Design of Charging Unit for Uninterruptible Power Supply

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Abstract – **This paper presents a design of charging unit or rectifier for uninterruptible power supply by using PWM switching technique. These basic conversion performances are implemented by using MATLAB SIMULINK (MLS). Selected switching frequency is 9 kHz, 6 kHz and 4 kHz to investigate the actual performance of the battery charger. MATLAB SIMULINK results are show the accuracy of modeling.**

Keyword – Uninterruptible Power Supply (UPS), modulation index (mi), Pulse Width Modulation (PWM), Matlab Simulink (MLS), Insulated-gate Bipolar Transistor (IGBT), Total Harmonic Distortion (THD).

I. INTRODUCTION

An UPS system is an alternate or backup source of power with the electric utility company being the primary source. The UPS provides protection of load against line frequency variations, elimination of power line noise and voltage transients, voltage regulation, and uninterruptible power for critical loads during failures of normal utility source. An UPS can be considered a source of standby power or emergency power depending on the nature of the critical loads.

The function of a rectifier is to change an ac input voltage to a dc output voltage of desired magnitude and frequency [1]. This paper presents a three phase controlled rectifier for the low power application. The driver circuit that has been used in this AC - DC converter is to generate the Pulse Width Modulation (PWM) commutation technique.

II. UNINTERRUPTIBLE POWER SUPPLY TOPOLOGY

A. Basic UPS Block Diagram

The basic static UPS system consists of a rectifier-charger, inverter, static switch, and battery as shown in figure 1. The rectifier receives the normal alternating current (ac) power supply, provides direct current (dc) power to the inverter, and charges the battery. The inverter converts the dc power to ac power to supply the intended loads. The dc power will normally be provided from the rectifier, and from the battery upon failure of the primary ac power source or the rectifier. The inverter will supply the loads under normal conditions. In the event of the failure of the inverter, the static switch transfers the load to an alternate ac source.

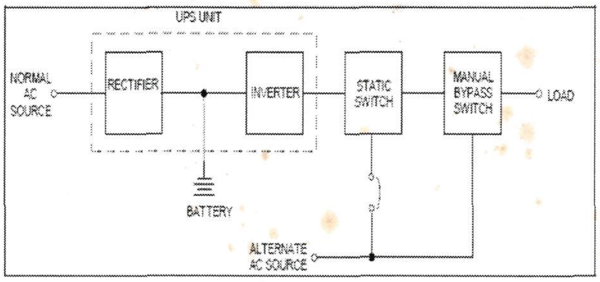


Figure 1. Basic UPS Block Diagram

B. Controlled Rectifier

In a controlled rectifier, the output dc voltage can be continuously maintained at any desired level whereas in an uncontrolled rectifier the output dc voltage (at no load) is a fixed ratio of the input ac voltage. Figure 2 shows the fundamental component of the proposed 3-phase rectifier topology.

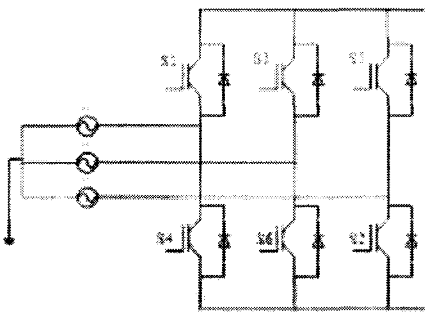


Figure 2. Rectifier controlled circuit

The rectifier transforms the AC voltage to DC waveform and normally PWM switching is applied in this process. The low pass filter attached at the output of the rectifier to filter the unwanted harmonics [2]. The system is represented as general scheme circuit diagram of the voltage source rectifier as shown in figure 3.

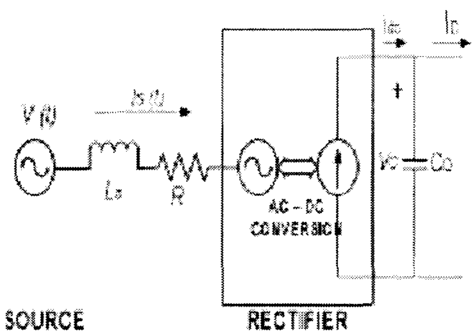


Figure 3. A General Scheme Circuit Diagram

III. Proposed Three Phase Rectifier

A. Pulse Width Modulation (PWM)

The output of the AC-DC converter is controlled using the PWM, generated by comparing a triangle wave signal with an adjustable DC reference and hence duty cycle of the switching pulse could be varied to synthesize the required rectifier AC - DC converter. This technique is used to produce a stream of PWM train to turn and off the switches [3]. Figure 4 shows the output of PWM when comparing the carrier signal with DC reference.

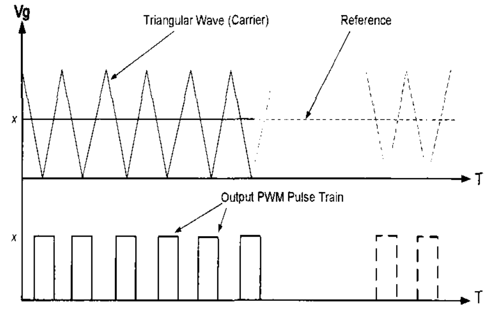


Figure 4. Pulse Width Modulation waveform

B. Switching Strategies

In theoretically, the switching sequence in the controlled rectifier must be instantaneous and simultaneous. Unfortunately, in practice this is not possible, because the transfer of current between two consecutive switches in a commutation group takes a finite time. This time, called overlap time, depends on the phase-to-phase voltage between the switch participating in the commutation process and the line inductance Ls, between the converter and power supply [4]. Figure 5 shows the process of commutation.

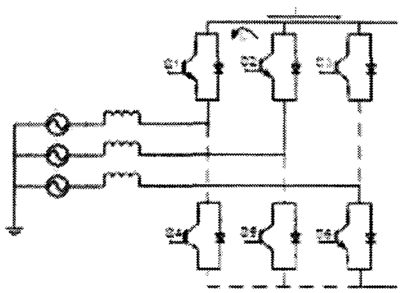


Figure 5. Commutation Process

During the commutation, two switches conduct at a time, which means that there is an instantaneous short circuit between the voltages participating in the process. As the inductance of each phase are the same voltage drop in each Ls, but with opposite sign because this current flows in reverse direction in each inductance.

C. Circuit Operation

The circuit diagram of three phase controlled rectifier is shown in figure 6. The circuit is designed with the input supply of 415V and the switching frequency used is 9 kHz. A rectifier consists of IGBT as a switch is used to convert AC power to DC power at the output V_{Load}.

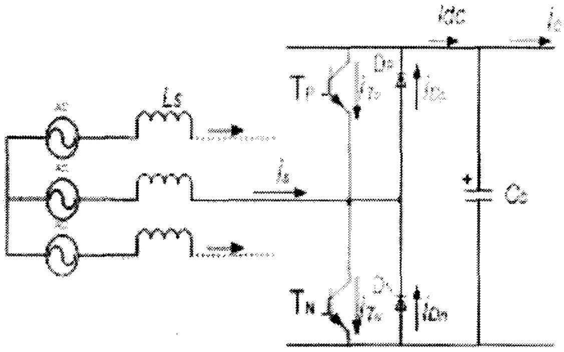


Figure 6. Current through the switch, diode and the *dc* link

Is in figure 5 is the rms value of the source current i_s. This current flows through the semiconductors in the way shown in figure above. During the positive half cycle, the transistor T_N conneted at the negative side of the dc link is switched ON, and the current i_s begin to flow through T_N (i_{Tn}).

The current can also go to the dc load and return through another transistor located at the positive terminal of the dc link. When the transistor T_N is switched OFF, the current path is interrupted, and the current begins to flow through the diode D_P, connected at the positive terminal of the dc link. This current called i_{Dp} (see figure 6), goes directly to the dc link, helping in the generation of the current i_{dc}. The current i_{dc} charges the capacitor C_D and permits the rectifier to produce dc power. The inductances L_S are very important in this process, because they generate an induced voltage which allows the conduction of the diode D_P. Similar operation occurs during the negative half cycle, but with T_P and D_N (see figure 6).

Under inverter operation, the current paths are different beacause the currents flowing through the transisitors come mainly from the dc capacitor CD. Under rectifier operation, the circuit works like a Boost converter, and under inverter it works as a Buck converter.

IV. MODELING AND SIMULATION

In the simulation implementation, Power System Block Set (PSB) in MLS are used to model and simulate the circuit. The circuits for AC to DC Converter were supplied by 415VAC voltage source. Figure 7 is the top-level simulation model with the power circuit switch arrangements as in in figure 8. The PWM model is as shown in figure 9; a constant representing a straight line or reference signal is compared with triangular wave as a carrier signal to produce the required respective PWM output. Table I shown the parameters used for AC to DC Converter Rectifier.

Table I. Parameters for AC to DC Converter

Component	Value
Supply Voltage (AC)	415V
Input Capacitor	0.01uF
Line inductance (L_S)	20mH
Output Capacitor	0.1F
Load Inductance	15mH
Load Resistor	100Ω
Carrier Frequency (f_c)	9 kHz, 6 kHz, 4 kHz
Modulation Index (mi)	0.9

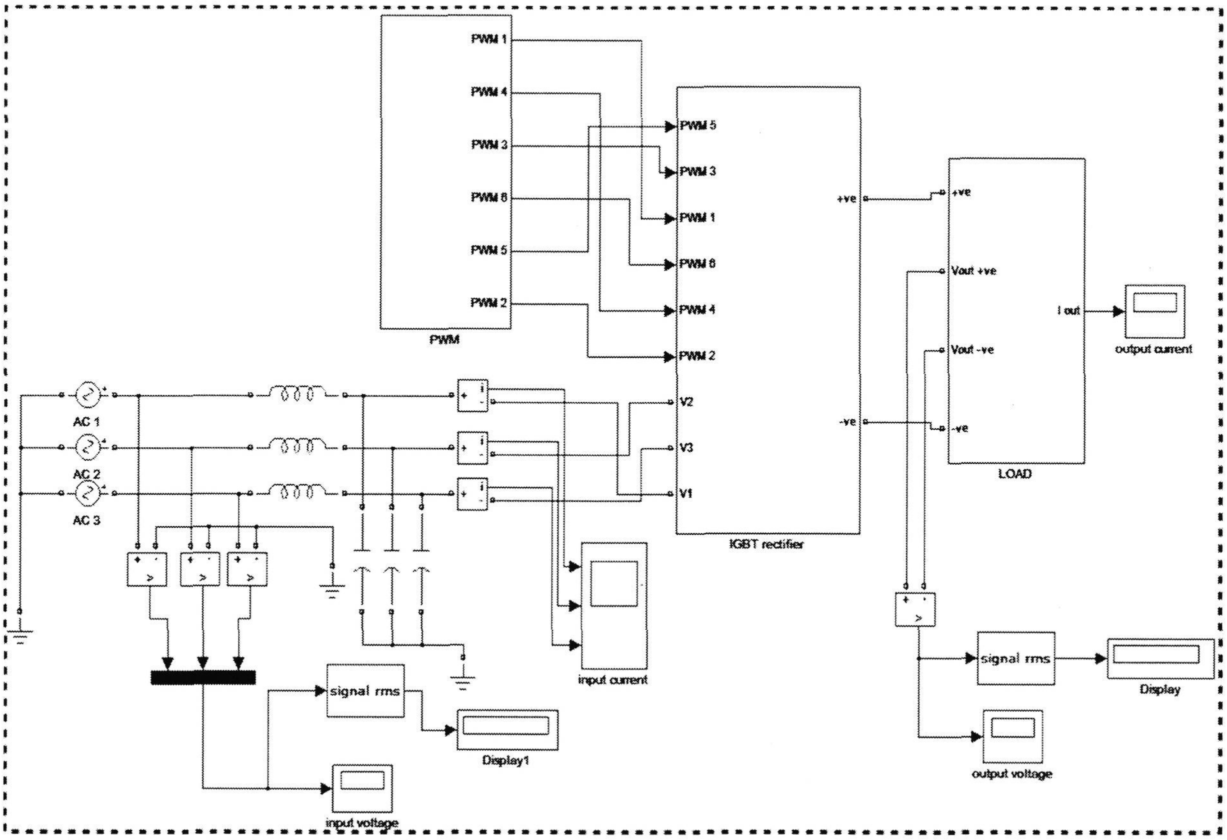


Figure 7. Top level main model of Controlled Rectifier in MLS

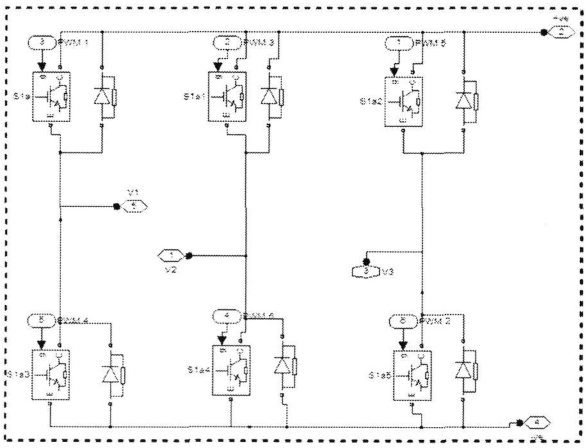


Figure 8. IGBT switch model in PSB

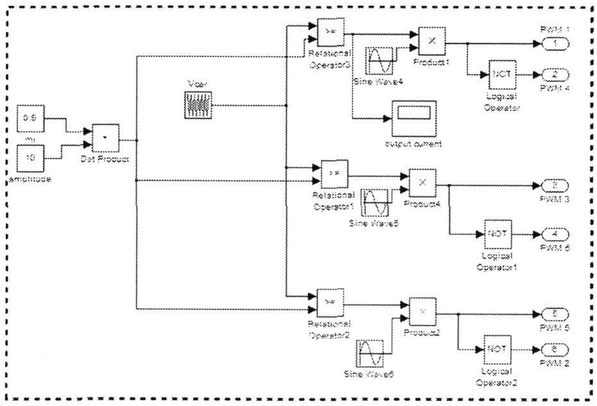
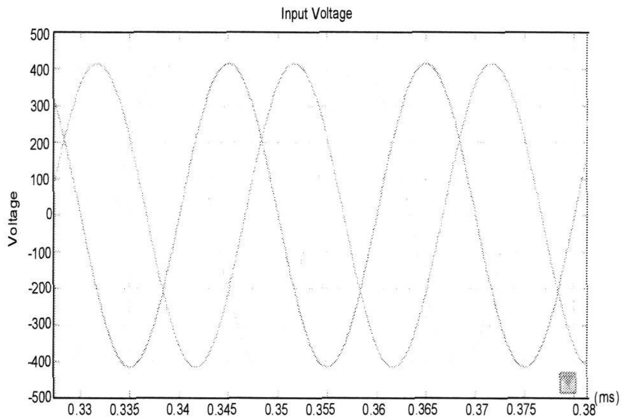


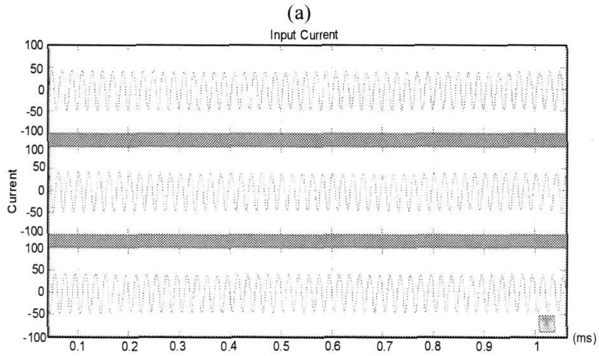
Figure 9. PWM model circuit in PSB

V. RESULT AND DISCUSSION

The result presented were arranged accordance to the following; the input voltage and current shows at figure 10. Figure 11 are shows results of output voltage rectifier converter by using MLS with switching frequency of 9 kHz, 6 kHz and 4 kHz respectively. By increasing the switching frequency, there is proportionate decrease in the output voltages. At the highest switching frequency, the output voltages are smooth. By using boost inductance, the output voltage will be greater than the input voltage.

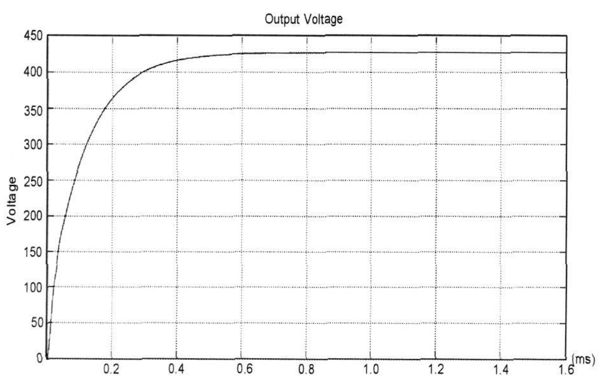


(a)



(b)

Figure 10. Simulation results MLS (a) input voltage, (b) input current



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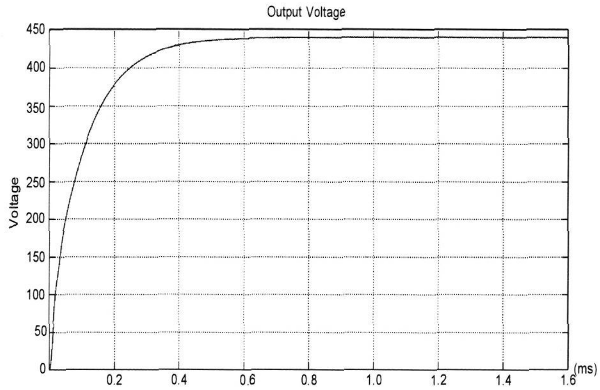

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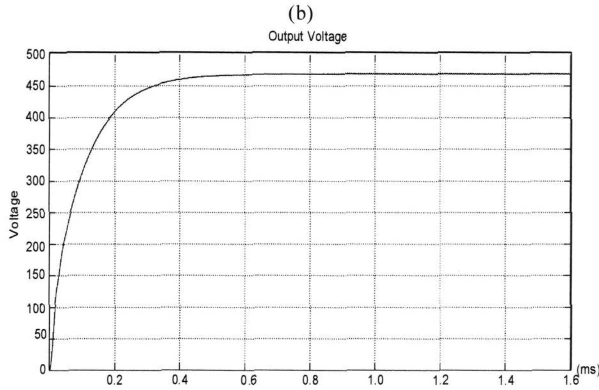
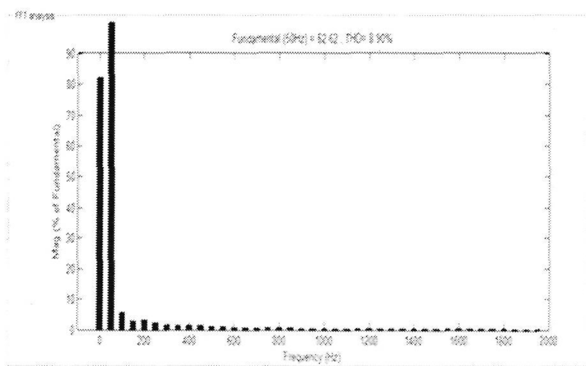


(c)

Figure 11. Output voltage (MLS) (a) at $f_C = 9$ kHz, (b) at $f_C = 6$ kHz, (c) at $f_C = 4$ kHz

The result shows that, when the value of switching frequency low, the output voltage become higher. We also can see the changes of the width output wave become smoother with the increase of the switching frequency.

Simulation results for THD are also presented in the following figure 12 for MLS



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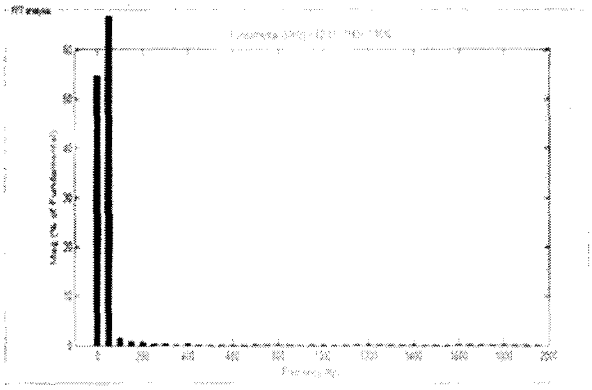

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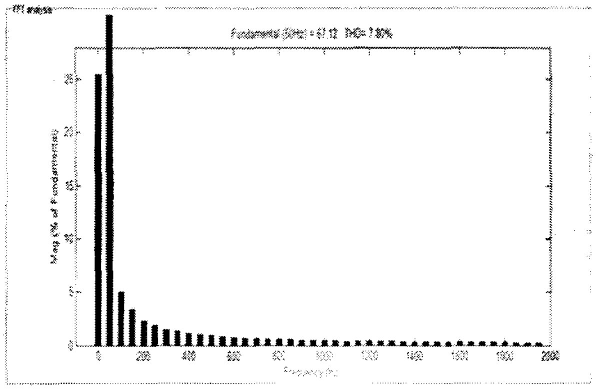

(c)

Figure 12. Total Harmocic Distortion (MLS) (a) at input current, (b) at output voltage, (c) at output current

VI. CONCLUSION

The results present successful design of rectifier for ups using PWM technique. The output DC voltage increase proportional with the decrease carrier frequency or switching frequency. The performances had been evaluated for different design constraints and the simulation results meet the design specifications. The design can be altered at minimum cost with fast reliable results. Simulation models in MATLAB/Simulink are used to study the behavior of the proposed technique of the results.

RECOMMENDATION

In this project, there are some improvements that we can do to make this project more successful, for example:

1. Use matrix converter concept as a power converter in order to make the system is more efficient because the number of devices connected in series is less in this system.
2. Put the inductor along with the side capacitor to discharge the noise by communicating with the capacitor to filter those unwanted noise.

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