AN EFFICIENT SMPS FOR DC MOTOR

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ABSTRACT

A switched-mode power supply (switching-mode power supply, switch-mode power supply, SMPS, or switcher) is an electronic power supply *that incorporates a switching regulator to* convert electrical power *efficiently. Like other power supplies, an SMPS transfers power from a source, like* mains power, *to a load, such as a* personal computer, *while converting* voltage *and* current *characteristics. Unlike a* linear power supply, *the pass transistor of a switching-mode supply continually switches between low-*dissipation, *full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power.* Voltage regulation *is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass* transistor. *This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. In this project the SMPS is applied for a DC motor and the output current and voltage are monitored by an LCD display unit.*

Keyword : - *SMPS, power conversion efficiency, transformerless SMPS*

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1. INTRODUCTION

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight is required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. A linear regulator provides the desired output voltage by dissipating excess power in ohmic losses (e.g., in a resistor or in the collector–emitter region of a pass transistor in its active mode). A linear regulator regulates either output voltage or current by dissipating the excess electric power in the form of heat, and hence its maximum power efficiency is voltageout/ voltagein since the volt difference is wasted. In contrast, a switchedmode power supply regulates either output voltage or current by switching ideal storage elements, like inductors and capacitors, into and out of different electrical configurations. Ideal switching elements (e.g., transistors operated outside of their active mode) have no resistance when "closed" and carry no current when "open", and so the converters can theoretically operate with 100% efficiency (i.e., all input power is delivered to the load; no power is wasted as dissipated heat).For example, if a DC source, an inductor, a switch, and the corresponding electrical ground are placed in series and the switch is driven by a square wave, the peaktopeak voltage of the waveform measured across the switch can exceed the input voltage from the DC source. This is because the inductor responds to changes in current by inducing its own voltage to counter the change in current, and this voltage adds to the source voltage while the switch is open. If a diode and capacitor combination is placed in parallel to the switch, the peak voltage can be stored in the capacitor, and the capacitor can be used as a DC source with an output voltage greater than the DC voltage driving the circuit. This boost converter acts like a step up transformer for DC signals. A buck–boost converter works in a similar manner, but yields an output voltage which is opposite in polarity to the input voltage. Other buck circuits exist to boost the average output current with a reduction of voltage.

Singh S proposed a system [7] that deals with the design, analysis, simulation and development of a PFC (Power Factor Corrected) multiple output SMPS (Switched Mode Power Supply) using bridgeless buck-boost converter at the front end. Single-phase ac supply is connected to a bridgeless buck-boost converter to eliminate the diode bridge rectifier for reducing the conduction losses associated with the diode bridge and also to improve power quality at front end. The bridgeless buck-boost converter is designed to operate in DCM (Discontinuous Current Mode) for inherent PFC operation and to reduce the complexity in control. The performance of the proposed bridgeless converter based multiple output SMPS is evaluated under varying input voltages and loads to demonstrate its improved performance. The performance of proposed bridgeless multiple output SMPS is simulated in MATLAB/Simulink environment and the obtained simulated results are validated experimentally on a developed hardware to verify the improved power quality.

Dailin Li proposed that [2] Switching Mode Power Supply (SMPS) is the most important source for electronic or electrical equipments, therefore its reliability acts as a fatal factor impacting on these devices' lifetime. Applications shows that aluminum electrolytic capacitors, and some power components like diodes and MOSFETs, all of which turn out to be key factors to SMPS' lifetime, are of higher failure rates in SMPS. In fact, the failure of electronic products is a gradual course, which is usually resulted from the degradation of separate electronic components. In this paper, a specific SMPS system is regarded as the research object and the experimental study of its degradation is discussed. To study the SMPS system's degradation owning to these critical components, such as power MOSFETs, diodes and aluminum electrolytic capacitors, the components' performance parameters which can reflect their degradation need monitoring. In order to gain remarkable effects, accelerated aging test is adopted in this paper. The study of SMPS' degradation on basis of the theory of PoF (Physics of Failure) in this paper is meaningful to the reliability research of SMPS and provides an approach for the prognostics of its RUL (remaining useful life).

Francis R, proposed a system [3] for the continuous request from the market for higher power density and lower cost in commercial power supplies that has forced semiconductor manufacturer to push device optimization to the limit or to develop new device solutions. Some of the new devices can surely improve performances, but in some cases the price to pay for increased complexity is too high. The IGBT device has a long history of success in motor drive and inverter applications, where switching frequencies are relatively low compared to SMPS. For this reason the development of new devices has always been driven by different requirements than SMPS ones. An NPT IGBT family has been developed and optimized targeting specifically SMPS applications. This paper shows the feature of this device in a critical comparison with equivalent products available on the market today.

Fry in his paper [4] describes the design of a SMPS for the new rack. The SMPS operates on 240V 50Hz s.p. A.C., producing a nominal 28A D.C. at a preset level between 52 and 58V D.C. The active element is a power transistor half-bridge switching the transformer primary winding at 20KHz between the centre tap of series connected capacitors across a D.C. link, using PWM for load-dependent regulation. The D.C. link is provided by af.w. diode bridge across the line, feeding a small reservoir capacitor, topped up by a shunt-transistor (boost) converter giving line-dependent pre-regulation. The rectified transformer output (40KHz) after filtering for ripple and RFI may be used to provide an output of either polarity. A low power auxiliary inverter provides isolated supplies for the transistor base drives. The module is totally enclosed for better mechanical protection and freedom from RFI, and has a single full length `thermal wall' heat sink carrying insulated devices, which forms the mechanical `back bone' of the module. 95% of the drilling and tapping operations are carried out in this heat sink using a steel jig. Almost all interconnections are made using PCB tracks, leaving only a few wire links between PCB and devices. Overall efficiency is better than 90% at f.l.c. and the psophometric ripple is about 1mV. Line power factor is better than 0.97 and fold back current limit below 40V cuts the current back to 2.

Yan-Fei Liu [8] states that Switching mode power supplies are used in nearly all electronic devices in our daily lives and in industry. This paper reviews recent developments in switching mode power supplies including technologies to reduce power loss, and digital control strategies to improve the dynamic and system performance. ith the rapid development of digital devices and semiconductor technology, switching power supplies are used in almost all applications with output power level above one watt including communications equipment, data centers, wireless base stations, computers, cell phones, and various types of battery chargers. Two types of commonly used switching power supplies are AC-DC and DC-DC. With AC-DC power supplies, the input voltage is from the AC utility and the output is a DC voltage, for loads such as a computer power supply, or battery chargers. With DC-DC power supplies, the input voltage is DC and the output voltage is another DC level for loads such as a USB charger, or Voltage Regulator (VR) in a computer motherboard.

Rodriguez E proposed [6] that Uninterruptible energy is highly appreciated in applications such as personal computers, medical equipment, workstations, portable measurement equipment, and others. Besides, the appearance of standards about the quality of demanded line current for this equipment has been the cause of development of new power supply schemes capable of integrating battery backup and power factor correction in simple structures which offer both, low cost and size alternatives. This paper describes a novel and simple structure which offers power factor correction and battery backup capability. The proposed structure has excellent characteristics in terms of cost, size and efficiency, taking into account the reduced number of components.

Basso [1] explains that loop control is an essential area of electronics engineering that today's professional needs to master. Rather than delving into extensive theory, this practical book focuses on what you really need to know for compensating or stabilizing a given control system. You can turn instantly to practical sections with numerous design examples and ready-made formulas to help you with your projects in the field. You also find coverage of the underpinnings and principles of control loops so you can gain a more complete understanding of the material. This authoritative volume explains how to conduct analysis of control systems and provides extensive details on practical compensators. It helps you measure your system, showing how to verify if a prototype is stable and features enough design margins. Moreover, you learn how to secure high-volume production by bench-verified safety margins.

Pressman's book [5] has been recognized worldwide as the definitive guide to power supply design for over 25 years, Switching Power Supply Design has been updated to cover the latest innovations in technology, materials, and components. This Third Edition presents the basic principles of the most commonly used topologies, providing you with the essential information required to design cutting-edge power supplies. Using a tutorial, how-and-why approach, this expert resource is filled with design examples, equations, and charts.

In a SMPS, the output current flow depends on the input power signal, the storage elements and circuit topologies used, and also on the pattern used (e.g., pulsewidth modulation with an adjustable duty cycle) to drive the switching elements. The spectral density of these switching waveforms has energy concentrated at relatively high frequencies. As such, switching transients and ripple introduced onto the output waveforms can be filtered with a small LC filter.

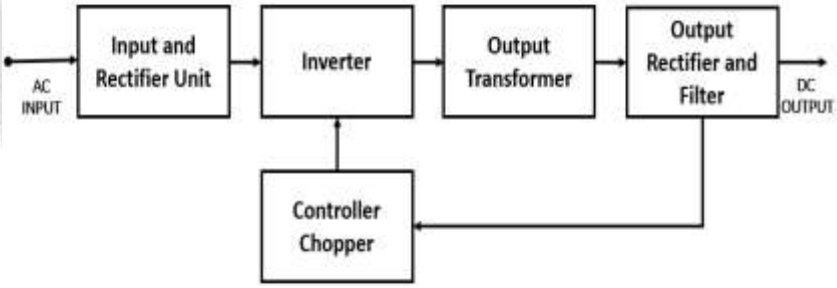

Fig -1: Block diagram of conventional SMPS

2. CONVENTIONAL METHOD WITH ELEVEN LEVEL CONVERTER

The SMPS has an AC input, which is converted to DC. This is called rectification. In some power supplies the rectifier circuit can be configured as a voltage doubler by the addition of a switch operated either manually or automatically. This feature permits operation from power sources that are normally at 115 V or at 230 V.

The inverter stage converts DC, whether directly from the input or from the rectifier stage to AC by running it through a power oscillator. The frequency is usually chosen to be above 20 kHz, to make it inaudible to humans. The switching is implemented as a multistage (to achieve high gain) MOSFET amplifier. The inverted AC is used to drive the primary winding of a high frequency transformer. This converts the voltage up or down to the required output level on its secondary winding. The output transformer in the Fig -2 diagram serves this purpose. If a DC output is required, the AC output from the transformer is rectified. The rectified output is then smoothed by a filter consisting of inductors and capacitors. For higher switching frequencies, components with lower capacitance and inductance are needed.

3. FLYBACK MODEL OF SMPS

A typical application of a DC power supply unit (PSU) is to convert utility AC voltage into a set of regulated DC voltages required for electronic equipment. The energy flow in a modern PSU is controlled with power semiconductors, which can operate in different modes. In original systems they operated in linear mode. Nowadays in most PSUs semiconductors are continuously switching on and off with high frequency. Such units are referred to as switched mode power supplies or SMPS. They offer greater efficiency compared with linear supplies because they can control energy flow with low losses: when a switch is on, it has low voltage drop and will pass any current imposed on it; when it is off, it blocks the flow of current. As the result, in such a switch the power dissipation which is the product of voltage and current can be relatively low in both states. Switching mode units are also smaller in size and lighter in weight due to the reduced size of passive components and lower heat generation. The industry trend toward miniaturization, advancements in semiconductor technology, as well as various energy efficiency regulations have made "switcher" the dominant type of PSU across practically the full spectrum of applications. Most PSU manufactured today for AC input applications also include a PFC front end.

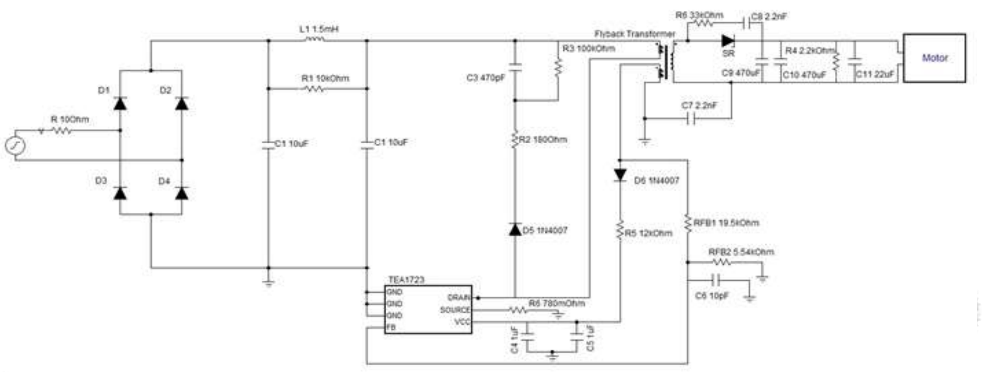

Fig -2: Circuit diagram of flyback SMPS

Here the SMPS is specifically designed for DC motor. The Choice for this SMPS is an isolated topology. It is termed as isolated topology because both the input and output terminals are totally isolated from each other or in other words the termed isolated also denotes the input and ground terminals are distinct. In the isolated topology a specific model termed as the flyback type is used in the design model. The SMPS design is in such a way that the motor is supplied with a constant voltage even when there is a change in its load conditions.

The hardware is a combination of two switch mode power supplies in which one powers the motor and other powers the LCD unit. Both the SMPS are isolated model with flyback transformer. The LCD unit comprises of a target board and LCD display. The motor parameters namely motor voltage and current is given to the LCD target board which is programmed to display the respective values of voltage and current. The target board which is also termed as the LCD driver is connected to the LCD display through the 16 pin FRC cable which enables of the communication between the 56F8006 processor and LCD display processor. The hardware snapshot is shown in the Fig -3 in which the numbering denotes the following components.

1) SMPS I which gives input supply to the motor
2) DC Motor
3) LCD Display board
4) SMPS II which gives input supply to the LCD target board
5) LCD target board or LCD driver

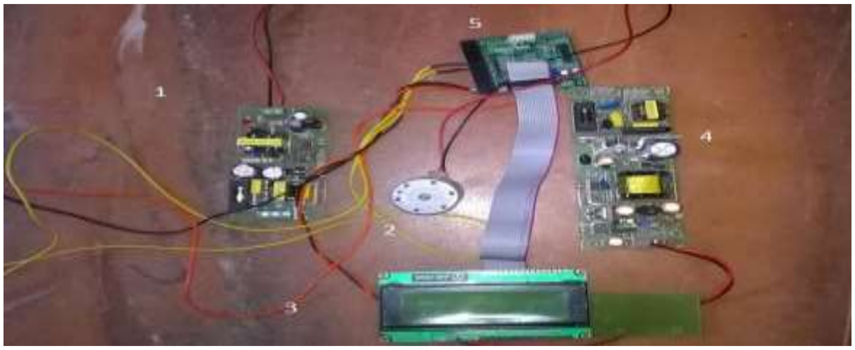

Fig -3: Hardware Snapshot

The input is 230 V 50 Hz single phase AC supply which gives a sinusoidal wave form. Basically this 230 V denotes the line value of the voltage so in terms of actual voltage which is the phase voltage it gives input voltage approximately to 400V
i.e.,230*√3 = 398 V .

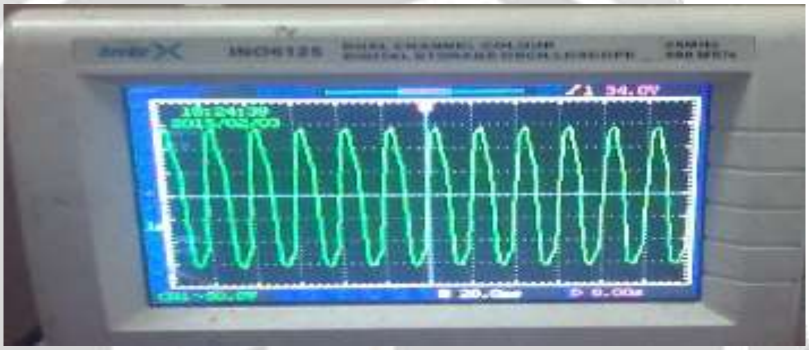

Fig -4: Input voltage waveform

Fig -4 gives input voltage of about 300 V. This is due to the voltage drop in the actual supply which is caused due to the practical limitations. There are also some distortions in the waveform which is generally caused due to the non-linear loads which are connected in parallel to the supply. The main aim of the primary AC to DC rectification process is to filter the distortion from the input waveform. For this purpose a bridge rectifier along with the smoothing inductors and capacitors are placed.

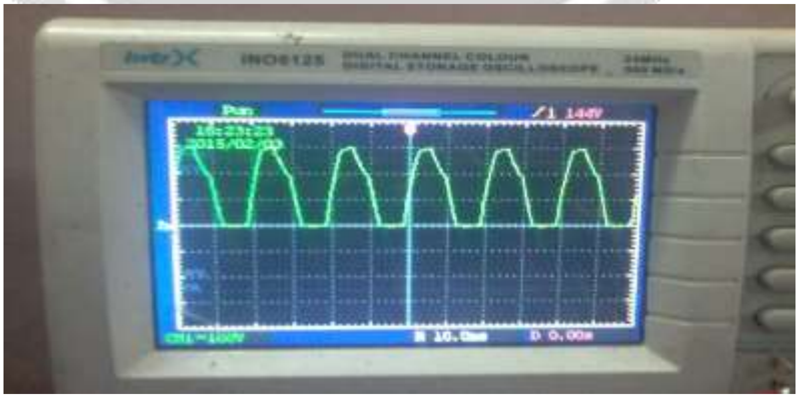

Fig -5: Output from the bridge rectifier

Fig -5 gives the rectifier output before being filtered. As the waveform denoted there are some distortions in the waveform which can be removed by passing it through the filter circuit. As the rectifier is a full wave type both the positive and negative peak are shifted to the positive voltage plane.The flyback transformer input is the DC voltage through a PWM controlled MOSFET switch. As the transformer cannot work in DC supply the switch turns ON and OFF alternatively based upon the PWM wave. Due to this the transformer gets a varying voltage with respect to time.

Fig -6: Flyback Transformer input

The flyback transformer input waveform is shown in Fig -6 in which there is an oscillation in the voltage. This oscillation is caused due to the MOSFET which is connected in between the supply and the transformer auxiliary. MOSFET when shifts from conduction state to blocked state the voltage does not reach zero immediately therefore there is presence of voltage oscillations in the waveform. The secondary terminal of the flyback terminal steps down the input of 300V to 12V as per the voltage requirement. Secondary winding is used in the discharge phase, and it builds a rectified voltage referenced commonly with the primary DC, considered on the primary side.

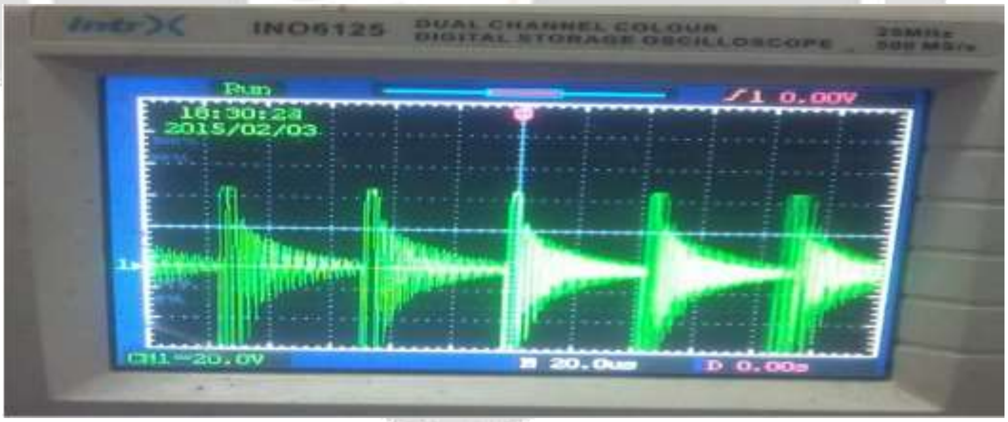

Fig -7: Flyback transformer output

In this case also there is a presence of voltage distortion in the waveform generated due to the non linear operation of the MOSFET. It is seen from the Fig -7 that the voltage level has been stepped down to nearly 18V. The distortion in the waveform can be removed by using rectifier and filter circuit. As seen from Fig -2 there is series combination of the RC placed in parallel with the Schottky rectifier which reduces the stress produced by the transformer. The final output waveform must be nearly 12V such that the motor does not get overexcited due to heavy input which may lead to the damage of the motor parts. The output from the rectifier is filtered such that the harmonic content is reduced and the output waveform is free from distortion.

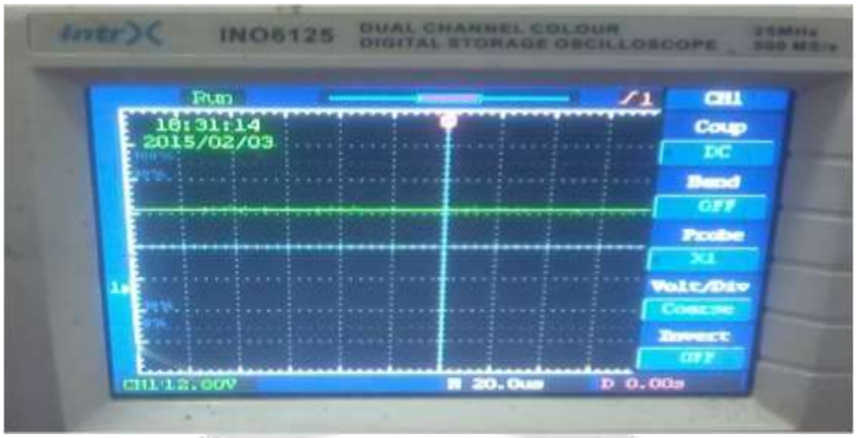

Fig -8: Regulated output voltage waveform

In Fig -8 the regulated DC output voltage is shown. The Output voltage of about 12V is produced by the SMPS which is nearly free from distortion and other disturbances. This is achieved by the use of π filters as shown in the Fig -2. A part of this output is given to the TEA1723BT microcontroller such that this voltage is compared with a reference voltage of about 12 V to achieve a constant voltage even when there is a change in the current.

4. CONCLUSION

A Switching mode power supply is a power supply that provides the power supply function through low loss components such as capacitors, Inductors and Transformers and the use of switches that are in one of the two states, on or off. The advantage is that the switch dissipates very little power in either of this two states and power conversion can be accomplished with a minimal power loss, which equates to high efficiency. SMPS, Designs relay upon the efficiency of a switch to control amount of power with relatively little losses. The primary advantage of the switching mode power supplies is then can accomplish power conversion and regulations at 100% efficiency given ideal parts. All power losses are due to less than ideal parts and power loss in the control circuitry.

Most commercial switch mode power supplies in the market today operate in the range 10 KHz to 50 KHz. There is now growing trend in research work and new power supply designs in increasing the switching frequencies upwards to 100 KHz and above. The reason being to reduce even further the overall size of the power supply in line miniaturization trends in electronic and computer systems. MOSFETs inherit lack of storage and fall time affects when turned off. Therefore MOSFETs are now increasingly replacing BJTs in new designs operating at much higher frequencies. But still the intrinsic characteristics of the MOSFET produce a large on resistance which increases excessively when the devices breakdown voltage is raised. Therefore, power MOSFET is only useful up to voltage ratings of 500V. Another new device likely to displace the BJT in many high power applications is the insulated gate transistor (IGT). This device combines the low power drive characteristic of MOSFET with the low conduction losses and high blocking voltage characteristic of the BJT. Therefore the device is highly suited to high power, high voltage applications. In future, more and more integrated power devices will be introduced so simplifying board layout and reducing component count. The driving force in every manufacturers design will always be the combined component and production costs. Therefore, any new device or topology will have to justify its implementation based on mainly commercial criteria.

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