Development of Switched Mode Power Supply (SMPS) Unit for Low-Power Electronic Devices

DIBOSA PIUS NNAMDI[1], ILOH J.P.[2], MBACHU C.B.[3]
[1, 2, 3]*Department of Electrical/Electronic Engineering, Faculty of Engineering, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria*

Abstract- Switched Mode Power Supply (SMPS) units are critical for powering modern electronic systems due to their superior efficiency and compact size. This paper presents the design, construction, and experimental evaluation of aflybackSMPS intended for low-power electronic devices. A flyback converter topology operating in discontinuous conduction mode (DCM) was utilized, targeting a wide AC input range of 85V to 265V and delivering a regulated 12V DC output voltage at 0.67A. The performance assessments revealed that the developed SMPS maintains stable output even at low input voltages (down to 40V), significantly outperforming a conventional linear power supply in regulation and efficiency. The SMPS achieved an average efficiency of 79.3%, making it a cost-effective and reliable alternative to imported models. The system is suitable for use in educational, research, and domestic applications.

Keywords: Switched Mode Power Supply, Flyback Converter, Low-Power Electronics, Power Regulation, Efficiency

I. INTRODUCTION

Power supplies are foundational to all electronic systems, providing the required voltage and current for proper operation. Traditionally, linear power supplies (LPS) have been widely used due to their simple design and low output noise. However, their bulky size, low efficiency, and high heat dissipation make them unsuitable for modern compact electronics (Vijaya & Reddy, 2016). In contrast, Switched Mode Power Supplies (SMPS) use high-frequency switching and energy storage components such as inductors and capacitors to offer a compact, lightweight, and energy-efficient solution (Mohan et al., 2015).

Among various SMPS topologies, the flyback converter is particularly suited for isolated, low-power applications due to its simplicity and ability to store and transfer energy effectively using a coupled inductor (Colonel &McLyman, 2020).Flyback Power Converters are multipurpose power electronics components that find utility in laptops and medical equipment (Tang,*et al,* 2013). Flyback converters are power converters that convert AC to DC with galvanic isolation between the inputs and outputs. It stores the energy when the current is flowing through the circuit and releases the energy when the power is removed. (George andHustan, 2013), it is used mutually coupled inductor and acts as an isolated switching converter for step-down or step-up voltage transformers. Also, it controls and regulates the multiple output voltages with a wide range of input voltages. The components required to design a flyback converter are few when compared to other switching mode power supply circuits (Weave 2010).

Flyback refers to the on/off action of the switch used in the design (Colonel, & McLyman, 2020). Alternatively referred to as isolated buck-boost converters, these converters are simple circuits that minimize electromagnetic interference while controlling a system's output voltage (V_{OUT}).

Most of the recorded works are not available for use locally since they need a specific device to work in Nigeria and have somewhat minimal working power, a portion of the references are recorded underneath.

Arno Berz delivered a paper in December 2014 named "Completely Protected Switched Mode Power Supply." A totally protected exchanged mode power supply for creating a stock voltage for an electrical gadget, as per his work, contains Y capacitors for hilter kilter impedance concealment of the switched mode power supply so that actions are accommodated lessening issue flows or spillage flows. The first and second electrical conduits of the switched mode power supply are for interfacing with a stage channel and a nonpartisan transmitter of a grounded AC or three-stage power supply framework, separately.
Furthermore, a gathering of scholastics drove by Sandeep Garg, Ashish Kumar, Ajitesh Jaryal, and Harpreet Kaur Channi directed research on the plan of a switched mode power supply in November 2017.

As per their examination, the Switched Mode Power Supply (SMPS) is an essential part of the PC that gives capacity to different parts by changing over rotating current (AC) into an assortment of proper dc voltages. A delegate step in the power transformation process is the DC converter. The central concerns with customary switched mode power supply (SMPSs) incorporate unfortunate influence quality deferred dynamic reaction and high gadget stress consonant rich occasionally thick peaky and twisted input current. Buck, boost, and Buck-boost converters are analyzed in this review.

II. DESCRIPTION OF SYSTEM OPERATION

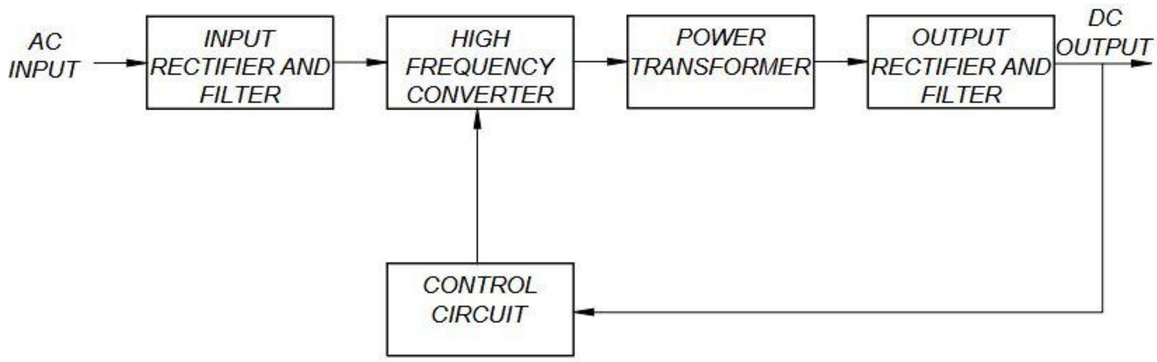

Figure 1: Block diagram of the flyback Switched Mode Power Supply under consideration

The Operation of flyback SMPS is as follow:

a. Considering the first block, the SMPS feeds in an alternative current (AC) power input voltage which is then rectified with the help of rectifying diodes to give a direct current (DC). A capacitor is used to filter the DC voltage and eliminate unwanted remaining ripples in the waveform

b. The DC is speedily toggled ON and OFF by a high frequency switching device such as MOSFET (TOP210) at the converter switching stage. This supplies a transformer with high frequency square-wave

c. This high frequency square-wave formed by this switching stage has to be in form of step down voltage, this is where coupled inductor comes in. The transformer primary windings are wired to the switch and the secondary side is to the output supply.

d. The high frequency AC voltage is rectified from the transformer and transformed into the more convenient DC voltage by the filter capacitor

e. The control circuit maintains a constant stable output voltage by continuously monitoring the output and adjusting the duty cycle of the switching device

The design of a flyback converter-based switched-mode power supply system involves several critical trade-offs and engineering decisions, (Danjiang, C. &Qiaowen, Z. 2011).

III. PARAMETER DETERMINATIONS

This section explores the key aspects of a basic power supply design in detail. The overall design flow for this work is illustrated in Figure 2.

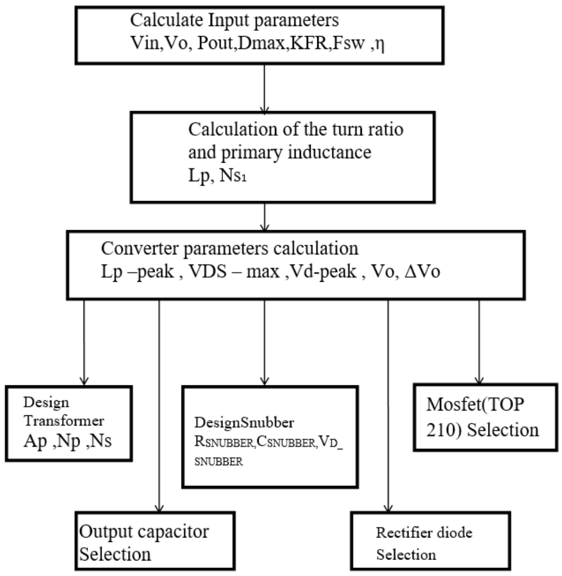

Figure 2: Power Supply Design Process

3.1 Determination of the Maximum Primary Inductance

The primary objective of the initial design step is to determine the maximum value of the main inductor, L_P. While multiple design strategies exist for flyback converters, the system in this case is configured to operate exclusively in Discontinuous Conduction

Mode (DCM).

Parameters	Value
Input voltage (V_{IN})	85V to 265V
Output voltage (V_{OUT})	12V
Output current (I_{OUT})	0.67A
Operation mode	DCM
Ripple factor (K_{FR})	1
Maximum duty cycle (D_{MAX})	0.48
Switching frequency (f_{SW})	100kH z
Estimated efficiency (η)	80%

Figure 3: Input parameters used

The appropriate inductor value can be calculated using equation 1

$$Lp = \frac{\eta\ X\ Dmax^{2}\ X\ Vin\_Min^{2}}{2\ X\ f_{SW}\ X\ K_{FR} X\ V_O} = \frac{0.8\ X\ 0.48^{2}\ X\ 85^{2}}{2\ X\ 100\ X\ 10^{3}\ X\ 1\ X\ 12} \approx 555\mu H \quad (1)$$

By applying the design inputs to Equation 1, the maximum permissible inductance is determined to be 555 μH. Subsequently, the required turns ratio (nS_1) is calculated using the same worst-case scenario—maximum input voltage (VIN) and maximum duty cycle (D). To enhance calculation accuracy, the forward voltage drop of the diode is also accounted for. Equation 2 is then used to estimate the turn's ratio (nS_1).

$$nS_1 = \frac{Vin\_\min\ X D_{MAX}}{(1-D_{MAX})\ X (V_O + V_D)} = \frac{85\ X\ 0.48}{(1-0.48) X\ (12+0.7)} \approx 6.18 \quad (2)$$

wherenS$_1$ =Turn's ratio of inductor, Vin = Min. input voltage, Vo = max. input voltage, Dmax = Maximum duty cycle,

3.2 Determination of MOSFET(TOP210)

The next phase involves selecting an appropriate integrated circuit (IC) for the application. This requires determining the maximum current and voltage the switching element must endure during operation. Begin by calculating the maximum voltage stress on the switch (VS_{MAX}) using Equation 3

$$VS_{MAX} = Vin_{\text{MAX}} + \frac{D_{MAX} X Vin_{\text{MIN}}}{1-D_{MAX}} = 265 + \frac{0.48\ X\ 85}{(1-0.48)} = 344 + 20\%\ \text{safety margin} = 413V.(3)$$

Where Vsmax = Max voltage of the Mosfet, Vin = Min. input voltage, Vo = max. input voltage, Dmax = Maximum duty cycle

A 20% safety margin is applied to the calculated V_{S-MAX}value to ensure robust and reliable converter operation under all expected conditions. The next step is to estimate the maximum current (I_{P-max}) using Equation 4

$$I_{P\text{-max}} = \frac{P_{IN}}{D_{MAX} X\ V_{IN-MIN}} + \frac{D\text{MAX}\ X V_{IN-MIN}}{2\ X f_{SW} X\ L_{P-MAX}} = \frac{12\ X \frac{1}{0.8}}{0.48\ X\ 85} + \frac{0.48\ X\ 85}{2\ X\ 100\ X 10^{3} X\ 555\ X 10^{-6}} = 0.736A (4)$$

Where Pin = input power, Fws= Switching frequency, Dmax = Maximum duty cycle, Vin = Min. input voltage, I_{P-max}= Maximum current, Vin = Min. input voltage

Then there will be search for the MOSFET that will certify this specification.

3.3 Rectifier Diodes Calculations

At this stage, the rectifier diodes are evaluated to ensure they can reliably handle the maximum voltage and current they may encounter during operation similar to the criteria used for the MOSFET. The peak reverse voltage that the diode must withstand is calculated using Equation 5.

$$V_{\text{DI\_PK}} = V_{\text{OUT}} + \frac{V_{IN\_MAX}}{\text{Ns1}} = 12 + \frac{265}{6.18} = 54.88\text{V} + 40\% \text{ safety margin } = 76.8\text{V} \quad (5)$$

By adding a 40% safety margin, the maximum reverse voltage is determined to be 76.8V

3.4 Output Capacitor Calculations

The output capacitor value is estimated under the assumption that second-order effects such as output crosstalk and parasitic components are negligible. Equation 6 is used to approximate the voltage across the output capacitor.

$$\text{Vc} = \frac{I}{C} X \int_0^{T_{SW}} I_{C(t)dt} = \frac{I}{C} X \int_0^{DT_{SW}} I_{C(t)dt} \quad (6)$$

Vc = output capacitor, C = capacitance, T_{sw}= periodic time of switching freq,

If Equation 7 is evaluated specifically at tON, it simplifies significantly. The output voltage ripple is then calculated using:

$$\Delta V_O = \frac{\text{D} \times \text{Io}}{\text{Fsw} \times \text{C}} \quad (7)$$

where*D* is the duty cycle, *IO*is the output current, *Fsw*is the switching frequency, and *C*is the output capacitance.In this case, a 240µF capacitor is used, which incurs a 12.5mV output voltage ripple.

3.5 The switched mode power supply Transformer Design and Calculations

The transformer area was estimated with Equation 8

Ap = Core Area of Transformer, A_E = Core Area and Aw =window Area

$$\text{Ap} = A_E X \ \text{Aw} \ [\text{mm}^4] \quad (8)$$

$$A_P = \left(\frac{LPXI_{PMAX}X \ I_{PRMS}}{B_{MAX} \ X \ 0.0085}\right)^{\frac{4}{3}} X \ 10000 = \left(\frac{555\mu HX \ 0.736A \ X \ 0.77A_{RMS}}{0.2 \ X \ 0.0085}\right)^{\frac{4}{3}} X \ 10000 = 1054\text{mm}^4 \quad (9)$$

Usually a stated input parameter, B_{MAX} is in the range of 0.2T to 0.3T for ferrite cores. An EE13 core and a bobbin with a minimum length of 0.28 mm have been chosen using the AP technique. Calculate the primary turn number with Equation 10

$$N_P = \frac{L_M X I_{PK-MAX} X 10^6}{B_{MAX} X A_E} = \frac{555 \ \mu H X \ 0.736 A X 10^6}{0.2 \ X \ 20.1 \ mm^2} \approx 102 \ \text{turns} \quad (10)$$

Estimate the secondary turn number with Equation 11:

$$\text{Ns} = \frac{N_P}{\text{nSI}} = \frac{N_P}{6.18} = \frac{102}{6.18} = 40.6 \text{ turns} \quad (11)$$

Where Np and Ns are the number of turns for primary winding and secondary winding respectively and ns is the inductance

The auxiliary winding turn number is calculated following the same procedure as the secondary output turn number, resulting in N_{aux} = 5.

3.6 Snubber Circuit Design

The design process for the snubber network consists of three main steps. First, the leakage inductance is estimated to be approximately 2% of the transformer's primary inductance. Second, the allowable voltage ripple across the snubber capacitor is limited to 10% of its peak voltage, ensuring efficient energy absorption and component safety. With these assumptions, the snubber component values can be estimated. The maximum voltage across the snubber capacitor is determined using Equation 12.

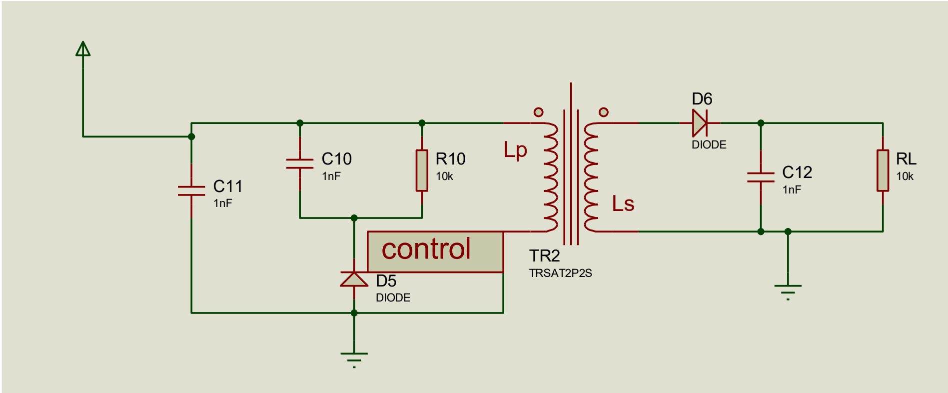

Figure 4: Snubber circuit

$$V_C(MAX)=VDS(MAX) \text{ X } 0.1 + \frac{D_{MAX}}{1-D_{MAX}} X V_{IN(MIN)} = 413 \text{ X } 0.1 + \frac{0.48}{1-0.48} \text{X } 85 = 119.8V \quad (12)$$

The power in the snubber resistor was estimated with Equation 13:

$$P_{R_{SNUBBER}} = \frac{I^2{}_{P(PEAK)} X L_{LEAK} X f_{SW}}{2} = \frac{(0.736)^2 X\, 1.06\mu HX\ 100KHZ}{2} = 0.03 \text{ W} \quad (13)$$

Using the power as a limiting parameter, calculate the snubber resistor value with Equation 14:

$$R_{SNUBBER} = \frac{(V_{C(MAX)})^2}{P_{R_{SNUBBER}}} = \frac{(119.8V)^2}{0.03X\ 6.18W} = \frac{(120V)^2}{0.1854W} = 77.41K\Omega \quad (14)$$

Estimate the value of the snubbing capacitor with Equation 15:

$$C_{SNUBBER} = \frac{1}{\Delta V_C X R_{SNUBBER} X f_{SW}} = \frac{1}{10\%\ X\ 77410\ X\ 100KHZ} = 1.3nF \quad (15)$$

Lastly, calculate the maximum voltage across thesnubber diode with Equation 16:

$$V_{DSNUBBER(PEAK)} \approx 1.2 \text{ X } V_{DS(MAX)} = 1.2 \text{ X } 413 \text{ V} = 496V \quad (16)$$

Since the parameters and values have been established, the TOP210 controller can be integrated with its external circuitry to form a fully functional SMPS AC/DC converter. The complete circuit as shown in figure 4, incorporates all previously identified components, including the rectifier diode (D), snubber network, output capacitor bank (consisting of C5, C6, and C7 for improved frequency response), the primary inductor (Lp), and the auxiliary inductor (Lp2).The complete circuit layout also features an auxiliary-side controller for the MP6004. The switching element, the TOP210 IC, and its supporting components form the core of the regulation stage, alongside a few additional noise-filtering elements. This implementation benefits from reduced system cost, a compact power footprint, and enhanced efficiency. Operating at 12 V, the design delivers 8 W of output power and achieves a nominal efficiency of approximately 80% under full load conditions

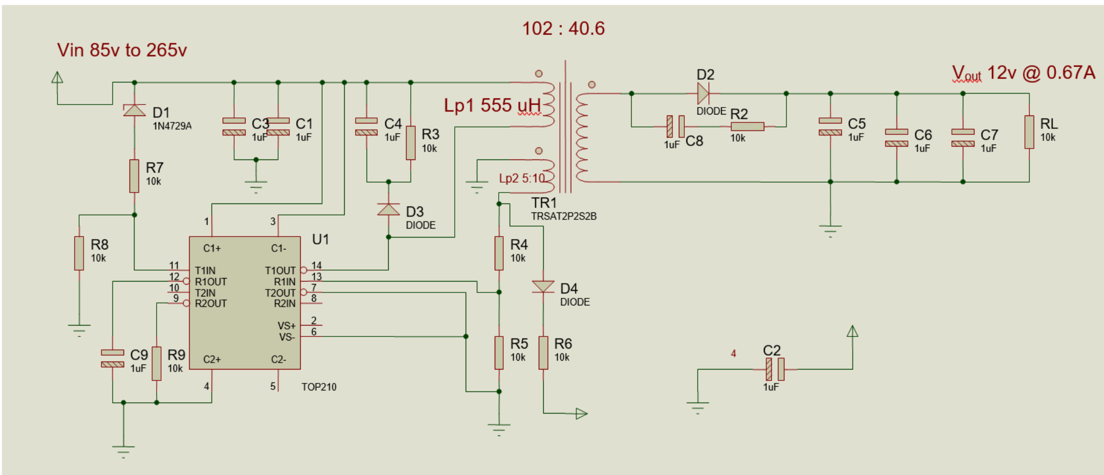

Figure 5: Complete circuits of SMPS

IV. TESTING AND EVALUATION PROCEDURE

The prototype was built on a veroboard and tested in a laboratory using a variac transformer and multimeter to measure input/output voltage and current as represented in the figure 6 below. Efficiency was computed using the ratio of output power to input power across varying input voltage levels.

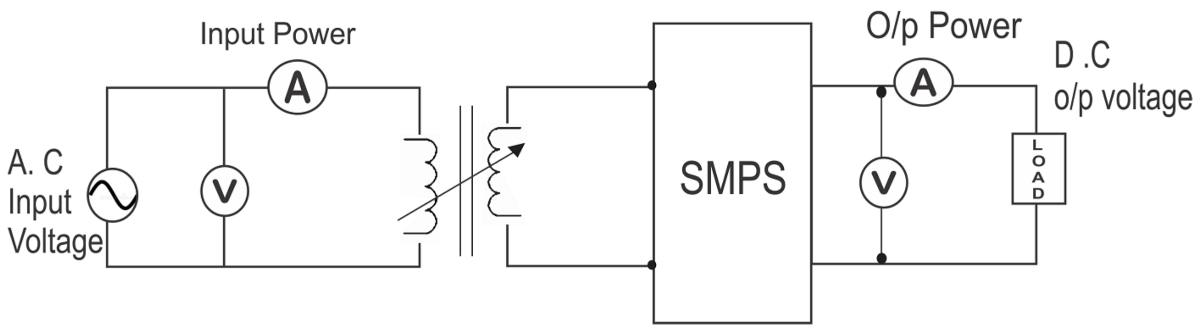

Figure 6: Experimental setup for evaluating the performance of SMPS on load

V. RESULT AND ANALYSIS

The output voltage of the SMPS circuit was tested by connecting it to a 230 V variable AC source (variac) as shown in figure 6. The system was first tested on infinite load and the result is presented in figure 7.

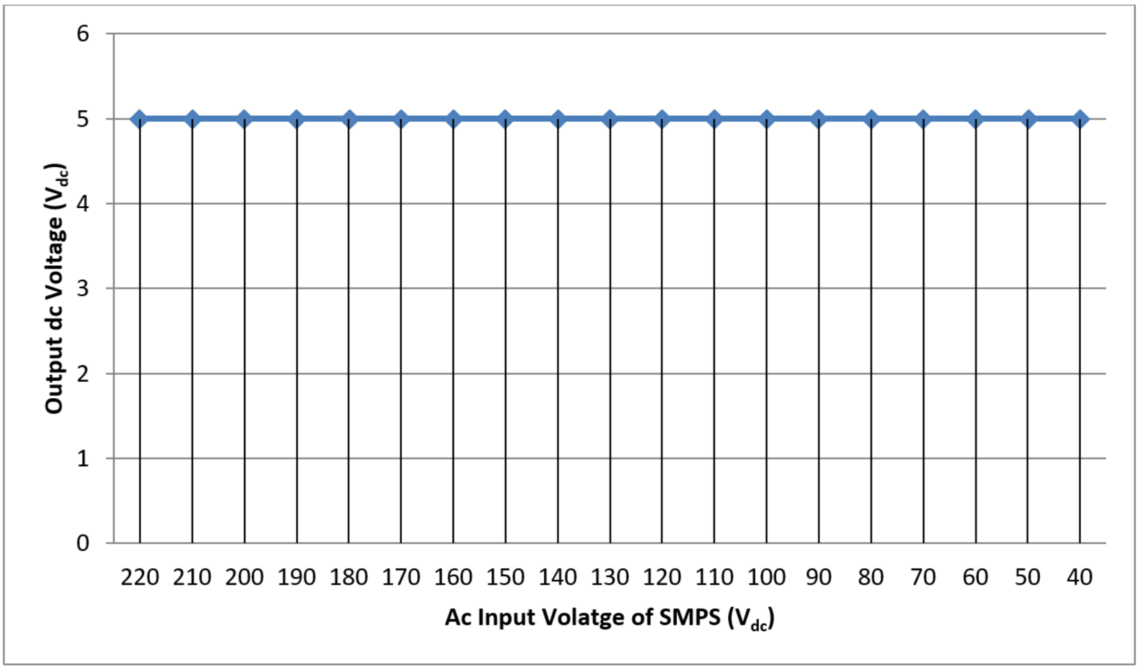

Figure 7: Result of Switch Mode Power Supply oninfinite

Figure 7 shows that when tested under infinite-load conditions, the switch-mode power supply (SMPS) maintained a stable output voltage close to the nominal design value. Minimal voltage fluctuation was observed, demonstrating the converter's ability to regulate effectively even without a connected load. This indicates good standby performance and highlights the system's efficiency in minimizing power loss during idle operation. A second test was subjecting the system to various load conditions and results in figure 8

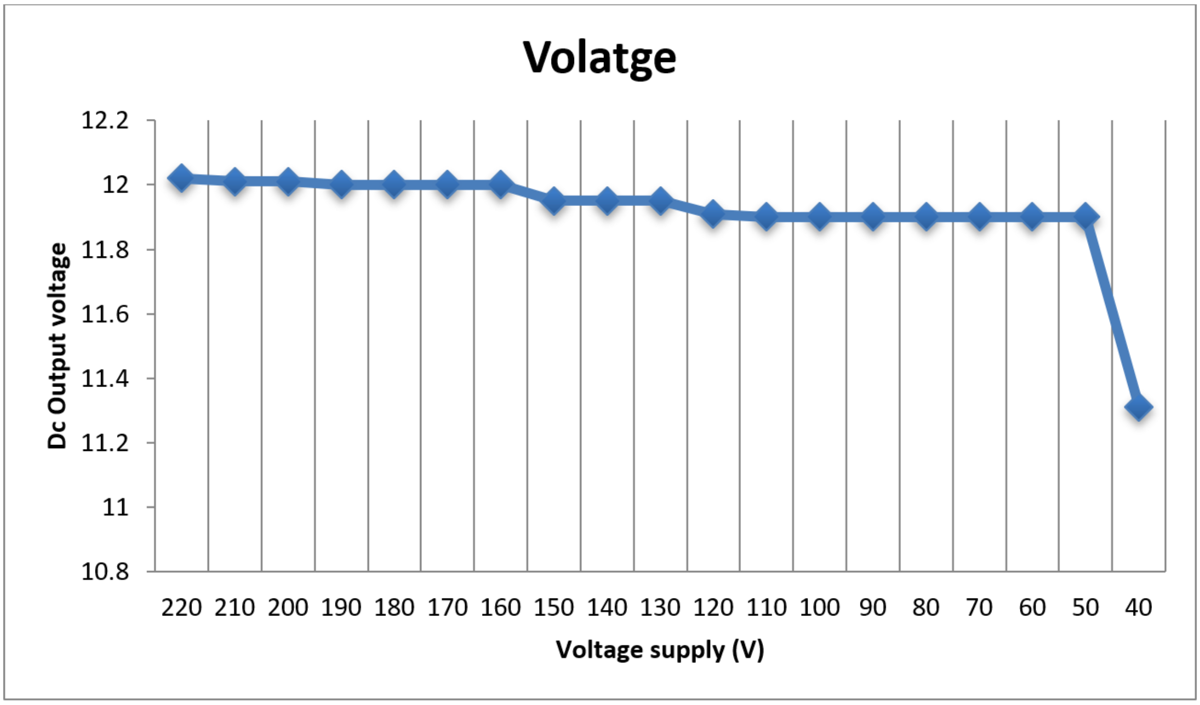

Figure 8 shows Load Test Results for the 12V Switch-Mode Power Supply.

Analysis shows that when subjected to varying load conditions, the 12V switch-mode power supply (SMPS) maintained a consistent output voltage near its nominal value, demonstrating effective voltage regulation. As the load current increased, only minor voltage dips were observed well within acceptable ripple and tolerance margins. This confirms the converter's stability and efficiency in delivering clean power under load.

The final test on the system was carried out by measuring the input Ac power to the system and the output Dc power delivered to the load and the result is presented in table1 and figure 8. This test was for computing the efficiency to the developed system.

TABLE4.5 4 TESTING THE EFFICIENCY OF SMPS ON LOAD

MEASURED SMPS INPUT AC POWER. P_{in}				MEASURED SMPS OUTPUT D.C POWER P_{out}			EFFICENCY $\eta = P_{out}/ P_{in} x\ 100$
S/N	VOLAGE (Volt)	CURRENT (Amp)	POWER (Watt)	VOLAGE (Volt)	CURRENT (Amp)	POWER (Watt)	%
1	257	0.050	10.25	12.04	0.680	8.26	80.6
2	230	0.055	10.20	12.02	0.678	8.20	80.4
3	220	0.057	10.20	12.02	0.677	8.13	80.0
4	210	0.060	10.20	12.01	0.672	8.04	79.0
5	200	0.063	10.19	12.01	0.670	8.04	79.0
6	190	0.066	10.18	12.00	0.670	8.04	79.0
7	180	0.070	10.18	12.00	0.670	8.04	79.0
8	170	0.074	10.18	12.00	0.670	8.04	79.0
9	160	0.079	10.16	12.00	0.670	8.04	79.0
10	150	0.084	10.16	11.95	0.670	8.00	79.0
11	140	0.091	10.16	11.95	0.670	8.00	79.0
12	130	0.097	10.15	11.95	0.670	8.00	79.0

13	120	0.105	10.15	11.91	0.66	8.00	79.0
14	110	0.115	10.12	11.90	0.66	7.97	79.0
15	100	0.125	10.05	11.90	0.66	7.97	79.3
16	90	0.139	10.05	11.90	0.66	7.97	79.3
17	80	0.156	10.03	11.90	0.66	7.97	79.4
18	70	0.179	10.03	11.90	0.66	7.97	79.4
19	60	0.208	10.03	11.90	0.66	7.94	79.2
20	50	0.250	10.02	11.90	0.66	7.94	79.2
21	40	0.309	9.89	11.31	0.66	7.94	79.3
AVERAGE			10.12			8.02	79.3

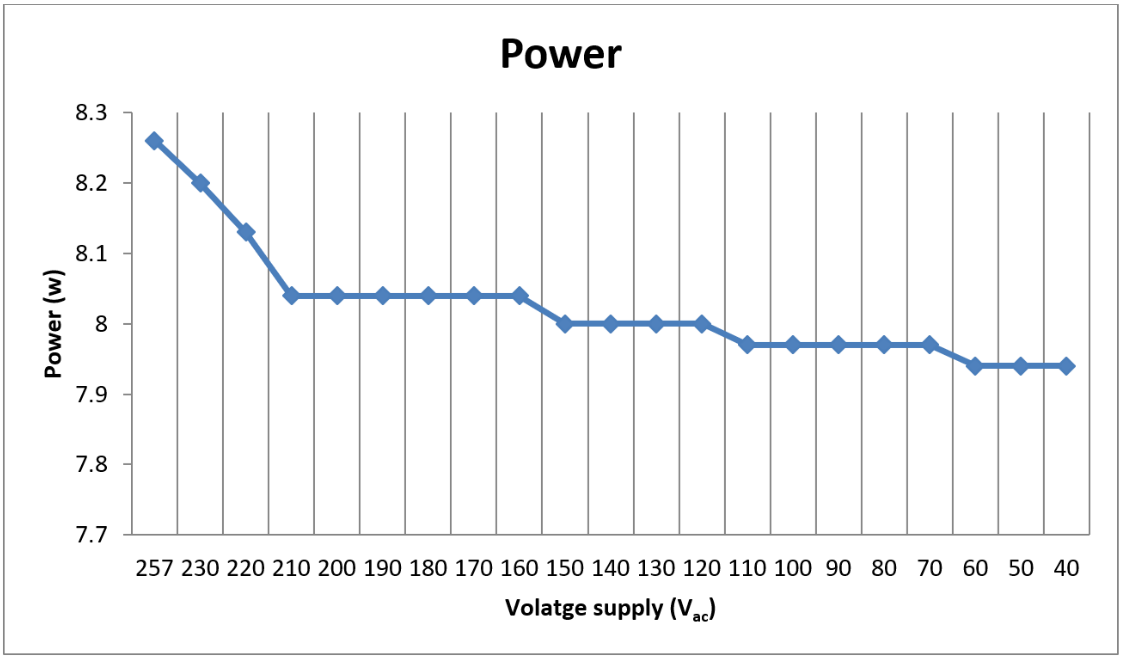

Figure 9: Switch mode power supply efficiency on load

VI. DISCUSSION

Testing showed that the developed SMPS provided a regulated 12V output across input voltages ranging from 85V to 265V AC, maintaining this stability even at a low input of 40V AC. This is supported by the work of Stephy and Nayana (2017) who posited that SMPSmaintained a consistent output voltage near its nominal value, demonstrating effective voltage regulation Ashot (2015). Efficiency measurements under load yielded an average of 79.3%, validating the design target. The SMPS also showed efficient regulation, remaining within ±1% of the nominal 12V output across the entire test range.

CONCLUSION

A Switched Mode Power Supply (SMPS) for low-power electronic devices was successfully designed, constructed, and evaluated. The results indicate that this SMPS design provides robust voltage regulation, high efficiency and reliable performance under fluctuating power conditions. The system can supports both educational and practical applications in environments with unstable mains supply. The design is replicable, affordable, and contributes to self-reliance in electronics development within developing countries. It is a reliable alternative source of other power supply types.

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