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Simulation and Design of Neutral Point Type Buck Converter

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Abstract*: *This paper presents the simulation and design of Neutral Point Type (NPT) converters that have been used to increase power factor near one (1) which is unity. The circuit of the simulation has been design using Simulink MATLAB. The circuit was set to 50 kHz to generate Pulse Width Modulation (PWM) with carrier signal and comparing it with the reference signal. By adjusting the capacitor in the main circuit, the result of the simulation shows that the input current and voltage were in phase which is unity power factor while the output current and voltage produced having a low ripple. Thus, the simulation shows that the Neutral Point Buck type converter is suitable for maximizing power factor close to unity (1).

Keywords: Neutral Point Type (NPT) Buck Converter, Pulse Width Modulation (PWM), Unity Power factor.

I. INTRODUCTION

Since fluorescent lamp's electronic ballast is important these days in order to improve the stability of voltage. The fluorescent lamp with high frequency is decided to be one of the important applications in electronic ballast performance assessment. Therefore, the development of early phase strategy of switching electronic ballast for fluorescent lamps is also important. This will have an effect on the high harmonic input current which will reduce the reduction of high harmonic input current. This leads to the reduction of the high harmonic input current. The use of electronic ballast using this approach will have the advantage of increasing the light intensity, overall efficiency, and longer lamp life and improved lighting quality, as noted in [1].

In an electrical system, a single phase rectifier is required to convert from a single phase AC power supply to a DC output voltage. Traditionally, a diode or thyristor circuit is used in a successor to produce controlled or uncontrolled DC output voltage. From this traditionally circuit, it will produce poor wave input and power factor [2]. As this circuit is not acceptable in many applications, the power quality standard has been tightened in the IEEE 519 standard [3]. Initially, the reduction of harmonic distortion (THD) was reached using two types of phase converters electronic ballast which consists of a combination converter and inverter circuit [1].

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The cost of increasing complexity occurred at these circuits but its having improved the quality of waveform of the input current.

Four or two active devices with their associated control circuits are required to PWM rectifier. [4]. Therefore, the one stage converter is introduced to reduce the circuit elements without reducing the circuit efficiency. This can be reached by employ the same switching strategy for inverter and inverter circuits [5].

The one stage converter presented in this study is the neutral point type (NPT) buck boost converter [4] stated that this converter is able to meet the International Standard on AC main current harmonic emission IEC 61000-3-2 and reduce the effects of inrush in NPT buck and boost converter. Finally, the development of switching strategy in electronic is compulsory, the soft switching technique developed in [1] [6] that can reduce the switching at higher switching frequency than hard switching.

The objectives of the research can be summarized as

i. To improve the power factor of the circuit to convert AC to DC voltage by using the proposed switching technique.
ii. To implement the pulse width modulation (PWM) technique using Simulink MATLAB with soft switching strategy in the neutral point type buck application.

II. METHODOLOGY

A. Circuit Topology

The operation of the NPT buck converter is based on the ON and OFF of the switching element. The circuit topology for NPT buck converter is shown in Fig. 1. The voltage measure at the output is usually opposed the supply voltage in term of its polarity. The flow of inductor current justifies the operation mode of this converter. In this paper, the assumptions of a control switching are defined for the NPT buck converter;

1. The switching element should have the frequency much higher than the input voltage frequency.
2. Every circuit component is an ideal current source.
3. Voltage across the capacitor will remain constant indicating the ideal output voltage of the capacitor.
4. Resistor (R) is used at the load for the output measurement.

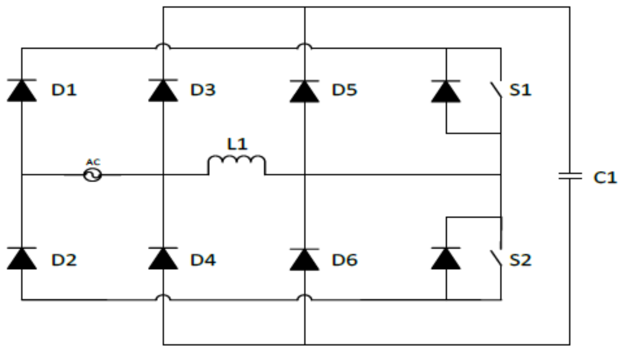

Fig. 1: Neutral Point Type Buck Converter

B. Circuit Operation

The operating mode for the NPT buck converter can be split into three modes. The continuous modes according to the current continuity [5] are shown in Table I.

Table I: Switching mode for NPT buck boost converter

	MODE 1	MODE 2	MODE 3
Switch S1	ON	OFF	OFF
Switch S2	OFF	ON	OFF

i. MODE 1 S1: ON, S2: OFF

In this mode, the output voltage is in reverse polarity. This is intended to produce a closed inductor voltage to Vin. D1 is a forward tendency that allows the current to flow through D1, inductors L1 and S1 as shown in Fig. 2. The complete loop of the closed loop will produce a flow of current around it. This operation is performed at t = 0.

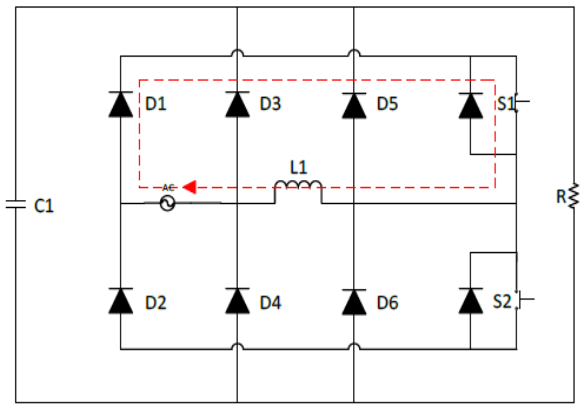

Fig. 2: Circuit's current flow during mode 1

As time increases, the inductor current increases as in:

$$I_L = \frac{1}{L}\int V_{IN}\,dt \qquad (1)$$

$$I_L = V_{IN}\frac{t_{on}}{L} \qquad (2)$$

The duration mode 1, t_{on} can be expressed as:

$$t_{on} = L\frac{\Delta I}{V_{IN}} \qquad (3)$$

Inductors will store energy. These energies can be expressed as:

$$E_L = \frac{1}{2}LV_{IN}\left(\frac{t_{on}}{L}\right)^2 \qquad (4)$$

$$E_L = \frac{1}{2L}{V_{IN}}^2{t_{on}}^2 \qquad (5)$$

ii. MODE 2 S2: ON, S1: OFF

When the switching S1 and S2 are turned off, the energy stored from the inductor during mode 1 operation. It will produce the back electromotive force. Then, the current passes through diode D3 before flowing through the capacitor. Then, it flows through diode D6 as shown in Fig. 3. It will cause the capacitor to charge up and store the energy.

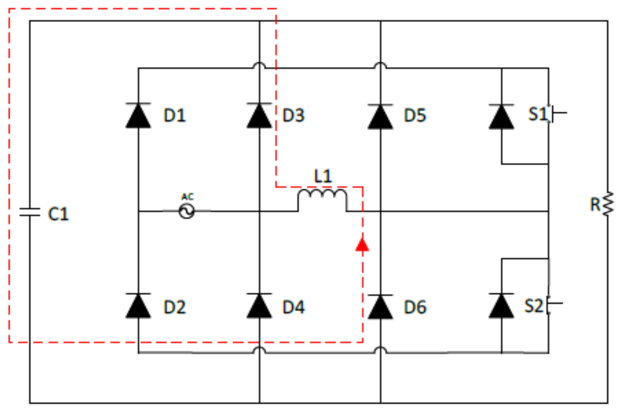

Fig. 3: Flow of current at mode 2 S2: ON, S1: OFF

The inductor current is assumed to decrease linearly in time t_{off}, therefore the voltage can be:

$$V_C = \frac{L\Delta I}{t_{off}} \qquad (6)$$

The interval period of time off, t_{off}

$$t_{off} = \frac{L\Delta I}{V_C} \qquad (7)$$

At t_{on} and t_{off} intervals with the same at steady state operation, the ripple inductor current can be expressed from the interval duration of time off and also from equation in duration mode 1 given by:

$$\Delta I = \frac{V_{IN}t_{on}}{L} - \frac{V_c t_{off}}{L} \qquad (8)$$

The energy need to be discharged during time off until current drop to zero because of the counter electromotive force can be developed:

$$\Delta I = \frac{V_{IN}t_{on}}{L} \qquad (9)$$

$$V_c = V_{IN} \qquad (10)$$

The magnitude of input and output voltage is equal when the duty cycle is set a 50%.

iii. MODE 3 S1: OFF, S2: OFF

The electromotive force (EMF) is generated by the energy stored in the inductor occurs in this mode as shown in Fig. 4. The EMF drives the current to flow through diode D3, D6 and capacitor. As current flow through the capacitor, the circulated process would cause the capacitor to store energy through the charging process [5].

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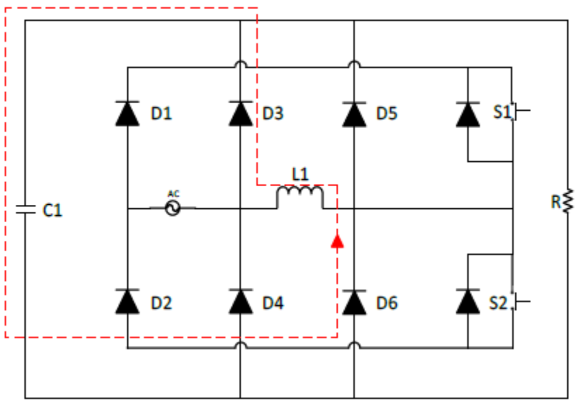

Fig. 4: Flow of current at mode 2 S1: OFF, S2: OFF

C. Switching Technique

Soft switching technique is used for the project because there is more efficient than hard switching technique. Using this technique, either voltage or zero current during switching, this substantially reduces switching loss and also increases the reliability of the power supply [6].

From this technique, it enables the main inductor current to operate at a small ripple current while providing good circuit output.

Table II: Comparison between Hard and Soft Switching

	Hard Switching	Soft Switching
Switching loss	Severe	Almost zero
Overall efficiency	Norm	Possibly Higher
Heat-sinking requirement	Norm	Possibly lower
Hardware count	Norm	More
Overall power density	Norm	Possibly Higher
EMI problem	Severe	Low
dv/dt problem	Severe	Low
Modulation scheme	Versatile	Limited
Maturity	Mature	Developing
Cost	Norm	Higher

Since there is more advantage on soft switching compared to hard switching as shown in Table II, soft switching is used for the circuit. For low conversion losses, higher efficiency, reduced torque ratios and increased speed, soft switching using IGBT is giving better performance than hard switching [9]. This method of switching is achieved by using the PWM technique.

The loss during hard switching is compensated by the introduction of the soft switching technique [4]. This technique has many advantages as such it improves the consistency for power supplies at high switching frequency. In this project, PWM at 50 kHz with 50% duty cycle for the simulation. As the switching rate of the PWM control the magnitude of supply voltage and current, this modulation technique is used to regulate the power supplied to electrical devices. This method of switching is achieved by using the PWM technique. Since PWM control the on and off of the switch in term of duty cycle, the main advantage of PWM is that switching device produce a very low loss. Normally no current flow when switch is turned off while power is being applied to the load when switch is turned on and the voltage drop across the switch is near to zero.

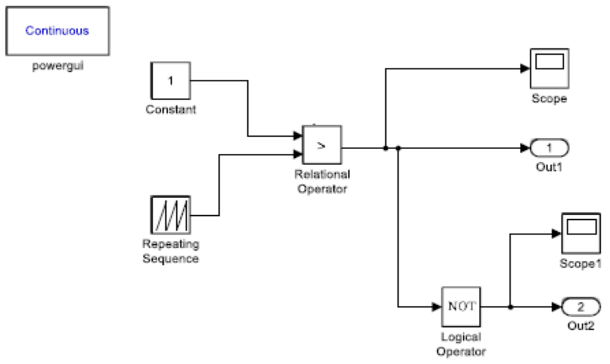

Fig. 5: PWM circuit model

Fig. 5 shows the PWM circuit model which is to control the output voltage that enters the driver. The circuit is set to 50 kHz and generates the carrier signal and this signal will compare with the reference signal. Firstly, PWM gives positive signal to the output and it's vice versa as shown in Fig. 6 and 7.

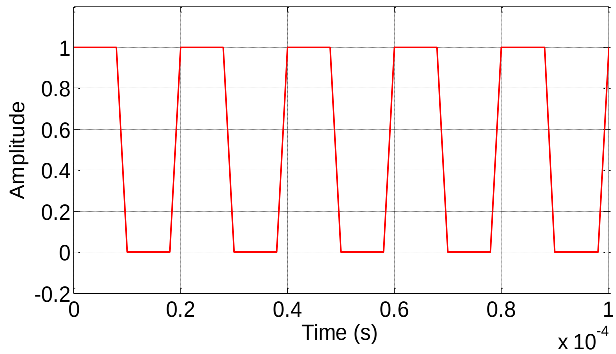

Fig. 6: Positive cycle of PWM switching

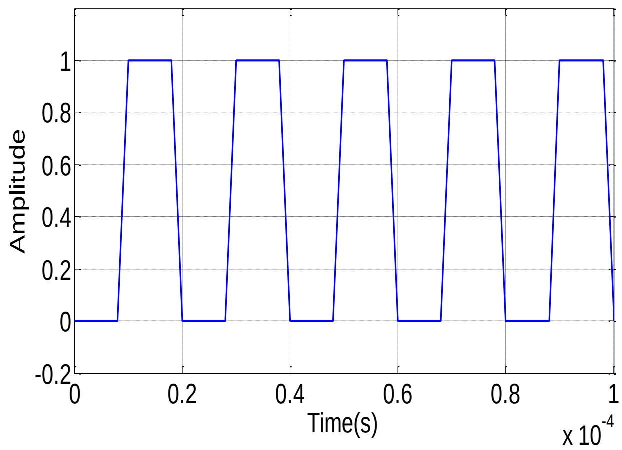

Fig. 7: Negative cycle of PWM switching

D. Flowchart

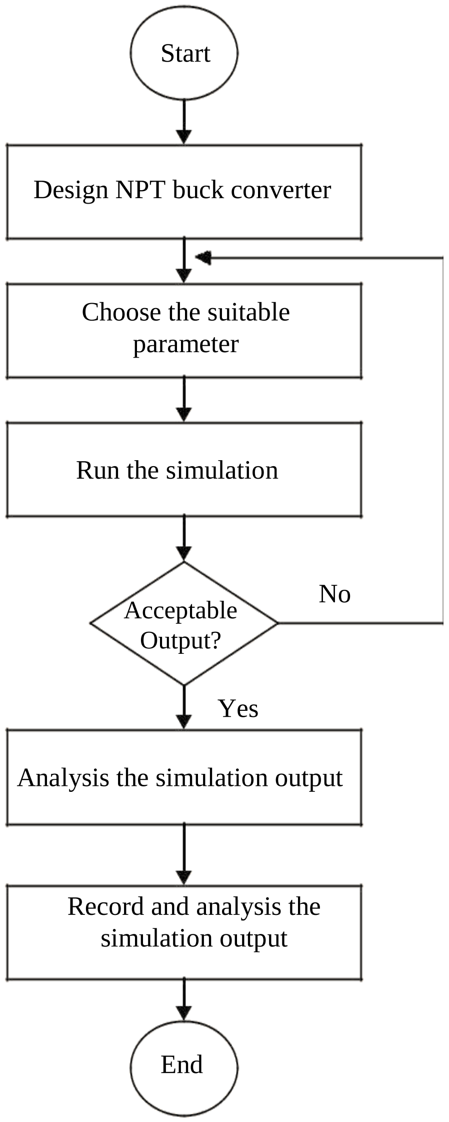

Fig. 8: Flowchart of the project

Firstly, do a research on how to use the MATLAB to design the simulation using Simulink. From the simulation, scope is used to implement the waveform of the current, voltage output, voltage input, and pulse. After that, record the suitable output and waveform of the output.

III. RESULT AND DISCUSSION

The NPT buck converter is proposed for use to convert AC voltage supply to DC voltage output. In order to give low conversion losses, higher efficiency, reduce torque and increase speed the soft switching technique are used compared to hard switching [9].

There are several components used for this project to improve power factor. Table III shows the component parameter for the circuit topology.

Table III: List of components and the specification

COMPONENTS	Specification
AC supply	100V
DC supply	12V 5V
MOSFET	IRF840
Diode	UF4007
Inductor	265mH
Electrolytic Capacitor	4700u F, 50V
Ceramic Capacitor	100n F
Resistor	10 Ohm
	1K Ohm
	30 Ohm

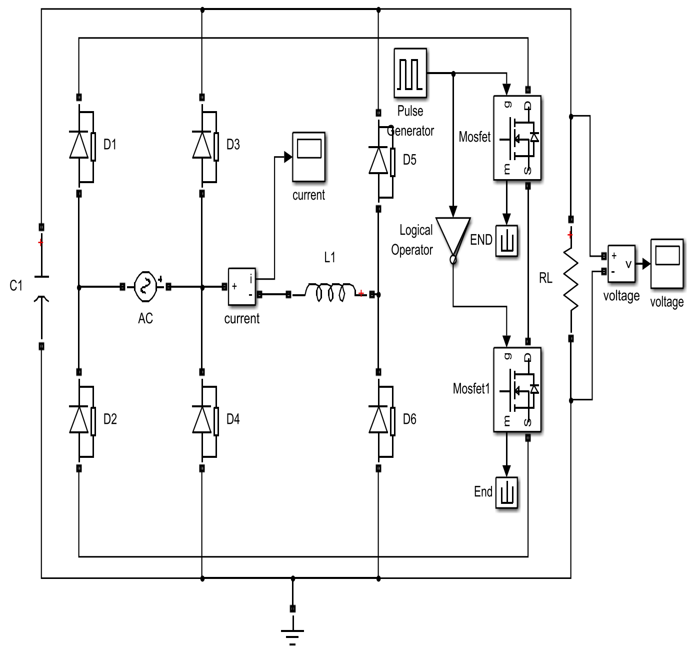

Fig. 9: Simulation model in MATLAB/Simulink

Fig. 9 shows the simulation circuit design that has divided into 4 parts which are input supply, the inductor, the MOSFETS, and output load. Each part has their own function. Firstly, the input supply is 100 V and the expected output voltage is less than 100 V. It happened due to the converter act as the buck converter. In the simulation, the oscilloscope is used to generate the waveform of voltage output, the input voltage, the input current, and the pulses. The inductor use is high inductor value because the switching frequency use is high. Besides, to get the best output voltage with minimum ripple, the input current will be difference by adjusting the value of capacitance.

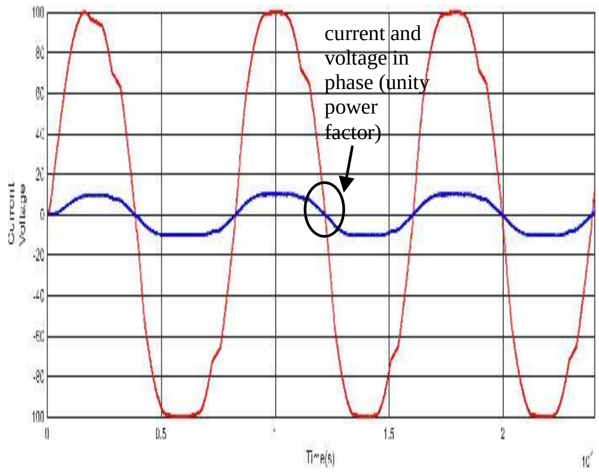

Fig. 10: Input Voltage (red) and Current (blue) (20 V/div, 0.5 A/div)

Since the wave of the input current and voltage in phase, it can be proceeding to the next step which is to measure the value of output voltage as shown in Fig. 10. A simulation is done in Simulink in order to analyze the behavior of the NPT buck boost converter as shown in Fig. 10. It can be concluded that the proposed switching strategy able to drive the circuit to produce unity power factor. The values of the input current and voltage are 100 V and 0.25 A respectively.

Fig. 11 shows the value of the harmonic spectrum of the circuit. The value of total harmonic distortion is 4 percent. Since the value of THD is not more than 5 percent, so the suggestions and values provided in this standard are purely voluntary. Lastly, ensuring low THD values in the circuit will continue to ensure proper equipment operation and long equipment life.

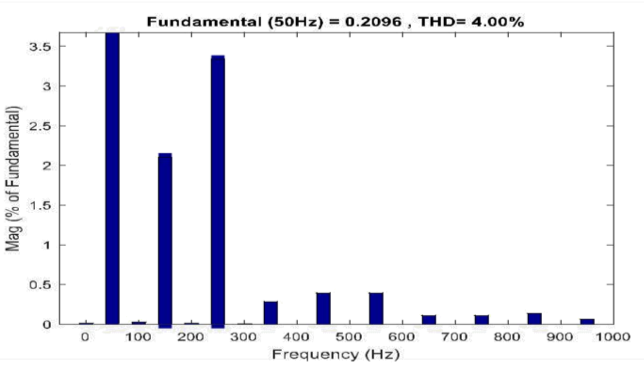

Fig. 11: Harmonic Spectrum for THD

Fig. 12, 13 and 14 shows the output current and voltage in one scope. The values of current are boost to 2.7 A with low ripple. It can be concluded that the simulation can be accept in order to improve power factor close to unity

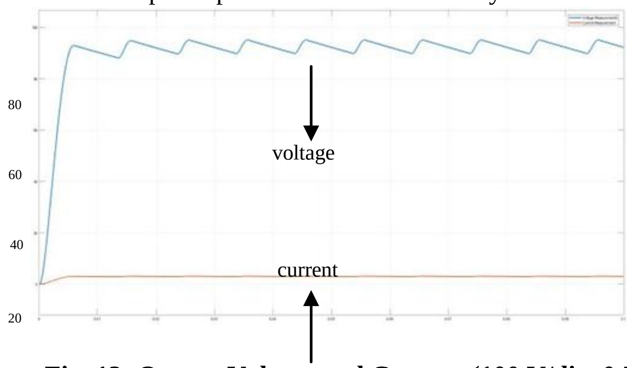

Fig. 12: Output Voltage and Current (100 V/div, 0.5 A/div)

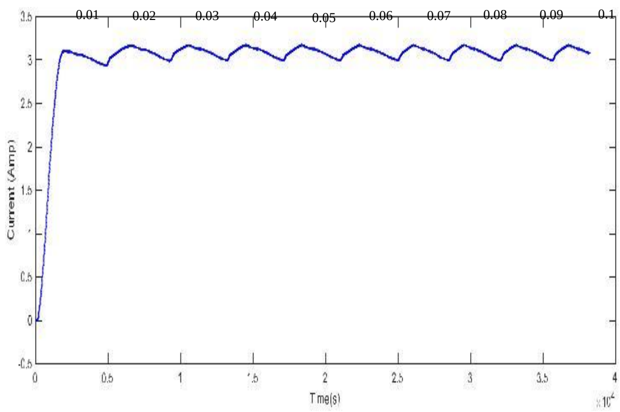

Fig. 13: Output Current (0.5 A/div)

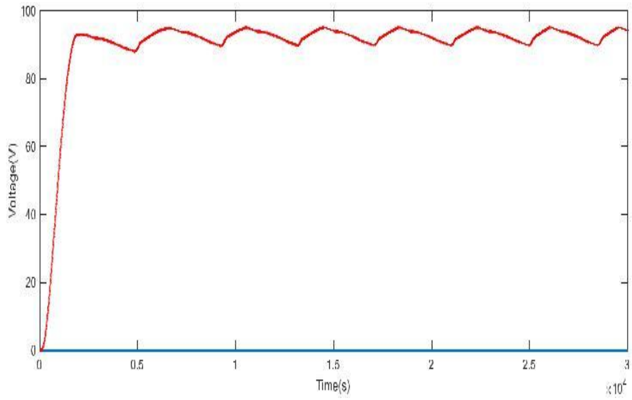

Fig. 14: Output Voltage (20 V/div)

IV. CONCLUSION

This paper presents a simulation for Neutral Point Type (NPT) Buck Converter. The main purpose for this project is to have a simulation of a circuit to have power factor of unity. MATLAB/Simulink is used to construct the circuit to observe the voltage and current. Since the current and voltage are in the phase, it can be concluded that power factor is near to '1' or indicates as unity power factor. Capacitor in the main circuit is to minimize the ripple. This indicates that the proposed soft switching technique is feasible solution to be implemented in the NPT buck converter.

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REFERENCES

1. N. A. Mohd Saad, Z. Othman, S. A. M. Al Junid, M. N. Hidayat, K. K, M.Sharif, and I.Musirin "Switching strategy of neural point type converter", Proc. 2013 IEEE 7th Int. Power Eng. Optim. Conf. PEOCO 2013, no. June, pp. 578–582, 2013.
2. N. A. Wahab, K. M. Idris, and N. M. Hidayat, "High power factor neutral point type converter," Proc. 2013 IEEE 7th Int. Power Eng.Optim. Conf. PEOCO 2013, no. June, pp. 402–404, 2013
3. T. S. Key and W. Hall, "IEEE and International Harmonic Standards Impact on Power Electronic Equipment Design," vol. 2, 1992
4. N. M. Hidayat, M. Nakamura, Y. Kato, N. Takahashi, S. I. Adachi, and Yokozeki, "Development of neutral-point type converter and application to electronic ballast," 2006 Int. Conf. Power Electron. Drives Energy Syst. PEDES '06, vol. 0, no. 2, 2006
5. N. M. Hidayat, M. Nakamura, Y. Kato, N. Takahashi, I. Yokozeki, and Itoh, "One converter type voltage free neutral point type converter and application to electronic ballast," Proc. IEEE Int. Conf. Ind.Technol., pp. 8–11, 2008
6. Y. Zhang and P. C. Sen, "A new soft-switching technique for buck, boost, and buck-boost converters," IEEE Trans. Ind. Appl., vol. 39, no. 6, pp. 1775–1782, 2003.
7. M. M. A. Rahman, "Single phase single-stage soft-switching AC-to-DC series resonant converter," Proc. 4th Int. Conf. Electr. Comput. Eng. ICECE 2006, no. December, pp. 485–488, 2007.

8. Y. S. Chen, T. J. Liang, K. H. Chen, and J. N. Juang, "Study and implementation of high frequency pulse LED driver with self-oscillating circuit," Proc. - IEEE Int. Symp. Circuits Syst., vol. 4, no. c, pp. 498–501, 2011.
9. N. Rathi, A. Ahmed, and R. Kumar, "Comparative Study of Soft Switching and Hard Switching For Brushless DC Motor," Int. J. Recent Trends Electr. Electron. Eng., vol. 1, no. 1, pp. 1–5, 2011.
10. A. T. De Almeida, "Overcoming problems with harmonics and low power factors." Energy, vol. 18, no. 2, pp.136-131, 2011

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