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PERFORMANCE ANALYSIS OF FUZZY CONTROLLER BASED ZVS DC-DC CONVERTER FOR SOLAR ENERGY CONVERSION SYSTEM

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Abstract- This present work emphasis on the improvement of resonant converter (DC –DC converter) for solar energy conversion system (SECS). It accentuations on plan and exhibiting periods of the distinctive constituents of the SECS like the rudimentary model of zero voltage switching (ZVS) converter, inverter, fuzzy logic controller, best maximum power point tracking (MPPT) system utilizing MATLAB/ Simulink. Here, a resonant converter represents the static and dynamic characteristics of an actual solar irradiance have been developed for simulation tests. The irradiance and temperature changes circumstances are performed using the resonant converter, which consist of PV system, whose control is implemented using Fuzzy logic control unit and MATLAB/ Simulink. This PV module can achieve maximum power using Perturb & Obserb algorithm. Under various abnormal conditions like change in irradiance and temperature, step change in irradiance etc. The control system is executed on a fuzzy logic control unit. Speculative outcomes are exhibited utilizing a 200W model of SECS to demonstrate the better aftereffects of the propelled framework and their control under steady- state and dynamic conditions.

Index Terms- Soft Switching techniques, Maximum Power Point Tracking (MPPT), Fuzzy logic controller (FLC), Zero voltage switching (ZVS), Photo voltaic array (PV array).

1. INTRODUCTION

This present work is for the most part worry towards applying delicate switching strategies for converter which is useful for Photo-Voltaic vitality conversion framework. The goal is to diminish switching losses by utilizing a resounding circuit with ordinary Buck converter. To affirm profoundly productive activity of photograph voltaic (PV) module, maximum power point tracking (MPPT) calculation is utilized for most extreme extraction of intensity. IGBT's are worked in the lower repeat reach out (up to 100 kHz) anyway MOSFET's are worked at generously higher repeat run appeared differently in relation to IGBT. The anticipated converter is worked under zero current switching (ZCS) and zero voltage switching (ZVS) condition which ensures upgraded capability, less electromagnetic impediment, etc.

1.1 Losses in Switching Devices

The gadgets utilized for switching in converters does not act as perfect in exploratory circumstances, henceforth they are wellsprings of loss of vitality in the framework. These losses are of two kinds which are portrayed beneath that are conduction losses and switching losses.

1.2 Soft Switching

The challenges if there should arise an occurrence of hard switching like switching misfortunes, EMI, current and voltage stresses can be decreased by utilizing the delicate switching strategy. ZVS and ZCS are the two switching systems. As on account of MOSFET, it comprises of capacitance C ds which is basically a mix of interior capacitance with extra outer capacitance. MOSFET can be turned on when it is certain that voltage over the switch just before the turned on is zero and MOSFET can turn-off with ZVS in light of Cds which keeps away from a sudden ascent in the voltage as the gadget is turn-off.

2. PROPOSED METHOD FOR RESONANT CONVERTER

In this section, modeling of different components of the proposed resonant converter (DC –DC converter) based SECS are presented in detail. Here, a resonant converter represents the static and dynamic characteristics of an actual solar irradiance have been developed for simulation tests. The irradiance and temperature changes circumstances are accomplished using the resonant converter, which comprise of PV system, whose control is implemented using Fuzzy logic control unit and MATLAB/ Simulink. This PV module can achieve maximum power using Perturb & Obserb algorithm and fuzzy logic controller.

2.1 Arrangement of Proposed PV System

The PV framework with MPPT by utilizing ZVS is appeared in the Fig. 2.1. The yield voltage and current

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of PV is given to the converter and ZVS based MPPT square which thus set the duty cycle of pulses to extract the maximum power.

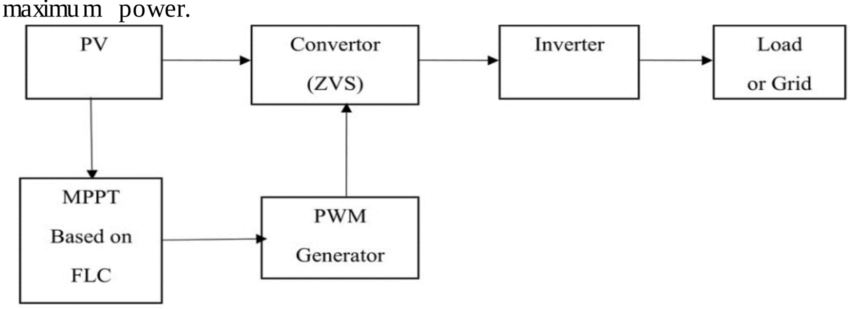

Fig. 2.1 Block Diagram of PV Standalone System with ZVS

2.2 MPPT fuzzy Logic-Based

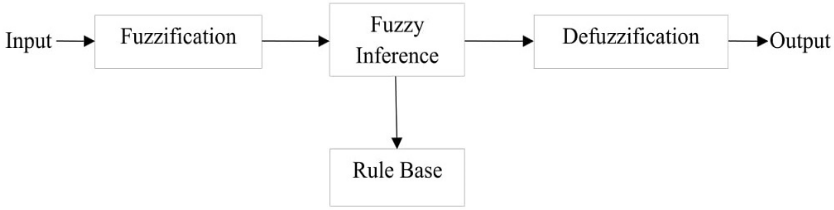

Fig. 2.2 Block Diagram of Fuzzy Control Unit

In the MPPT control, FLC is utilized to decide the duty cycle of the buck convertor. When all is said in done, the contribution on the FLC is error value (E) and modification in error (ΔE) at test time k, anyway the yield of FLC is the yield voltage (V) and power (P).

$$E(k) = P(k) - P(k-1) \div V(k) - V(k-1) \quad (2.1)$$

$$\Delta E(k) = E(k) - E(k-1) \quad (2.2)$$

Five fluffy dimensions are utilized for all the info and yield variable. NS (negative little), NB (negative enormous), ZE (zero), PS (positive little) and PB (positive huge). The control rules are demonstrated in Table- 2.1.

Table-2.1 Fuzzy Rule Base for MPPT

ΔE(K)/ E(k)	**NB**	**NS**	**ZE**	**PS**	**PB**
NB	PB	PB	PS	PS	PS
NS	ZE	ZE	PS	PS	PS
ZE	NS	NS	ZE	PS	PS
PS	NS	NS	NS	ZE	ZE
PB	NB	NB	NS	NS	NS

One E and ΔE are purposeful, they are changed into etymological factors and after that the yield is created by after defuzzification. The centroid technique is utilized for defuzzification due to its great averaging properties.

2.3 MPPT Control for PV System

In P&O strategy, the purpose of the past annoyance and the purpose of the past addition in the power are utilized to choose what the following irritation ought to be on the left of MPP augmenting the voltage cause builds the power while on the privilege decrementing the voltage cause expands the power.

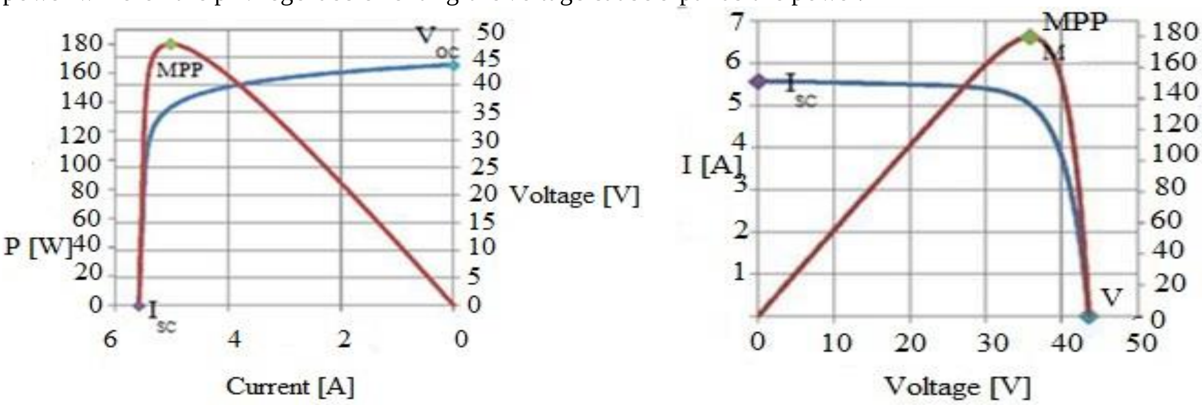

Fig. 2.3 PV Panel Characteristic Curves

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On the off chance that there is an addition in the power, the irritation ought to be kept a similar way and on the off chance that the power diminishes, the following bother ought to be the other way. On Basis of these certainties, the calculation is connected. This irritation technique is intermittent until the point when the MPP isn't obtained. At that point the working point vacillates about the MPP. Same constant irritation reprobate is basic likewise to the INC technique, as was notice prior. A plan of the calculation is appeared in Fig.2.3.

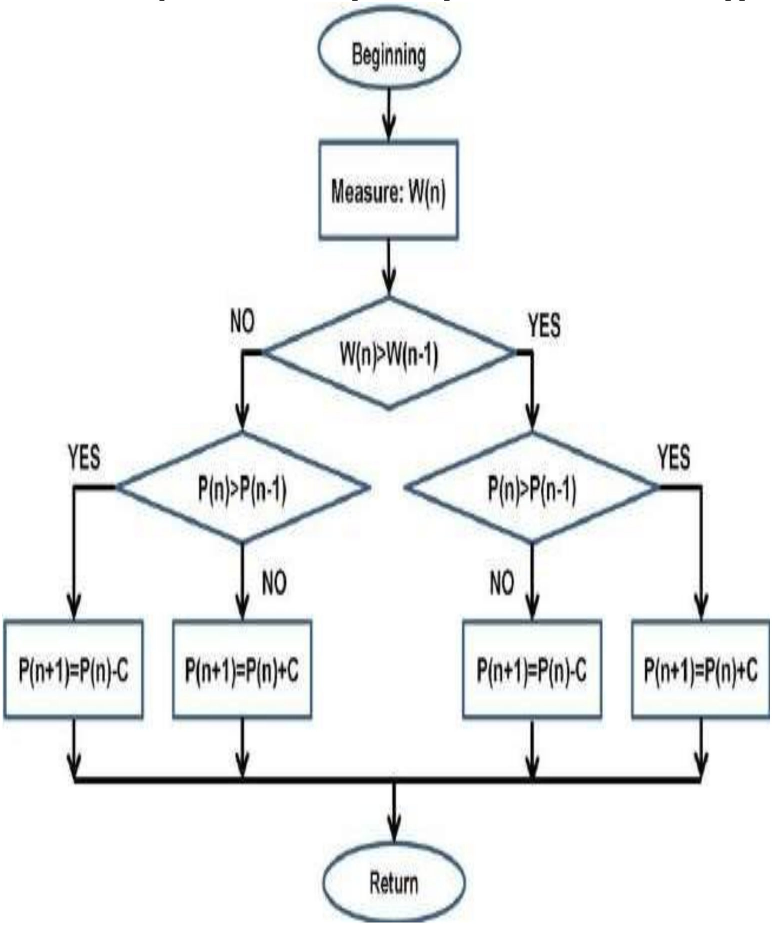

Fig. 2.4 Flow Chart P &O Method MPPT

3. MATHEMATICAL MODELING OF RESONANT CONVERTER

This section contributes a thought on soft-switching buck converter. There are numerous DC-DC converters exist. What's more, the buck converter utilizing delicate switches make the entire framework increasingly powerful. How it builds the capability of framework and detail dialog on soft-switching strategies.

3.1 Simulation of the converter

The converter used in this circuit is simulated in matlab2015a environment by taking this component specification.

Table 3.1: Components Specification for Simulation

S.No.	COMPONENT	SYMBOLS	SPECIFICATION
1.	Resonant inductor	L_r	12.65 µH
2.	Resonant capacitor	C_r	8 nf
3.	Buck inductor	L_{in}	100 µH
4.	Output capacitor	C_o	1 µF
5.	Input voltage	V_{in}	40 V
6.	Switching frequency	f_{sw}	200 kHz

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3.2 Loss Calculation and Comparative Study

In order to pass on the relative investigation, a traditionalist hard switching converter is purposeful for similar stipulations. A buck converter with the constituent qualities is reproduced and the losses of both the converters are thought about.

$$P = V_0 \times I_0 \times F_{sw} \times \frac{T_{on} + T_{off}}{2} \qquad 3.1$$

3.2.1 Losses in the Soft Switching Converter

Under zero voltage condition the fundamental switch's turn-on and changeover happens. Hence, from the above recipe the switching losses of the main switch amid turn-on are zero.

$$P_{swon} = 0 \text{ W} \qquad 3.2$$

The fundamental turn-off changeover happens at decreased voltage and the voltage amid turn-off is estimated and is observed to be 40V and the pinnacle current through this change is estimated to be 4A.
The turning losses amid turn-off time are determined as same however for this situation voltage cross the switch is likewise zero so the switching loss of the main turn-off is zero.

$$P_{swoff} = 0 \qquad 3.3$$

The total switching losses are:

$$P_{sw} = P_{swon} + P_{swoff} = 0 + 0 = 0W \qquad 3.4$$

The conduction losses of the switches are conscious utilizing the equation. The RMS current of the main change is estimated to be 2.82 Amperes and the conduction losses are determined as pursues

$$P_{cond\_sw} = 1.8 * 2.822 * 0.85 = 12.16 \text{ W} \qquad 3.5$$

The conduction losses of the diode are result of the forward voltage drop (VF) over the diode and the normal current (ID) coursing through it. The current through it is the load current that is 0.625 Amperes and voltage drop is 0.8027 Volt. In this manner, the conduction losses of the diode are determined as.

$$P_{cond\_Diode} = V_F * I_D = 0.8027 * 0.625 = 0.5016 \qquad 3.6$$

The total losses in the converter are:

$$P_{losses} = P_{sw} + P_{cond\_sw} + P_{cond\_Diode} \qquad 3.7$$

$$P_{losses} = 0 + 4.32 + 0.502 = 4.8196W$$

So the efficiency of the converter calculated as:

$$\eta = \frac{P_{out}}{P_{out} + P_{loss}} \times 100\%$$

$$\eta = \frac{160}{160 + 4.8196} \times 100\% = 97.07\% \qquad 3.8$$

3.2.2 Losses in Conventional Hard Switching Converter

The main switch in this converter is hard switched and the switching losses are determined utilizing the condition. The voltage over the turn amid ON and OFF conditions is 40V and the pinnacle current is estimated to be 4A. The switching losses of the switch in customary Buck converter are:

$$P = V_0 \times I_0 \times F_{sw} \times \frac{T_{on} + T_{off}}{2}$$

3.9

$$P = 40 \times 4 \times 10^5 \times \frac{200 \times 10^{-9} + 200 \times 10^{-9}}{2} = 3.2W$$

The rms current moving through the change is estimated to be 2.82 Amp. The conduction losses are calculated as:

$$P_{cond\_sw} = 1.8 * 2.822 * 0.85 = 4.32W$$

The conduction losses of the diode are result of the onward voltage drop above the diode and the normal current coursing through it. The forward voltage drop is estimated to be 0.8027 Volts and the present moving through it is the load current which is 0.625 Amperes are determined utilizing.
The conduction losses of the diode can be calculated as:

$$P_{cond\_Diode} = V_F * I_D = 0.8027 * 0.625 = 0.5016$$

The total losses in the converter are:

$$P_{losses} = P_{sw} + P_{cond\_sw} + P_{cond\_Diode}$$

$$P_{losses} = 3.2 + 4.32 + 0.502 = 8.022W \qquad 3.10$$

The efficiency of the converter is calculated as:

$$\eta = \frac{P_{out}}{P_{out} + P_{loss}} \times 100\%$$

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$$\eta = \frac{160}{160 + 8.022} \times 100\% = 95.23\% \qquad 3.11$$

All the result computed/obtained from the comparative study are tabulated and shown in table:

Table-3.2 Comparative Study between Hard and Soft Switching

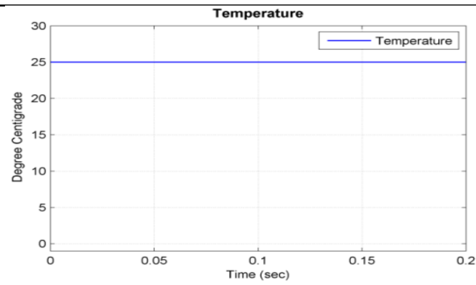
S.No.	Soft Switching Specification	Hard Switching	Soft Switching
1.	P_{sw}	6.4	0
2.	P_{cond}	12.16	12.16
3.	P_d	0.502	0.502
4.	% Efficiency	89.34	92.96

4. RESULTS AND DISCUSSION

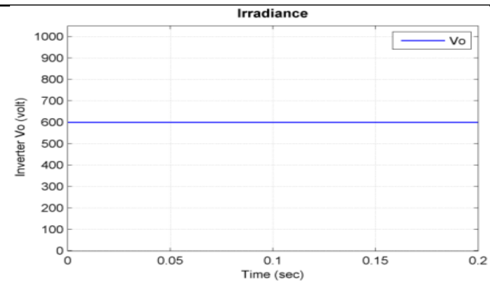
This section shows the simulation results obtained from proposed system, which has been verified under various input conditions and later results are verified.

4.1 Response During Constant Irradiance and Temperature at 800, 25°C

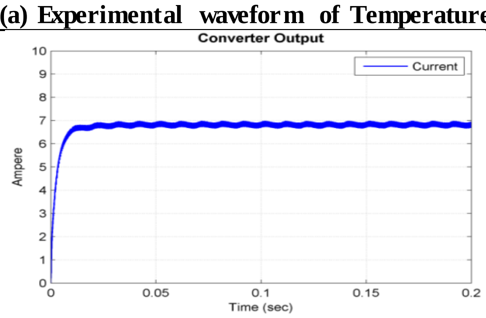
For this case reference temperature set to 25° C Fig. 4.1(a) and Irradiance is set to 600 Fig. 4.1(b), for both controller models. Model is simulated for 0.2 sec and simulation plots for this case given below.



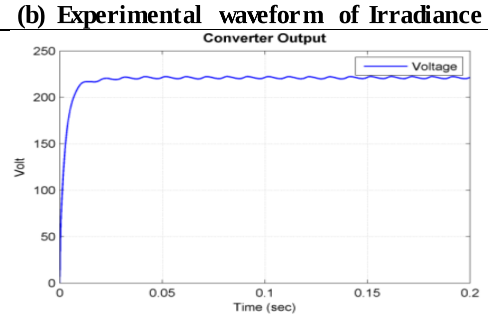
(a) Experimental waveform of Temperature



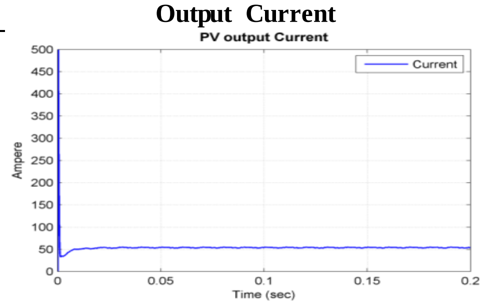
(b) Experimental waveform of Irradiance



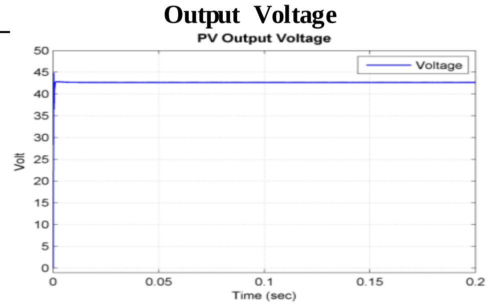
(c) Experimental Waveform of Converter Output Current



(d) Experimental Waveform of Converter Output Voltage



(e). Experimental waveform of PV Output Current.



(f). Experimental waveform of PV Output Voltage.

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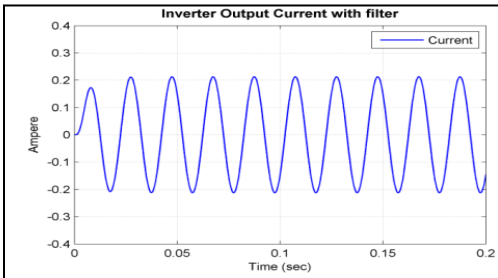
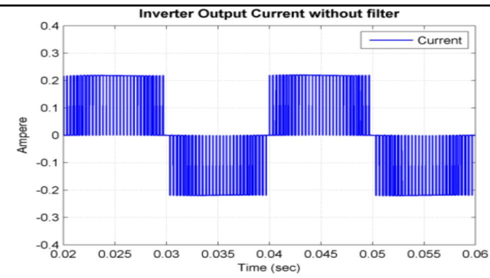
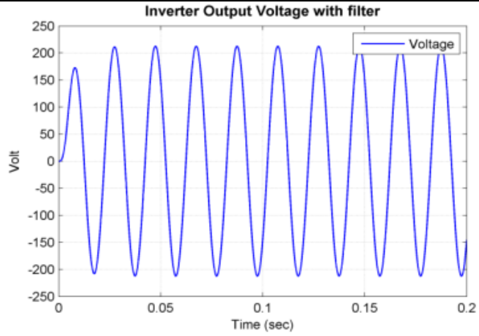


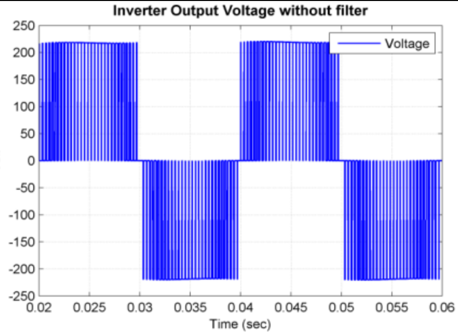
(g) Experimental waveform of Inverter Output Current with filter



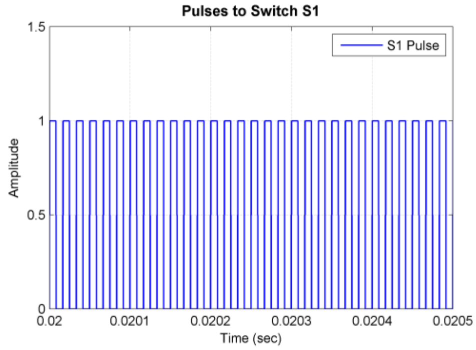
(h) Experimental waveform of Inverter Output Current without filter



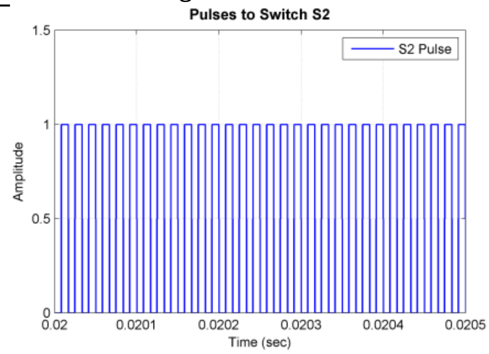
(i) Experimental Waveform of Inverter Output Voltage with Filter



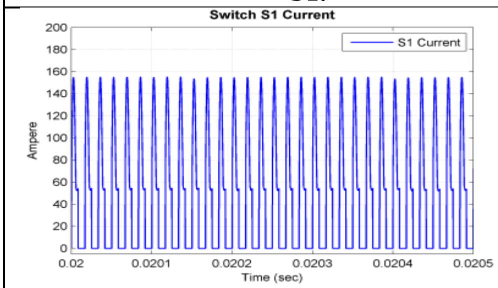
(j) Experimental Waveform of Inverter Output Voltage Without Filter



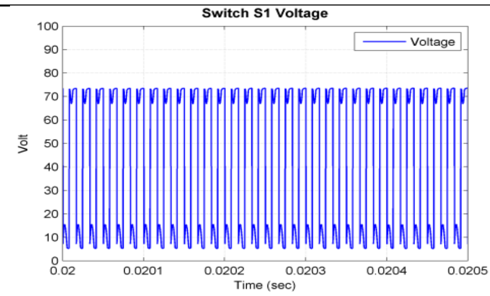
(k). Experimental waveform of Pulses to Switch S1.



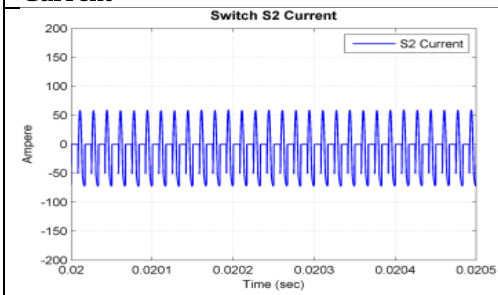
(l). Experimental waveform of Pulses to Switch S2.



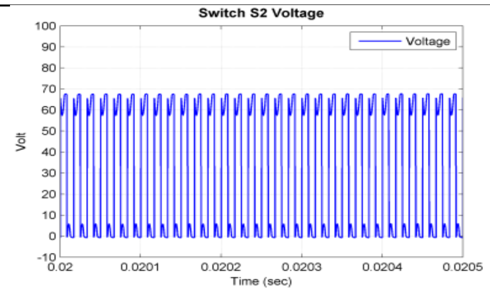
(m) Experimental Waveform of Switch S1 Current



(n) Experimental Waveform of Switch S1 Voltage



(o) Experimental waveform of Switch S2 Current



(p) Experimental waveform of Switch S2 Voltage

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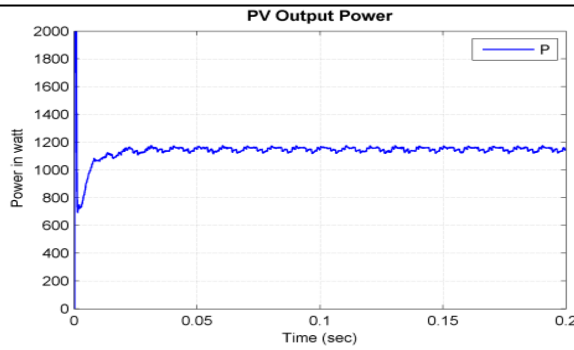
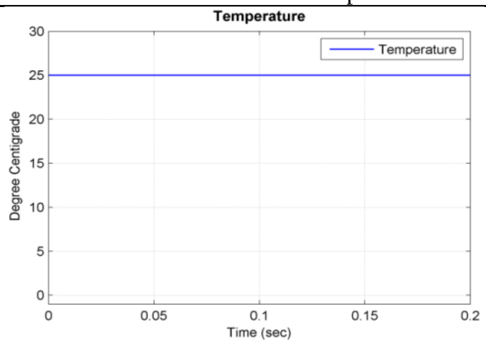


(g) Experimental waveform of PV Output Power

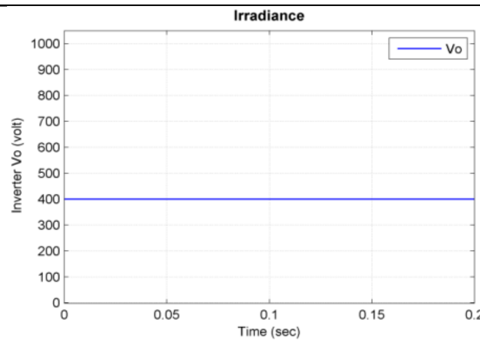
Fig. 4.1: Experimental Waveforms during Constant Resistive Load of 1 kW at 600 Irradiance and 25° C Temperature

4.2 Response during Constant Irradiance and Temperature at 400, 25° C.

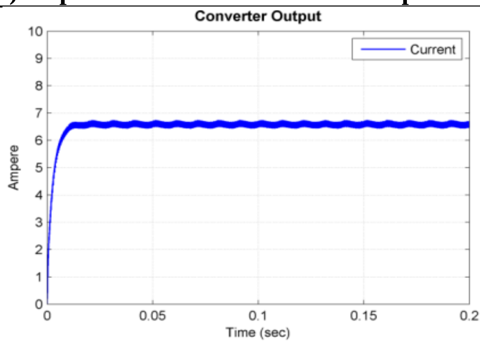
For this case reference temperature set to 25º C Fig. 4.2(a) and Irradiance is set to 400 Fig. 4.2(b), Model is simulated for 0.2 sec and simulation plots for this case given below.



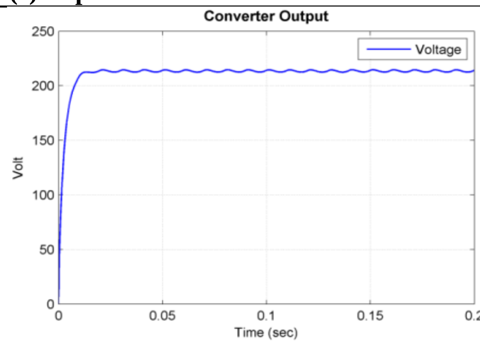
(a). Experimental Waveform of Temperature



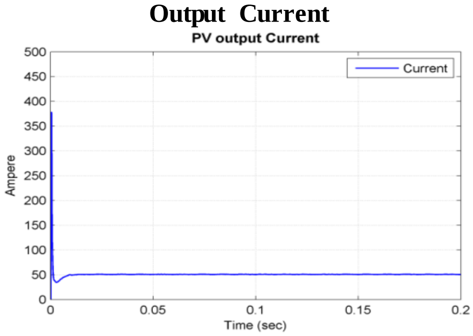
(b) Experimental Waveform of Irradiance.



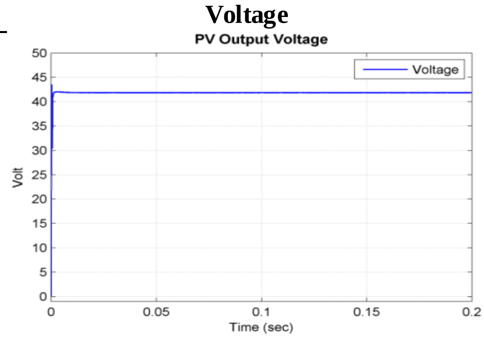
(c) Experimental Waveform of Converter Output Current



(d) Experimental Waveform of Converter Output Voltage



(e).Experimental waveform of PV Output Current.



(f). Experimental waveform of PV Output Voltage.

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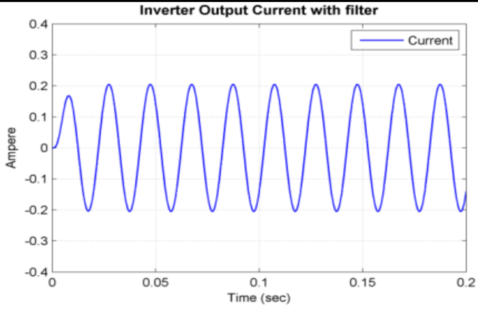
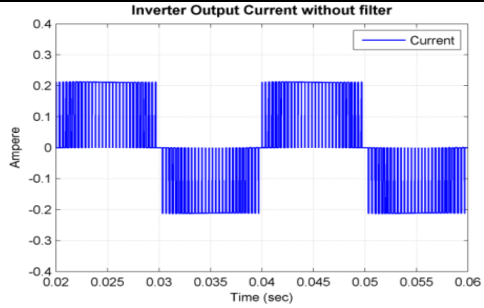
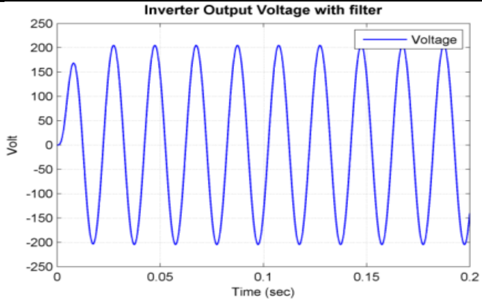


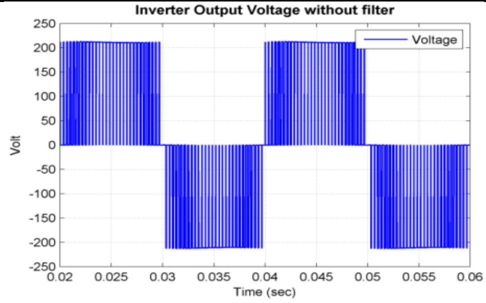
(g) Experimental Waveform of Inverter Output Current with Filter



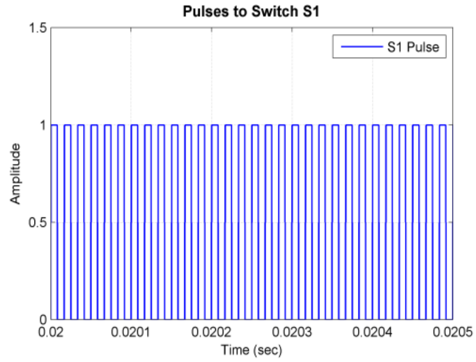
(h) Inverter Output Current without Filter



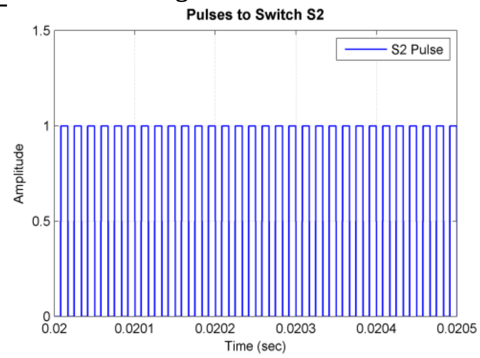
(i). Experimental waveform of Inverter Output voltage with filter.



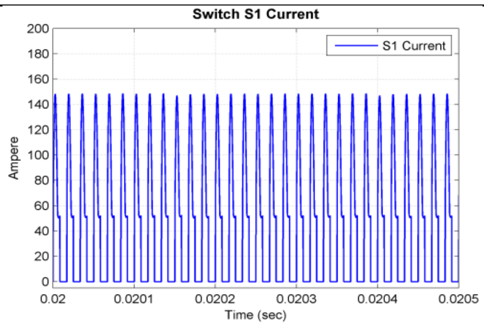
(j). Experimental waveform of Inverter Output voltage without filter.



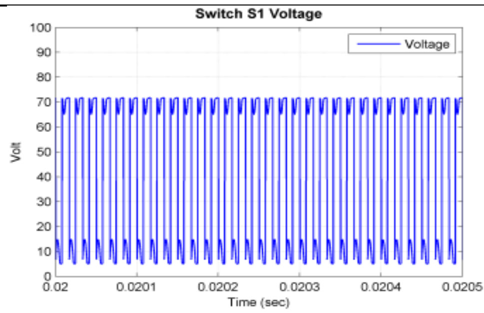
(k) Experimental waveform of Pulses to Switch S1



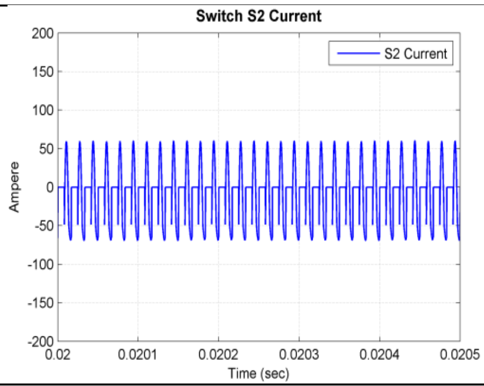
(l) Experimental waveform of Pulses to Switch S2

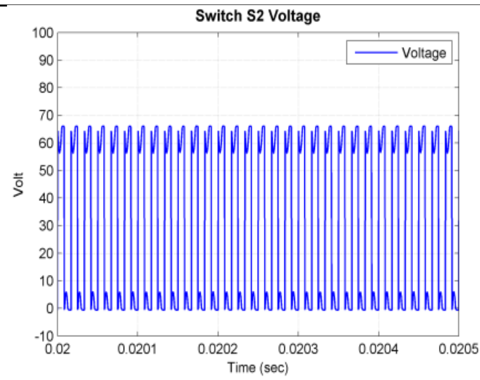


(m). Experimental waveform of Switch S1 Current.



(n). Experimental waveform of Switch S1 Voltage.





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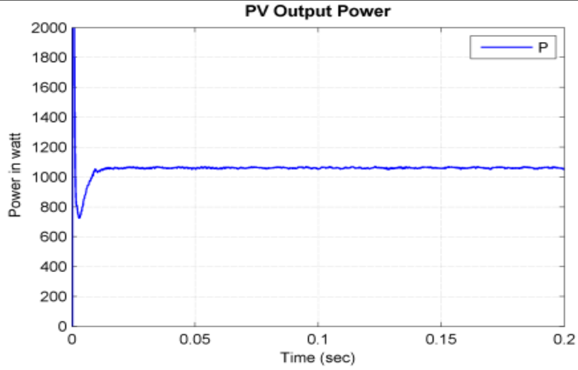
(o). Experimental waveform of Switch S2 Current.	(p). Experimental waveform of Switch S2 Voltage.



(q) Experimental waveform of PV Output Power

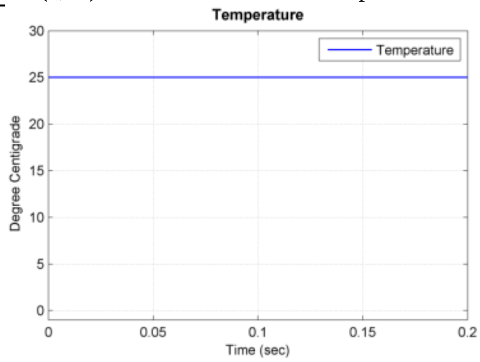
Fig. 4.2: Experimental Waveforms during Constant Resistive Load of 1 kW at 400 Irradiance and 25° C temperature

From test waveforms of Fig. 4.4 (g, i) a great harmony conditions among the load flows and voltages can be figured it out. Additionally, the heap voltage and current waveforms are precisely balanced.

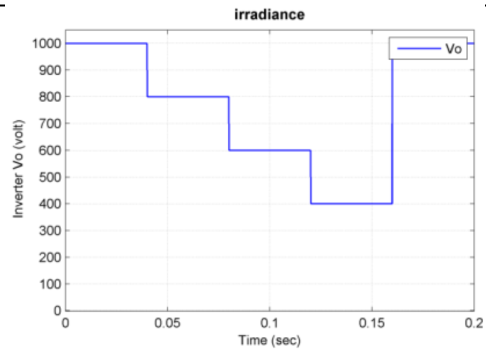
4.3. Response during step change in Irradiance and Temperature 25°C

For this case reference Irradiance is change in step and temperature is set to 25° C. Figures 4.5 illustrate various experimental waveforms of PV output voltage, output current, output power, converter voltage, current, inverter voltage, current with and without filter, switch pulse, current voltage and inverter power.

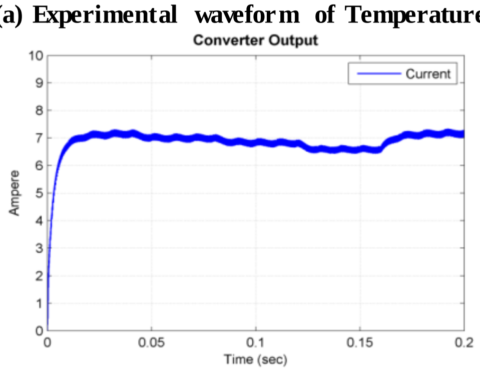
Fig. 4.5 (a, b) shows the reference temperature is 25° C figure and Irradiance varies from 1000-800-600-400.



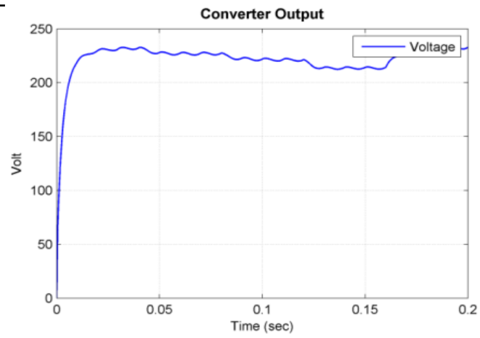
(a) Experimental waveform of Temperature



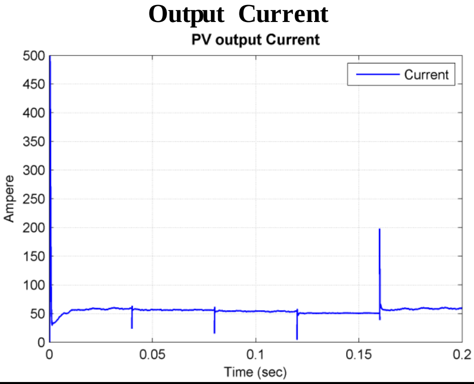
(b) Experimental waveform of Irradiance

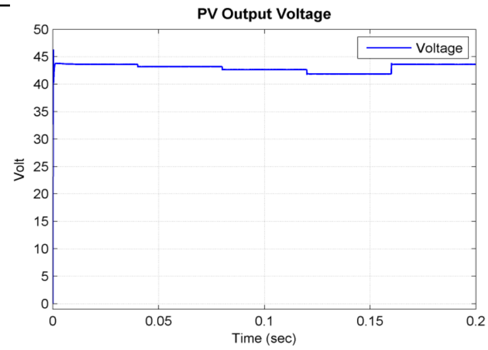


(c) Experimental waveform of Converter Output Current



(d) Experimental waveform of Converter Output Voltage





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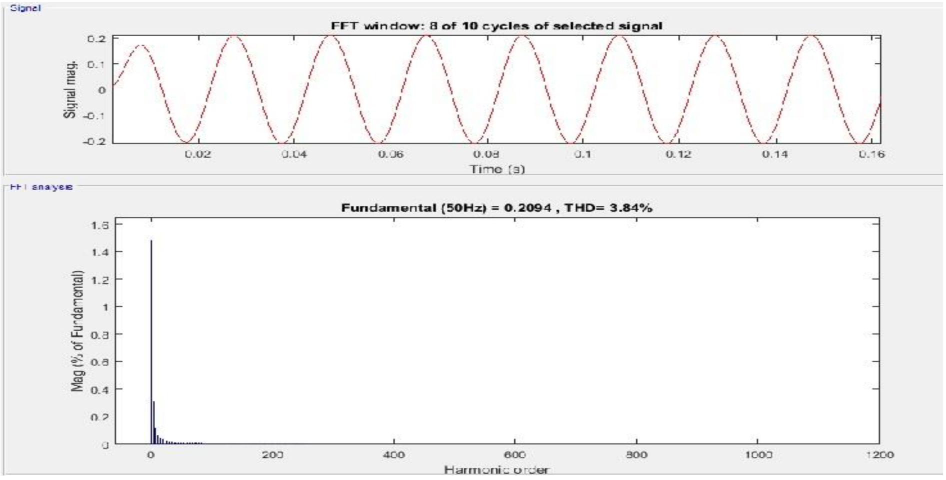
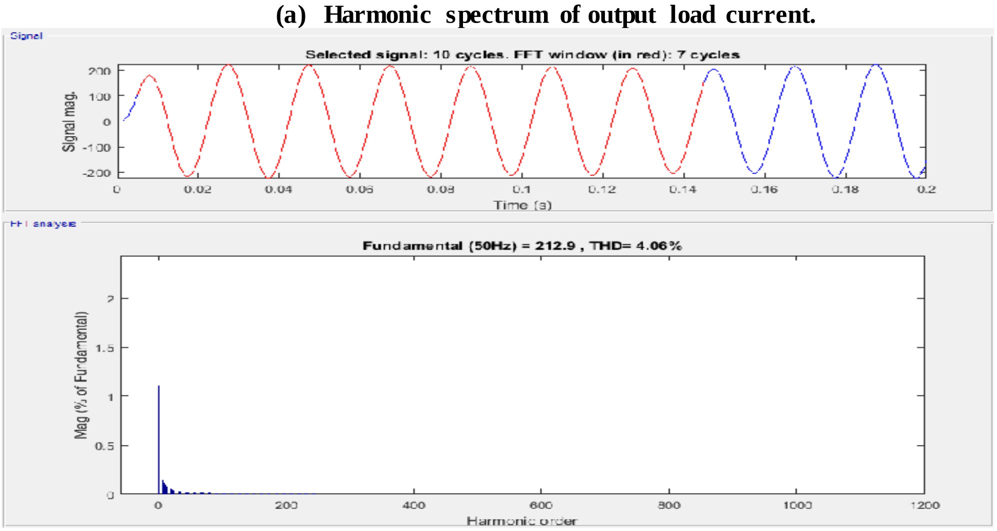
(e) Experimental waveform of PV Output Current	(f) Experimental waveform of PV Output Voltage

Fig. 4.3: Waveforms during constant resistive load of 1 kW at step change in Irradiance at 25°C temp.

From the load current and voltage symphonious range examination which are appeared by Fig. 4.4(a, b), it very well may be fathomed that add up to symphonious bending (THD) of load yield current is 3.84%, stack yield voltage is 4.06%, which is under 5% and it is in assent with the admissible furthest reaches of IEEE 1547, IEEE-519 and IEC 61727 models.



(a) Harmonic spectrum of output load current.



(b) Harmonic spectrum of output load voltage.

Fig. 4.4 Experimental Response of Harmonic Spectrum of Current and Voltage

From experimental results, it is examined that controller works very well and shows outstanding performance in terms of well-adjusted and regulated voltages and currents with low-THD of 3.84 % as per IEEE standards.

CONCLUSION

In this work, a resonant converter for solar energy conversion system (SECS) is proposed and 200W laboratory prototype of the same has been developed. Experimental exploration of the laboratory prototype of resonant converter based SECS is carried out under different irradiance conditions and constant temperature. Various important points are concluded as:

- The main switch losses of ordinary converter are a lot more noteworthy than that of delicate switching based converter. Be that as it may, the switching losses commitment of the hard switching converter overwhelms in the estimation of aggregate losses and henceforth the delicate switched full converter is observed to be more effective than the customary hard-switched converters.
- It is seen that the controller effectively regulates the load voltage and frequency quite well under unbalanced and varying irradiance conditions.
- The load voltage and current waveforms are reasonably balanced. Likewise, it very well may be understood that total harmonic distortion (THD) of load voltage and load current is 3.84% and 4.06% individually, which is under 5% which assent within reasonable limits as indicated by the IEEE standard 1547, IEEE-519 and IEC 61727.
- During shifting irradiance condition, it is seen that load voltage is all around kept up. The trial

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results demonstrate that the age framework can settle stack voltage under fluctuating irradiance.

FUTURE WORK

To continue and complete the work presented in this thesis, one can focus on a number of specific areas such as:

- Multilevel inverter interfaced SECS can be investigated to improve the energy capture with aspect to its configuration, advanced switching strategy and developing its dynamic model.
- Hybrid sensor-less control technique can be developed and examined experimentally for different operating conditions.

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