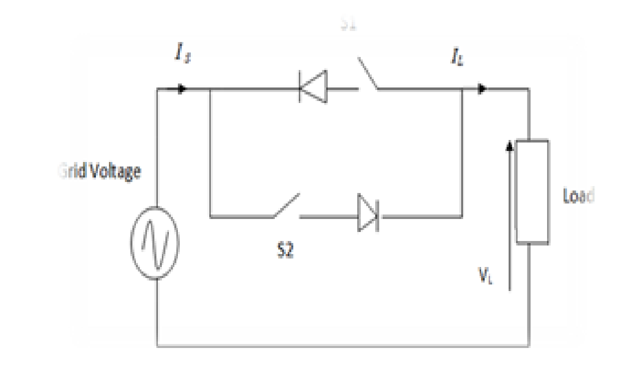

Fig. 4.The typical conventional ac chopper with unidirectional voltage control

State switches are implemented using insulated gate bipolar transistors (IGBT). Each IGBT is connected in series with a diode to block the reverse voltage. The series connected (Two anti-paralleled IGBT with series diodes) regulate the power delivered to the load, this switch is a switch capable of passing current in both directions thus allowing power to flow in both direction. The output voltage may be controlled by changing the modulation index, So=ton/(ton+toff), of the series IGBTs S1 and S2 . The chopper circuit shown, with an R-L load has three modes, in mode (I) S_1 and $S_2$are both turned off when the load power equal to VSI power there is no current and voltage supply from the grid . Mode (II) $S_2$is chopping and $S_1$is closed when the load power is less than VSI power which corresponds to positive supply voltage and positive load current. Mode (III) $S_1$is chopping and S_2 is closed in this mode, the load feeds power back to the supply through $S_1$when the load power is excess the VSI power corresponds to positive supply voltage but negative load current.

6 FUZZY LOGIC CONTROLLER DESIGN

Fuzzy logic control is developed usingthe fuzzy toolbox. The inputs to the Fuzzy Logic Controller are voltage source inverter power (act as PV power) and load power demand. The change of Grid Power Contribution is the output. By triangular membership functions are described the fuzzy logic variables. Fife triangular membership functions are chosen are chosen for simplicity and Table 1 shows the fuzzy rule base created in the present work based on intuitive reasoning and experience. Fuzzy memberships VS, S, M, L, VL are defined as very small, small, Madame, large. The block diagram for fuzzy logic controller is shown in Figure 5.

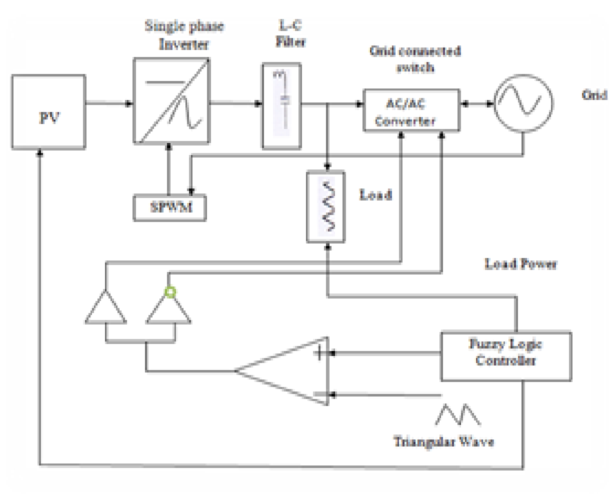

Fig .5.The diagram of fuzzy control for grid connected PV system

Table 1: Fuzzy Rule Table for Output

PV / Load	VS	S	M	L	VL
VS	Z	SP	P	BP	VP
S	SN	Z	SP	P	BP
M	N	N	Z	SP	P
L	BN	N	SN	Z	SP
VL	VN	BN	N	SN	Z

7 RESULTS AND DISCUSSION

The voltage source inverter provides peek voltage (337V), 50 Hz sinusoidal output voltage waveform which is very similar to the voltage waveform is received from the grid as showen in Figures 6 and 7.

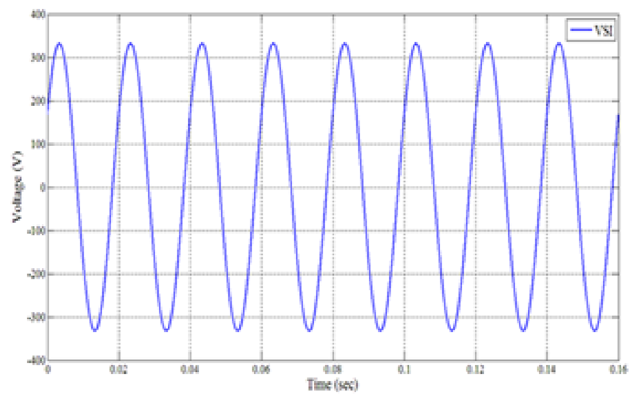

Fig.7. Single phase filtered inverter output voltage

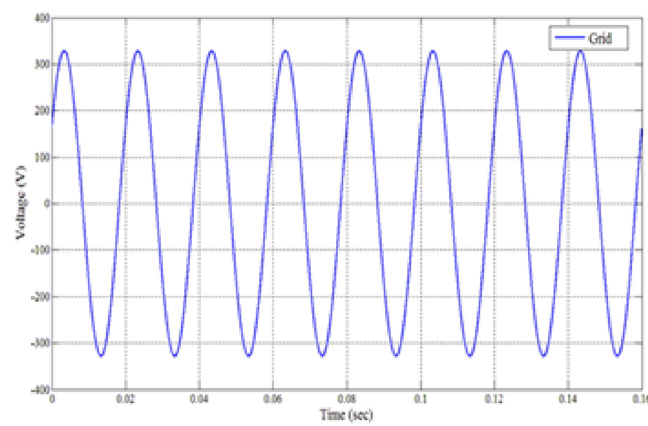

Fig.8. Grid output voltage

The inverter output voltage is synchronous with grid voltage (332.126V)at the same phase and frequency (50HZ) as showen in Figure 9.

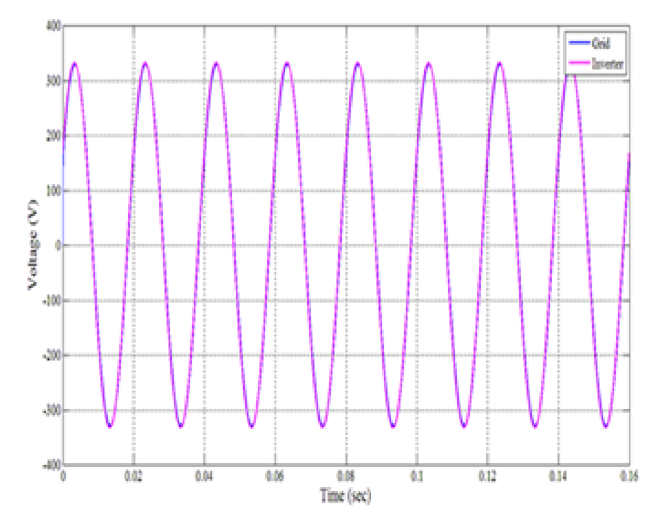

Fig.9. Synchronized between the inverter voltage and the grid voltage.

Grid current is at unity power factor with grid voltage; this can beshow in Figure10.

Where:
θ= 0 , Power Factor = cosθ=1

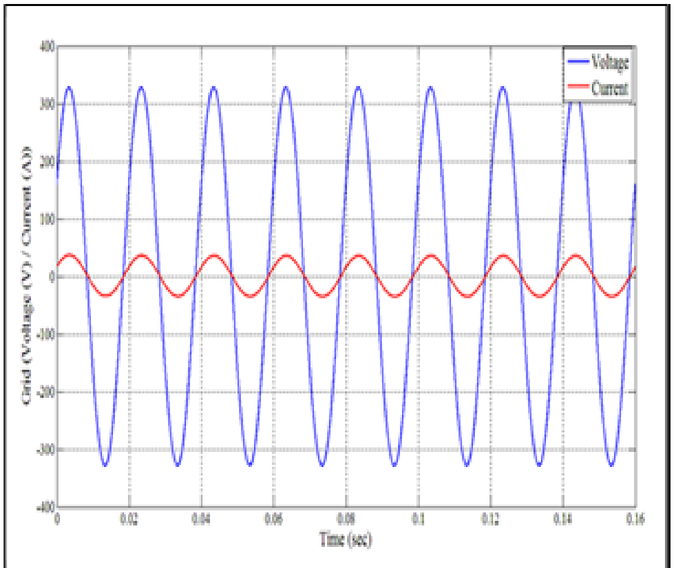

Fig.10. Simulation result Grid voltage and Grid current at unity power

The output sine wave has very little harmonic distortion resulting. The total harmonic distortion (THD) for the inverter output voltage waveform is 2.07% below 5% of IEEEstandard as show in Figure 11.

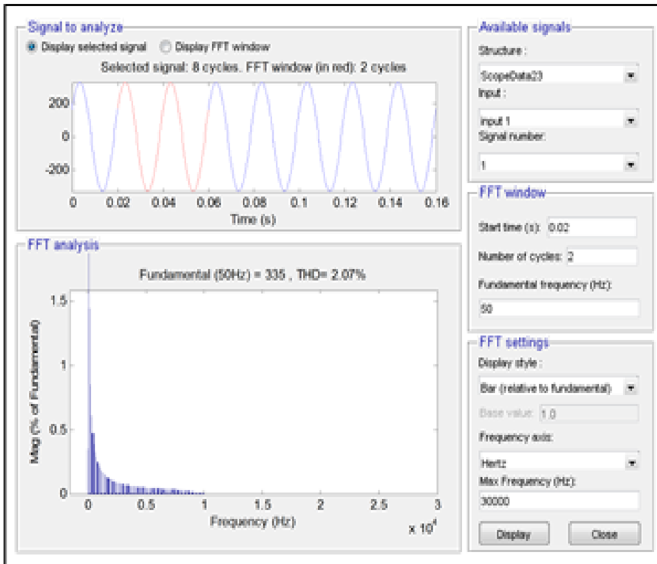

Fig.11. THD and harmonics spectrum of inverter output waveform

The product result of adjusting the system power flow is demonstrated in Figure 12. Forthe period of t = 0 second to t = 0.049 second, and since the voltage source inverter power generation (5200W) equals the load power demand,the all power generated by the (VSI) is transferred to load the system in an standalon mode.As a result no power extracted from or sent to the grid and this is shown by 0 kW on the grid contribution profile. It can be noticed from the figure that the extra load, 2500W, is extracted as a needed power from the grid for the period between t = 0.049 second and t = 0.1 second. This is illustrated via the amount of 2500W section on the grid contribution profile shown in blue in the figure, this is where the voltage source inverter (VSI) power generation is 5200W (indicated in green), but the load demand (indicated in red) is 7700W, which is higher than the(VSI) power generation. Subsequently, the extra required power is extracted from the grid. Another possible scenario demonstrated in the figure is between the period of t = 0.1 second to 0.16 second, where the load (indicated in red) is 2700W and the the voltage source inverter generation is 5200W (indicated in green). There is an excess power of 2500W produced by the the voltage source inverter that is sent to the grid. This is demonstrated in the grid contribution curve(indicated in blue).The result of system power flow analysis implies the effectiveness of the control system algorithm in both standalone and grid-connected operation.

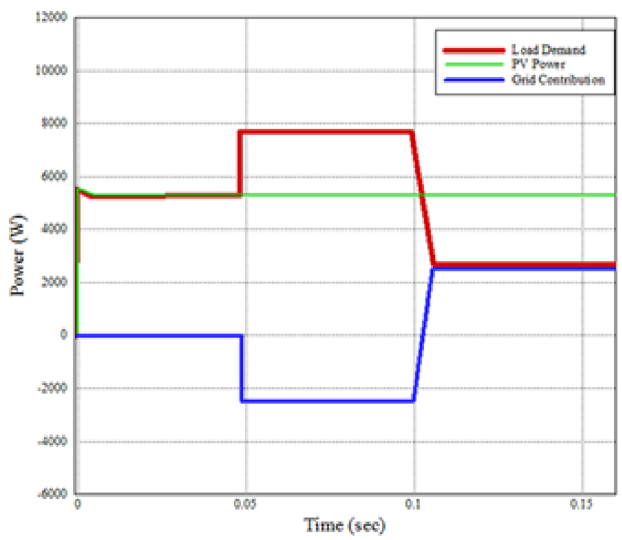

Fig.12 Power flow, P_{load}, P_{VSI} and P_{grid} showing power drain from grid and dispatch to the grid

8 CONCLUSIONS

The investigation of the single phase grid-connected for the PV system has been presented. The developed of active power control system modeling is carried out in MATLAB/SIMULINK environment with different load power demands.The presented results showed that the inverter control is successful in converting (VSI) DC power to AC powerfor supplying power to the load and grid as well. it is suggested that the proposed control system exhibits a good performance. The simulation results waveforms such as AC output voltages, current and system power flow are presented to validate the efficacy ofthe control system.

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