MPPT using Boost Derived Hybrid Converter in Solar PV array

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***Abstract*—This paper proposed a hybrid converter topology which can supply simultaneous dc and ac loads from a solar PV array. This topology is realized by replacing the controlled switch of single-switch boost converters with a voltage-source-inverter bridge network. The resulting hybrid converters require lesser number of switches to provide dc and ac outputs with an increased reliability, resulting from its inherentshoot-through protection in the inverter stage.**

I. Introduction

THIS paper presents the technique of using solar energy which is a clean renewable source to run simultaneously both DC and AC loads.

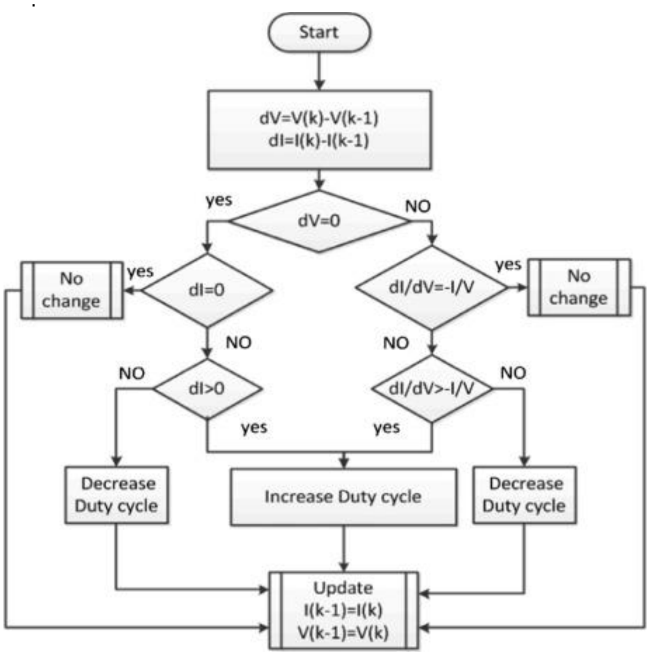
MPPT stands for Maximum Power Point Tracking, which is a technique used in photovoltaic (PV) systems to maximize the power output of solar panels. The power output of a solar panel is affected by several factors, including the intensity of the sunlight, the temperature, and the load impedance. The MPPT algorithm works by continuously adjusting the load impedance to maintain the maximum power point (MPP) of the solar panel.

The MPP is the operating point at which the solar panel produces the maximum power output for a given set of environmental conditions. The MPP is determined by the intersection of the panel's current-voltage (I-V) curve and the load line. The load line represents the voltage and current that the load is drawing from the solar panel. The load impedance is adjusted by the MPPT algorithm to match the load line with the I-V curve at the MPP.

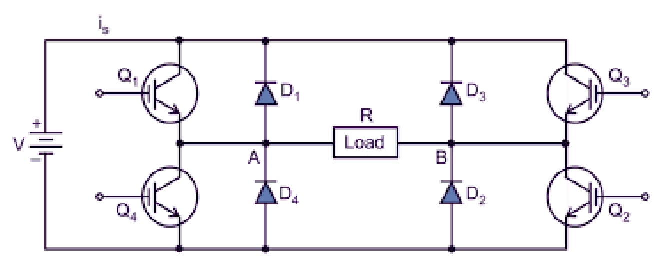
A. Incremental Conductance Method

The Incremental Conductance method is a Maximum Power Point Tracking (MPPT) algorithm used in photovoltaic (PV) systems to optimize the power output of solar panels. It works by continuously monitoring the PV panel voltage and current and adjusting the load impedance to maintain maximum power transfer.

The method is based on the observation that the slope of the PV panel power-voltage (P-V) curve is zero at the maximum power point (MPP). Therefore, by measuring the panel voltage and current and computing the incremental conductance (dP/dV), the MPP can be tracked in real-time.



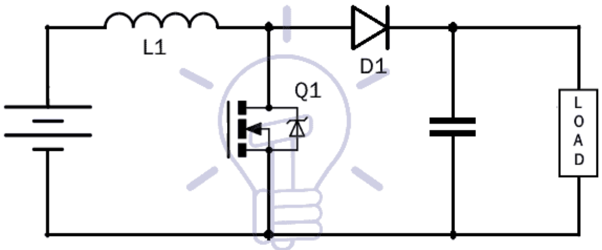
B. Inverter



An H-bridge inverter is a type of power electronic circuit used to convert DC voltage into AC voltage of variable frequency and amplitude. It is called an H-bridge because of its four switching elements arranged in an H-shaped configuration. These switching elements are typically MOSFETs or IGBTs and are controlled by pulse width modulation (PWM) signals generated by a microcontroller or other control circuit.

The H-bridge inverter works by selectively switching the four switches in a specific sequence to create an AC waveform. The sequence of switch operations is determined by the desired frequency and amplitude of the output waveform. By controlling the pulse width of the PWM signals, the amplitude of the output waveform can be adjusted.

C. Boost Converter



A boost converter is a type of DC-DC converter that steps up or boosts the input voltage to a higher output voltage. It works on the principle of energy storage and transfer, using an inductor and a switching element such as a transistor or a MOSFET.

The boost converter consists of an input capacitor, an inductor, a switching element, a diode, and an output capacitor. When the switching element is closed, the input voltage is applied to the inductor, causing a current to flow through it. This current causes energy to be stored in the magnetic field of the inductor. When the switching element is opened, the current through the inductor cannot change instantaneously, and the stored energy is transferred to the output capacitor through the diode.

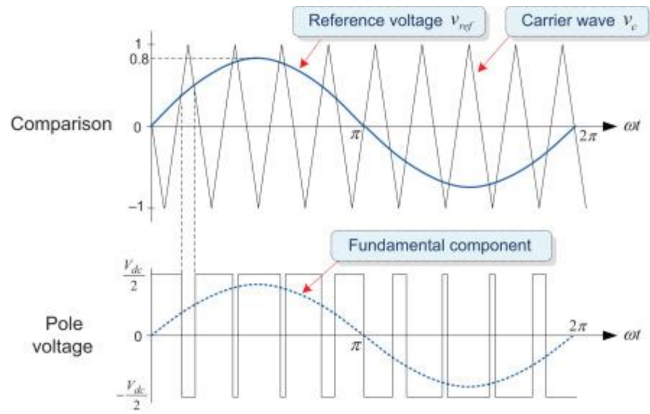
D. Inverter Switching Scheme

Pulse Width Modulation (PWM) is a technique used in electronics and control systems to control the amount of power delivered to a load. It involves varying the width of a pulse or a series of pulses of a fixed frequency, while keeping the amplitude and frequency constant. The width of the pulse is typically controlled by a microcontroller or a specialized PWM controller, which adjusts the duty cycle of the pulse.

The duty cycle of a PWM signal is the ratio of the pulse width to the period of the waveform. The period is the time it takes for one complete cycle of the waveform to occur. The duty cycle is expressed as a percentage, and it determines the average voltage or power delivered to the load.

Sinusoidal Pulse Width Modulation (SPWM) is a modulation technique used to control the output voltage of an inverter, which converts DC power to AC power. The output voltage of an inverter is a pulsating DC waveform that can be filtered to obtain a sinusoidal waveform. SPWM is used to generate a high-frequency pulse train with a varying duty cycle that replicates a sinusoidal waveform. The pulse train is then used to control the switching of the inverter's power switches, such as IGBTs or MOSFETs.

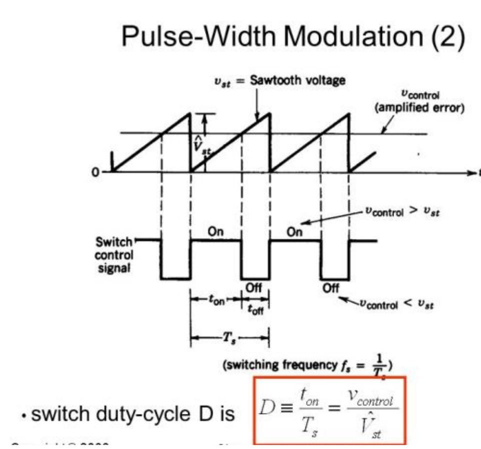
The SPWM technique is based on comparing a reference sinusoidal waveform with a carrier waveform, which is a high-frequency triangular waveform. The reference waveform represents the desired AC waveform that needs to be generated, while the carrier waveform provides the frequency and amplitude of the output waveform. The carrier waveform is compared with the reference waveform, and the difference between the two waveforms is used to generate the PWM signal.



E. Converter Switching Scheme

The switching scheme for a duty cycle in a pulse width modulation (PWM) circuit depends on the specific application and the type of controller used. In general, the duty cycle is adjusted by varying the on-time of the PWM waveform, which is a square wave with a fixed frequency. The on-time of the waveform is the duration for which the waveform is in the high state, and it is controlled by adjusting the width of the pulse.

One common switching scheme for duty cycle control is the constant frequency, variable duty cycle method. In this method, the frequency of the PWM waveform is kept constant, while the duty cycle is varied by adjusting the width of the pulse. The width of the pulse is controlled by a voltage or current reference signal, which is compared with a ramp signal generated by a sawtooth oscillator. The comparison produces a PWM waveform with a variable duty cycle that is proportional to the reference signal.



2. Boost Derived Hybrid Converter

A. Circuit

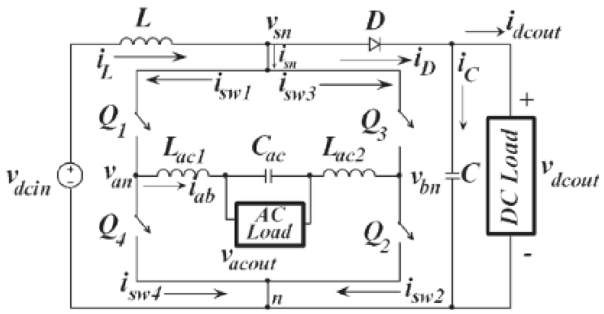


Figure 1 Boost Derived Hybrid Converter

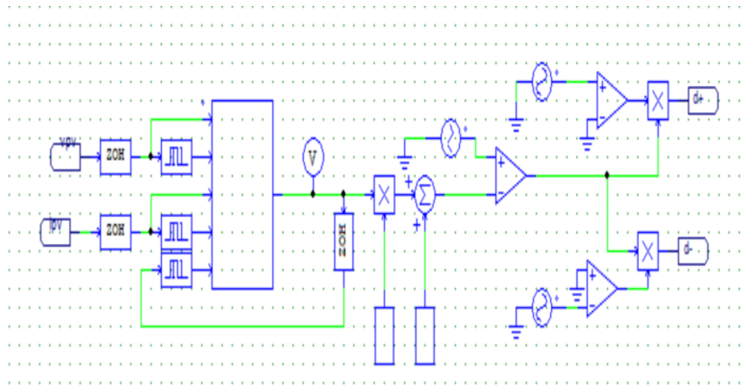


Figure 2 Duty Scheme for MPPT

B. Equations

For the purpose of analysis, we assume that the output dc capacitor voltage and the input inductor current have small ripple compared to their dc values. Hence, the expression for the voltage gain of the dc output is similar to that of a boost converter and can be derived as

$$\frac{V_{\mathrm{dcout}}}{V_{\mathrm{dcin}}} = \frac{1}{1 - D_{st}}.$$

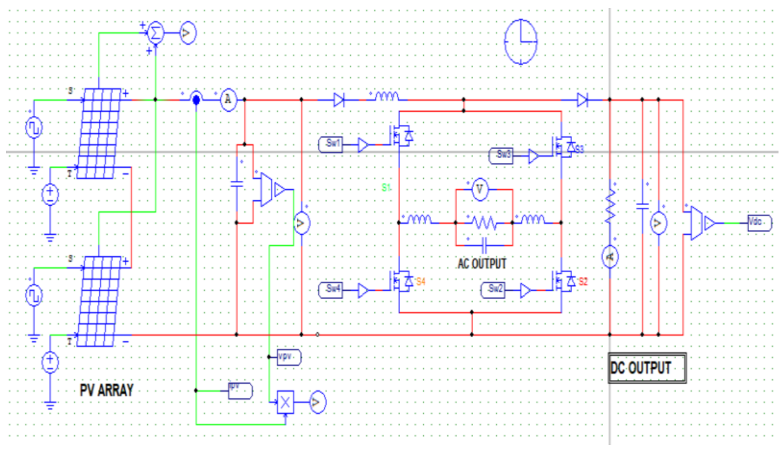


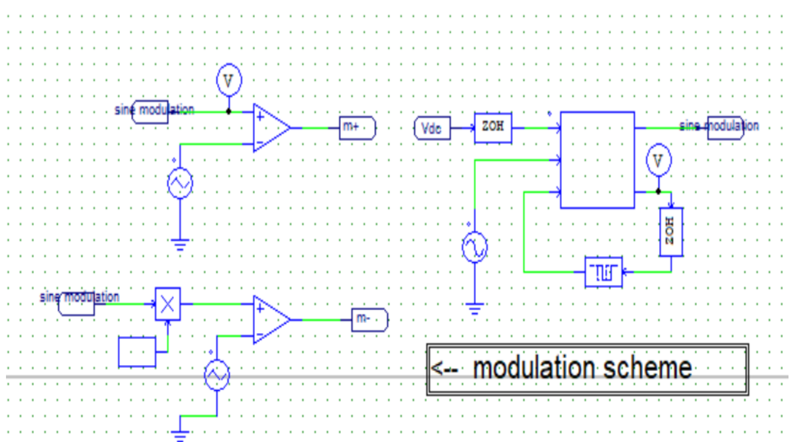
Figure 3 Circuit Model

As the same set of switches controls both the dc and ac outputs, there is limitation to the maximum duty cycle or modulation index that can be achieved for this topology. The switching strategy must satisfy the following constraint:

$$\mathrm{M_a} + \mathrm{D_{st}} \leq 1.$$

The peak output ac voltage is related to the input as :

$$\frac{\hat{v}_{\mathrm{acout}}}{V_{\mathrm{dcin}}} = \frac{M_a}{1 - D_{st}}.$$



3. Simulation setup

We have simulated our circuit model on PSIM software and found the satisfactory results with load as well as irradiation variations.

Below are the diagrams that show different switching schemes being implemented along with the circuit model.

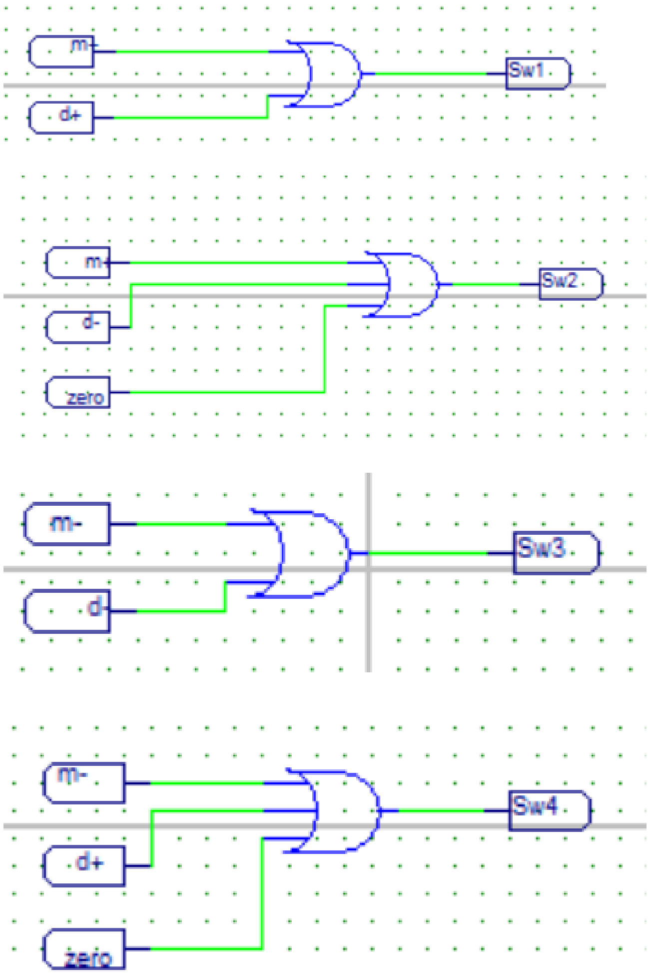


Figure 4 Switching Scheme

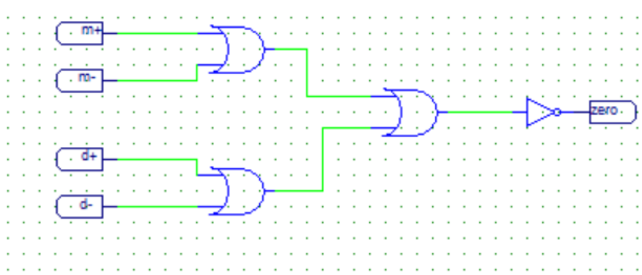


Figure 5 Zero Interval switching scheme

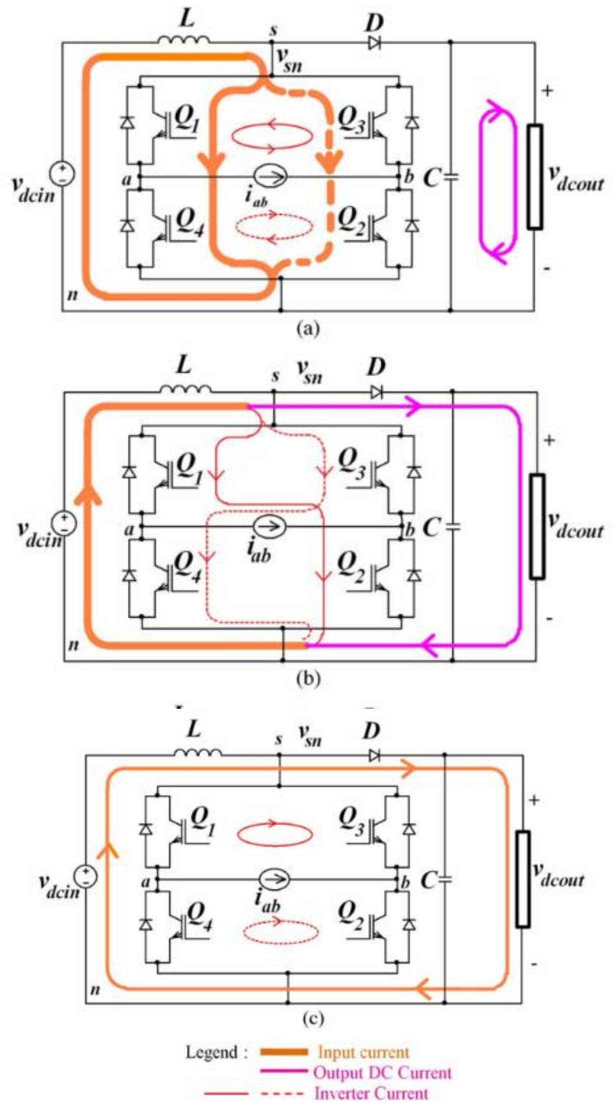


Fig. 5. Equivalent circuits and current directions of the BDHC during (a) shoot-through interval, (b) power interval, and (c) zero intervals.

TABLE I
STEADY-STATE EXPRESSIONS OF BDHC IN DIFFERENT MODES OF OPERATION [REFERENCE DIRECTIONS SHOWN IN FIG. 3(b)]

Interval	Shoot-through	Power	Zero
Diode Current	$i_D = 0$	$i_D = i_L - \lvert i_{ab} \rvert$	$i_D = i_L$
Capacitor Current	$i_C = -i_{dcout}$	$i_C = i_D - i_{dcout}$	$i_C = i_D - i_{dcout}$
Inverter output voltage	$v_{ab} = 0$	$v_{ab} = v_{dcout}$ if Q_1 and Q_2 are 'on' $v_{ab} = -v_{dcout}$ if Q_3 and Q_4 are 'on'	$v_{ab} = 0$
Switch node voltage	$v_{sn} = 0$	$v_{sn} = v_{dcout}$	$v_{sn} = v_{dcout}$

4. Results

Here are the results showing output waveforms with varying irradiations from 1000 W/m^2 to 800 W/m^2 at interval of 0.5 seconds.
The values of elements like capacitor and inductor are taken in accordance with the circuit condition and load demand and various calculation have been made to derive there values.

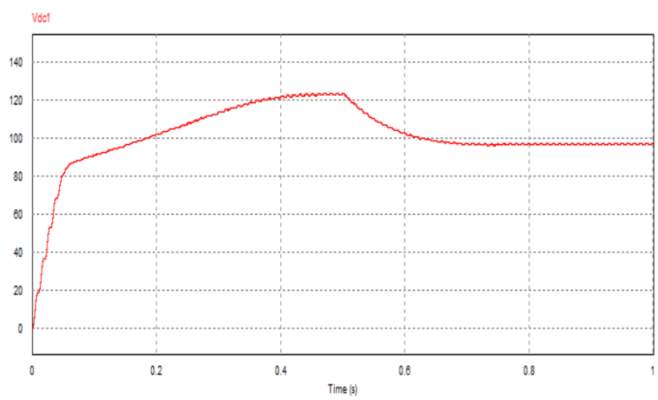


Figure 6 DC output Voltage

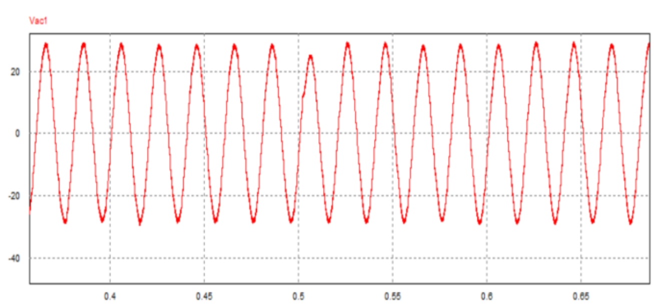


Figure 7 AC output Voltage

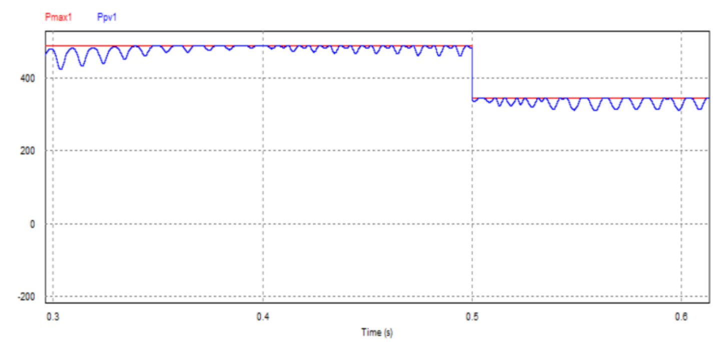


Figure 8 Tracking of maximum power

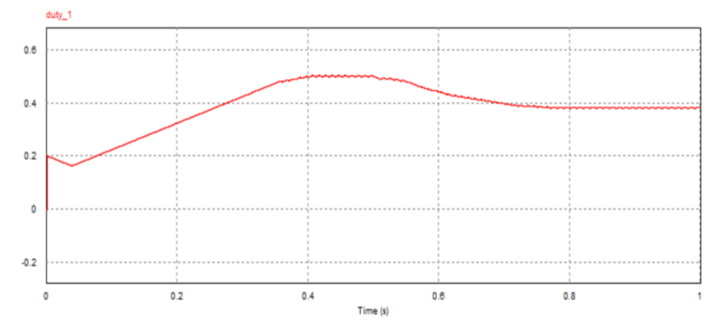


Figure 9 Duty Cycle

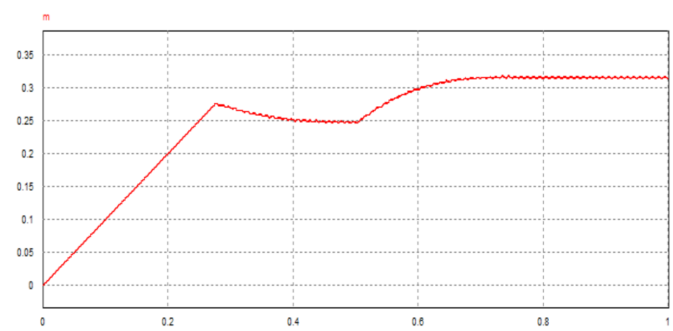


Figure 10 Modulation Index

5. Conclusion

This paper has proposed hybrid power converter topologies which can supply simultaneous dc and ac loads from a single dc input. The various advantages of using this single converter stage like shoot-through protection have been described. Along with varying irradiation, it has been shown that the AC output voltage remain constant at the reference value while all the variation has taken up by the DC side as proposed in the model.

6. References

[1] Olive Ray, Student Member, IEEE, and Santanu Mishra, Senior Member, IEEE, “ Boost derived hybrid converter with simultaneous AC and DC outputs” IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 50, NO. 2, MARCH/APRIL 2014

[2] M.H Rashid, “ Book on Power Converter and its Applications”