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HARDWARE IMPLIMENTATION OF LINEAR CURRENT BOOSTER FOR SOLAR PUMPING APPLICATIONS

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ABSTRACT

Solar photovoltaic systems have got widely varying characteristics. In order to match the system characteristics with the load, a maximum power point tracking is inevitable. There are several MPPT techniques proposed till date. But the major concern is how efficiently the system works by the inclusion of tracking system with the existing system. In the case of solar irrigation systems, where electric motors are used will be in need of high starting current in early morning and late evenings. The panel may be unable to provide this required power to the motor. In this paper a new technology called Linear Current Booster (LCB) is being introduced which will increase the current by sacrificing the voltage.

Keywords: solar pumping, LCB, solar panel, solar photovoltaic system.

INTRODUCTION

The most common power converter topology is the buck power converter, sometimes called a step down power converter. Power supply designers choose the buck power converter because the output voltage is always less than the input voltage in the same polarity and is not isolated from the input. The buck converter is a high efficiency step-down DC/DC switching converter [1]. The converter uses a transistor switch, typically a MOSFET, to pulse width modulate the voltage into an inductor. LCB is also a buck converter topology that bucks the voltage thereby increasing the current along with some MPPT techniques.

The requirement is to have high current and low voltage for the dc motor load. A panel with an open circuit voltage of 36 V is employed to power a 24 V dc motor. So we have to reduce 36V to 24V. This is because the 24V solar panel may give an open circuit voltage of 36V. The load is a dc motor of 24V specification. In order to perform this bucking we have to select the inductor and capacitor at the output side accordingly. The inductor performs the bucking action and the capacitor will filter the ripple. To achieve high current slew rate the inductor L should be as small as possible. This in turn will achieve faster transient response and cause the output voltage ripple to increase. So a compromise between two is made for the inductor calculation.

To reduce output voltage ripple, the switching frequency should be increased but this lowers the efficiency. This means that the selection of the switching devices will be an important issue. The output voltage ripple can also be reduced by increasing the output capacitance; this means a large capacitor in practical design [2]. The voltage rating of the capacitor is another main criterion.

DESIGN

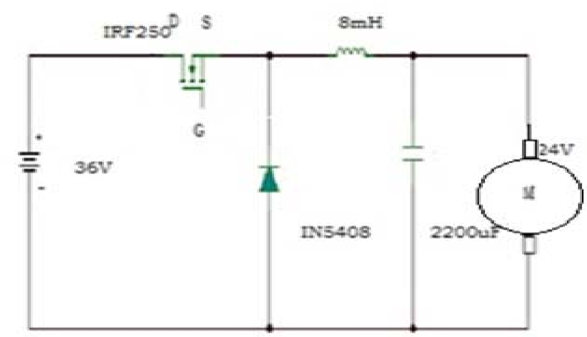

Figure-1. Circuit diagram.

Initial Design Specifications

- Input Voltage = 36 V
- Duty Cycle (D) = 0.666
- Nominal output voltage at no load (VONL) = 24 V
- Maximum output Current (IO)= 1.5 A
- Minimum output current step (d IO) = 1 A
- Switching frequency per phase (fSW) = 10kHz

Inductor Design

Magnetic component design is based on the load current and other core saturation criterion [3]. Inductor design includes certain formulas and also it has to compromise with the market availability

L=Vo (1-D)/ Ir*fs
Where,
L- inductance value H
Vo- output voltage V
D- duty ratio
Ir- ripple current A
fs- switching frequency Hz
L= 24*(1-.666)/.1*10*10^3
= 8.16mH
Choose 8mH inductor

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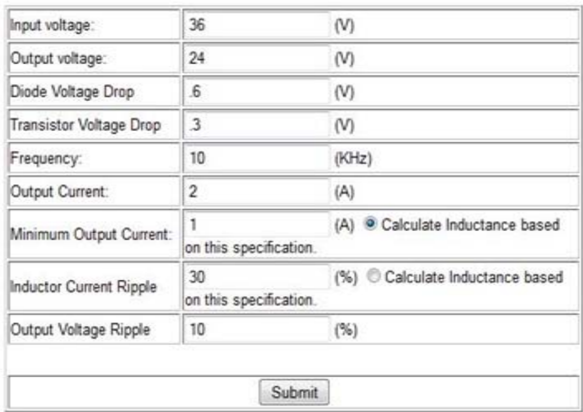
Capacitor Design

Capacitor has a filtering action. Increasing the capacitor value will reduce the ripples. Only the voltage rating has to be considered. Online calculations are available. The higher the value of the capacitance more the filtration will be.

A 2200uF Capacitor was chosen.



Input voltage:	36	(V)
Output voltage:	24	(V)
Diode Voltage Drop	.6	(V)
Transistor Voltage Drop	.3	(V)
Frequency:	10	(KHz)
Output Current:	2	(A)
Minimum Output Current:	1 on this specification.	(A) ◉ Calculate Inductance based
Inductor Current Ripple	30 on this specification.	(%) ○ Calculate Inductance based
Output Voltage Ripple	10	(%)
	Submit	

Figure-2. Online buck converter parameters.

PLATFORM

In order to provide the gate signals a driver circuit was adopted. The input to it has to come from a controller. Hence we make use of the ARDUINO processor for the same.

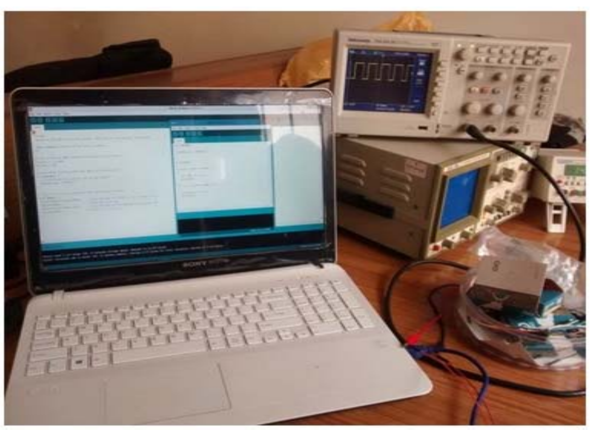


Figure-3. PWM generation.

The variation of solar panel voltage is assessed and taken as an input to the processor. Feedback is also provided to monitor the output as well.

Signals generated using ARDUINO is supplied to the gate driver circuit. In turn 7667 will drive the MOSFET. PWM is changed in accordance with the program. This is connected to the buck converter topology. A pump load is connected across it. Many tracking algorithms are available in solar pumping systems but lacks reliability [4-6]. This one will provide more efficiency.

OVERALL CIRCUIT DIAGRAM

AC supply is given to the transformers (230/9V, 230/15V) and they are rectified using bridge rectifiers. The output is being regulated using regulator ICs 7805 and 7812 respectively. 5V supply is given to the ARDUINO board and 12V supply to the driver and isolator ICs. Regulator circuits are just a part of the main circuit. ARDUINO signals are given to the driver IC 7667 via an opto coupler 6N137. PWM pulses are given to the gate of the MOSFET IRF250. Freewheeling diode is employed. The inductor capacitor combination bucks the voltage and gives filtered output to the pump.

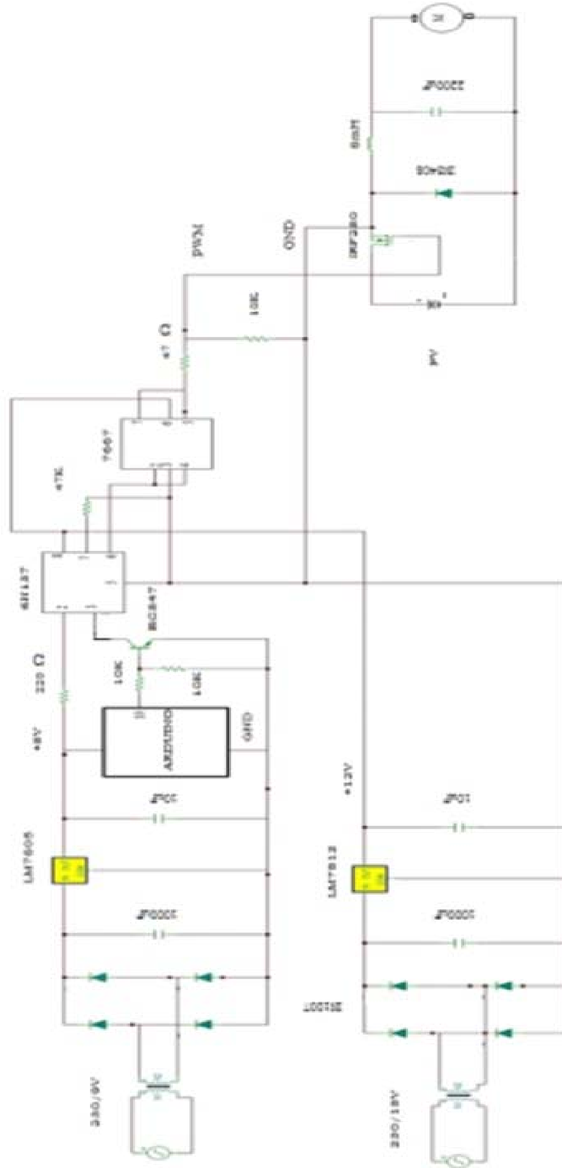


Figure-4. Overall circuit diagram.

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RESULTS AND DISCUSSIONS

The pump load was connected across the dc supply from the panel and the following results were obtained.

Table-1. Output values of hardware.

Input voltage (v)	Output voltage (v)	Flow rate (l/min)
24	24	0.9
25	24.3	0.95
26	25.2	1
27	26.5	1
28	27	1.23
29	27.1	1.3
30	27.15	1.34
31	27.2	1.35
32	27.3	1.39

As the input supply from the panel increases in accordance with the irradiation the supply to the pump has to be decreased. We can see that the minimum voltage maintained is 24V. Some tolerance level is allowed. Flow rate increases as the voltage increases. The graph indicates that the effective area under the curve or the pumping duration increases as we employ LCB instead of directly coupled system. Outer curve indicates the system with LCB.

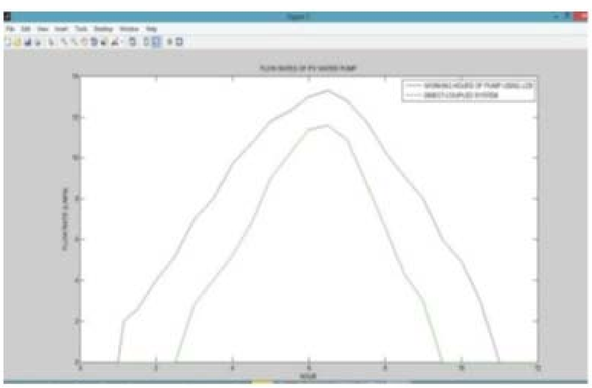

Figure-5. Graph showing variation of flow.

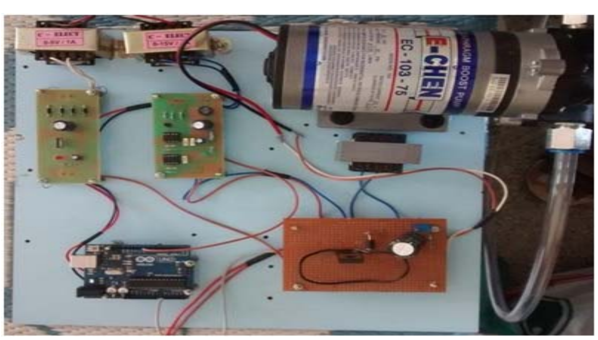

Figure-6. Hardware assembly.

CONCLUSIONS

The results show that the direct-coupled PV water pumping system has a severe disadvantage because the pump stays idle for nearly two more hours in the morning while the same system with LCB is already pumping water, same case in the evening also. The PV water pumping system without LCB has poor efficiency because of the mismatch between the PV module and the DC pump motor load. Using this new technology called LCB the motor can pump up to 60% more water than the system without this MPPT logic. This will be highly useful to the manufactures of solar pumps and their beneficiaries like farmers.

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