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Design and Performance Analysis of Open Loop Converter Controller

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Abstract- A standalone PV system is preferred over the grid connected system for the residential and rural area load demands. The lot of lots of research is already carried out for the power electronics converter design of renewable energy systems as well as the controller adopted. The various controllers for inverter operation available are Fuzzy logic, PI, PID and MS-PI. All these controllers are for the PV based system and works on the principles of closed loop system. This work proposes an improved inverter voltage controller using open loop control system. This makes the PV inverter system more easy and reliable. Also the inverter is open loop system hence a relay base time dependent controller is proposed here. The inverter is also cable of meet power demand with the variation in load. Based on the results, the proposed controller has proven that its performance is robust and efficient in terms of total harmonic distortion (THD), regulated voltage amplitude in term of oscillation. The harmonic investigation is also performed. The proposed system is validated through simulation results.

Keywords - PV System, Open loop Controller, and Supervisor Control.

I. INTRODUCTION

A stand alone system can provide electricity independent of the local electricity network. A standalone system allows households, farms or lodges, whether remote or urban, to generate their own electricity. These SAPS systems shown in Figure1are usually based on a renewable energy resource and/or a battery/UC.

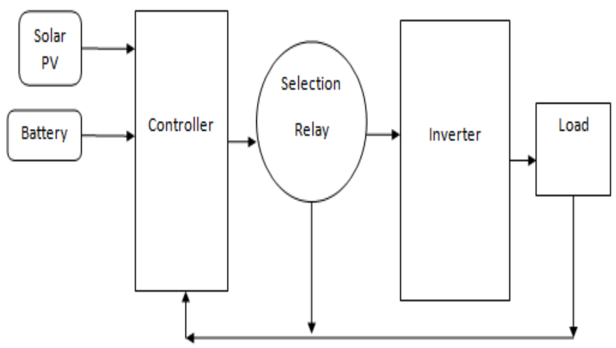

Fig 1. Functional Block Diagram of Standalone system.

A SAPS system can be used to avoid electricity connection costs or by people who wish to be independent of the mains electricity network or 'grid'. The many resident peoples are using SAPS systems. Which is not either currently connected to the local electricity distribution network, or want to disconnect. The type of system installed depends on your specific energy requirements and the renewable energy resources available in particular area.

There is many different SAPS system configurations-Solar, wind, micro-hydro or diesel engine generation sets; it can provide independent electricity supplies. Renewable energy sources are omnipresent, easily available, and environmentally friendly. This is very useful in distant and remote area locations, so that it is becoming very popular and can be used for rural electrification of remote areas. Rural electrification is the process of bringing electrical power to rural and remote areas. Electricity is used not only for lighting and household purposes, but it also allows for mechanization of many farming operations, such as threshing, milking, and hoisting grain for storage.

II. METHODOLOGY

In this section the modeling of PV-Battery/UC system, DC-DC converter, Inverter, filter and open loop controller is performed. The controller operation is also discussed. The detailed about the mathematical standard battery model is also discussed.

1. Simulation Model of PV- Battery/UC System:
PV system with battery unit is modeled in MATLAB as shown in figure 2. For the inverter input the constant voltage level and continuous power is demanded. The constant DC voltage is achieved by using DC-DC converter with variation in duty cycle. The constant dc output is applied to inverter input.

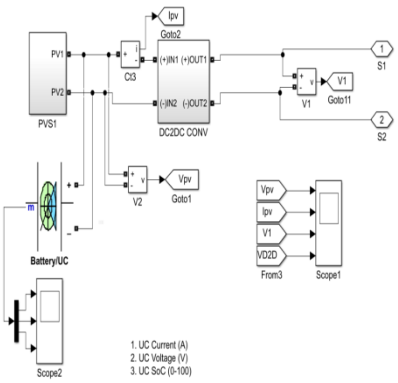

Fig 2. Simulation model of PV- Battery/UC system with DC-DC converter Unit.

2. Simulation of open loop controller Inverter:
The simulation of inverter is performed in MATLAB. The output voltage from the PV system after DC-DC converter is used as the input for the inverter. The conventional inverter with four IGBT as shown in figure 3 is designed.

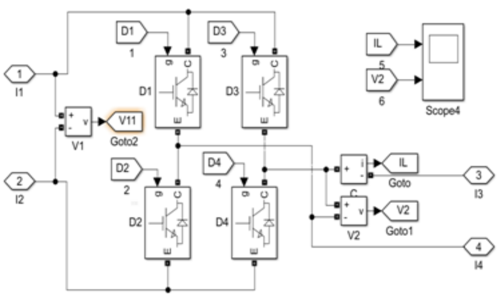

Fig 3. Simulation model of Inverter Unit.

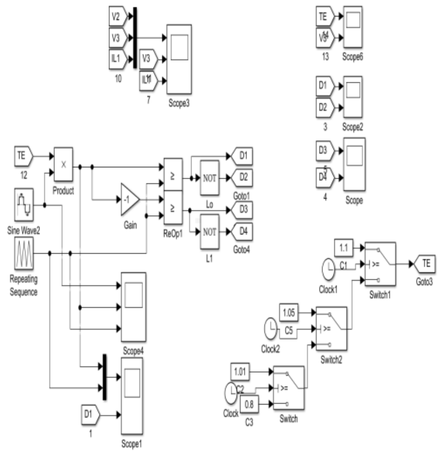

Fig 4. PWM Pulse Scheme for inverter and controller operation.

The PWM pulse Scheme for inverter along with the open loop controller is shown in figure 4with load variation. The controller will operate as per load demand and availability of energy sources. The main purpose of controller is to maintain continuous power supply and maximize the usage of solar and Battery/UC with the variation in load. The variation in load is shown in figure 5.

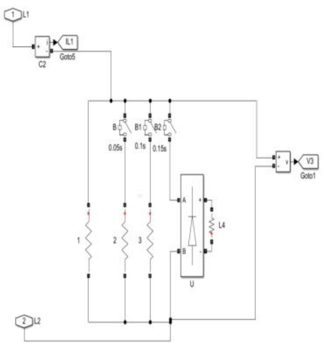

Fig 5. Load variation Unit with controller operation.

The inverter is designed for integration of renewable energy sources in a single unit. The simulation parameters of the voltage source inverter are mentioned in table. The constant DC output voltage from the hybrid renewable energy system through hybrid controller is achieve by integrating all the three different units in a single one and act as a input voltage for the inverter.

A DC-DC converter is also used to maintain the contact voltage level. Voltage level may vary by varying the duty cycle to maintain the DC bus voltage constant. Also an inverter with controller action maintains a constant AC voltage of 200 V i.e.

peak to peak values. A filter unit is used to maintain the THD within the permissible limits.

Table 1. Simulation Parameters of VSI.

D DC Source		
Solar Photo Voltaic Panel:		
	PP PV output Voltage, V_{PV}	50V
	Irr Irradiation	1000W/m2;
	Te Temperature	25°C
	Pa Parallel Strings	4
	Se Series modules per String	2
	Module	1Soltech 1STH-350-W
	x Maximum Power (W)	349.59
	Open Circuit Voltage, V_{OC} (V)	51.5
	S Short Circuit Current, I_{SC} (A)	9.4
	V Voltage at Max Power Point, V_{mp} (V)	43
	Current at Max Power Point, I_{mp} (I)	8.13
	Temp Coefficient of V_{OC} (% per °C)	-0.36
	Temp Coefficient of I_{SC} (% per °C)	0.09
	Cells per module, N_{cell}	80
	Light generated Current, I_L (A)	9.4447
	Diode Saturation Current, I_o (A)	3.23e-10
	Diode Ideality Factor	1.045
	Shunt Resistance, R_{sh} (Ω)	47.96
	Series Resistance, R_{se}(Ω)	0.22828
Battery		
	Nominal Voltage, (V)	36
	Rated Capacity, (Ah)	6.5
	I Initial State of Charge (%)	100
	Battery Response Time, (s)	30
D DC-DC Converter		
	Vout	200V(dc)
	Duty Ratio, δ	0.62
	Carrier Frequency SPWM, f_c	10kHz
	Line inductor, L	15uH
	DC Link Capacitor, C	22uF
DC-AC Inverter		
	Vout=200V(ac); Carrier Frequency, fc=10kHz; SPWM Frequency of modulating signal, f_m=50Hz	
Filter	L_f =5.2mH ; C_f= 67uF	
Load	L1 = 4KW; L2 = 8KW; L3 = 12KW; L4 = 15KW	

III. RESULT & DISCUSSIONS

The completed simulation model of proposed system is shown in figure 6. The proposed system is modeled in MATLAB and it consists of PV- Battery system, Inverter, Filter and Load unit. The detailed about the controller operation and model of all the individual units is already discussed in section 3.

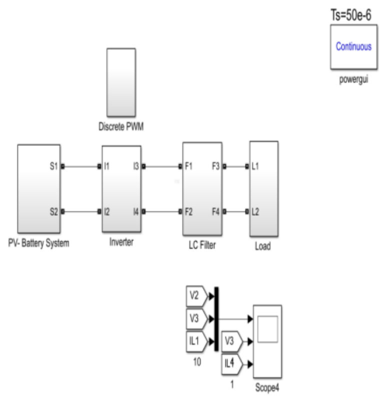

Fig 6. Simulation model of proposed PV system.

The results obtained from simulation work, indicates the efficient working of the proposed system and their control scheme. Figure 4.2 shows the simulation results of load voltage V, load current I with the voltage waveform before filter unit. Different loads of L1 = 4KW; L2 = 8KW; L3 = 12KW; L4 = 15KW are applied at the simulation time of 0.1 sec., 0.2 sec., 0.3 sec. respectively. The loads are sequentially increased as can be observed by the waveform of current which is increasing every time as the load is being changed.

The controller maintains constant voltage across the load of 200V. Controller is also accommodating the effects of transients at the instants of switching hence rendering the system dynamically stable. The controller output is the function of the modulation index (MI) and from the combined waveform it can be observed that as the load is increasing the controller is changing the modulation index so as to maintain the voltage at the load terminals constant. Since the time varying (sinusoidal) signals are rather difficult to control than the time in-varying (dc) signals hence in the proposed scheme a single phase ab0 to dq0 transformation block is used to convert ac signal into its dc equivalent the method of transformation is based on the Park's transformation method.

It is easy for the controller to detect the changes taking place in Vd and Id on account of varying the load.

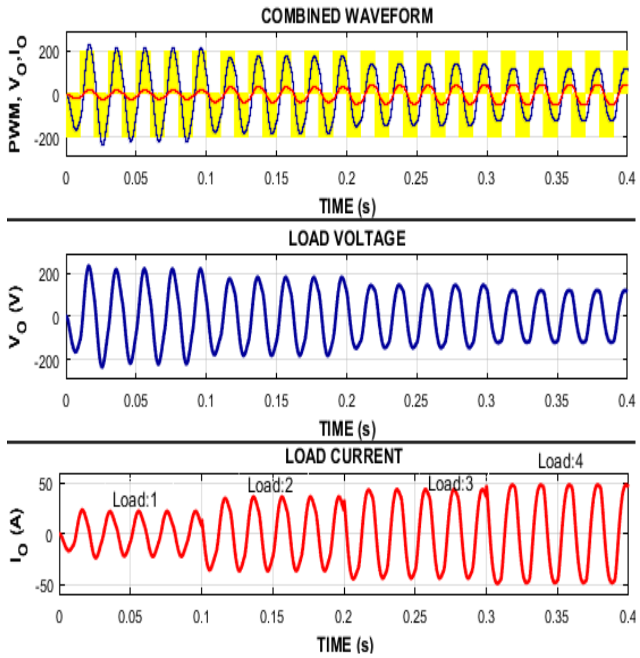

Fig 7. Output voltage and current waveforms without control action.

In figure 7 the top section shows the combined-Pulse, Load Voltage and Load current waveforms when no feedback controlled was applied.

The middle and the bottom sections of the figure represent the Load Voltage and Load Current respectively.

It is apparent from the load voltage and current waveforms that with the increase in load, the load voltage experiences a reduction in its magnitude. In order to maintain a constant voltage under a wide range of load change demands for the application of feed-back control system. Loads are applied at 0, 0.1, 0.2, 0.3, and 0.4 sec. controller is able to maintain the load voltage constant as in figure8 .

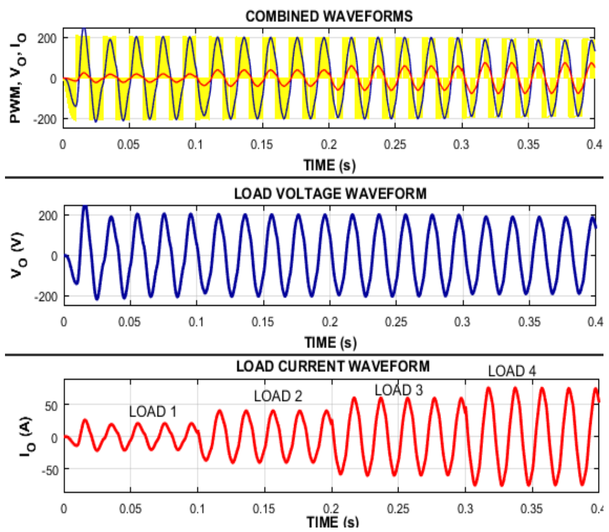

Fig 8. Output voltage and current waveforms with control action.

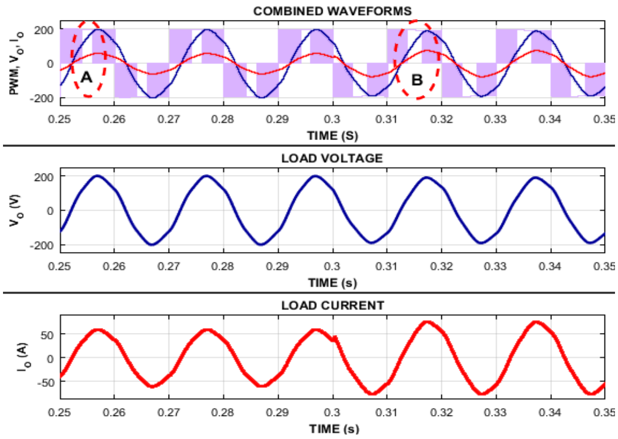

Fig 9. Observed change in Pulse Width with change in load.

Figure 9 is the closer view of the figure. 8 For the purpose of clear analysis of the converter operation. Within encircled regions A and B in the figure, it can be observed that with the load changes the controller is controlling the width of the pulse to maintain the voltage constant at load terminals.

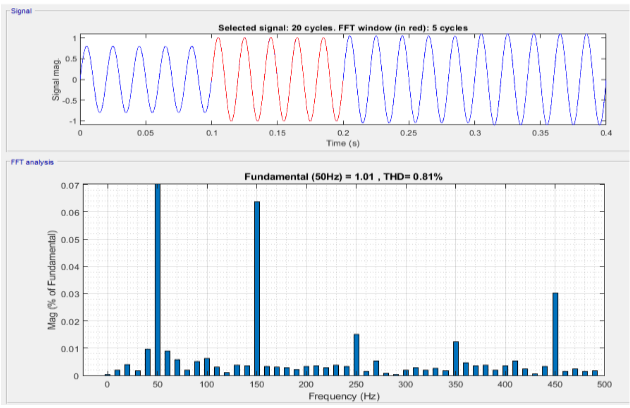

Fig 10. Load Current FFT.

FFT analysis of the load current and voltage after filtering unit is shown in the figure 9 and figure 10 respectively and it is observe that harmonic distortion is under permissible limit.

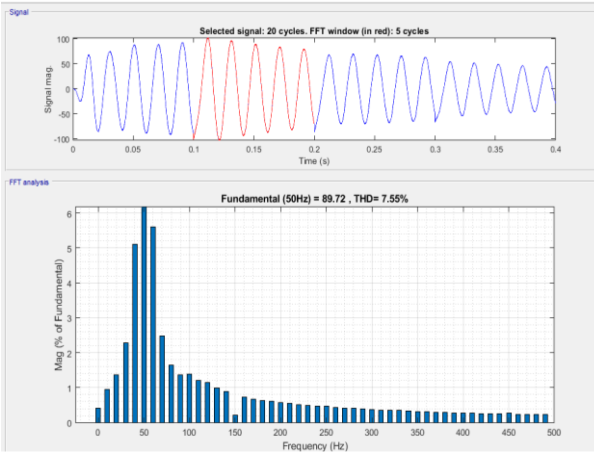

Fig 11. Load Voltage FFT.

IV. CONCLUSION

This study presents an elaborative model of anopen loop voltage controller forStandalone PV system. The simulation model is developed to study the behavior of PV system with open loop controller. Firstly the mathematical model of PV- Battery/UC system is performed; then the open loop system controller is designed with the variation in load.

The harmonic investigation of proposed system with filter unit is investigated and compared with the other closed loop controllers and it is observed that the proposed system is nearly meeting the THD criteria as per the IEEE standards. Also the details comparison of proposed work is presented in table 5.1.

A harmonic profile investigation is also performed with the filtering unit and the THD of load current and load voltage is found to be 0.81 5&7.61%both which are within the permissible limits. This ensures that improvement of power quality of the proposed system. The complete system is reliable during the transient period as well as for the steady state operations.The proposed system may be implemented at the rural sites for the purpose of electrification although it can be further tested through the hardware implementation to ensure the reliability of the system.

Table 2. Comparison of proposed system with existing ones.

S.No.	Parameters	Reference (1) Scopus/SCI	Reference (2) IEEE	Proposed Work
1.	Controller	PSO-PI Algorith	Fuzzy Logic	Multistart (Relay Based Controller)
2.	Load variation	YES	NO	YES
3.	Multiple Energy Sources	NO	NO	YES
4.	Control System	Closed Loop System	Closed Loop System	Open loop system
5.	Switching	SVPWM	SVPWM	SPWM
6.	Energy Systems	PV only	PV only	PV+ Battery/UC
7.	%THD Load Voltage	1.84% (With constant o/p Voltage)	Not Presented	7.61% (With Variation in output voltage as load varies)
8.	%THD Load Current	2.98%	Not Presented	0.81%

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