CHAPTER 12

Switched Mode Power Supply (SMPS)

12.1 Switched Mode Power Supply (SMPS)

With advances in electronics, need for dc power supplies for use in integrated circuits (ICs) and digital circuits has increased very much. The 6-pulse ac-dc converter is good for the DC motor with high rotor inertia. But for IC's we require good quality DC supply. This ripple is high for IC's so we cannot use this 6-pulse ac to dc converter.

The two major things that are required are:

1. Conversion efficiency should be high.
2. Ripple's should be very low.

Use of the Isolation transformer increases the efficiency and Isolates load and source.

- SMPS provide good quality of power supply which is required for some of the sensitive circuits like IC's and digital circuits etc.
- A good power supply requires lesser harmonics so that filtering requirement is reduced.
- SMPS operation is based on chopper principle. At very high frequency the ripple is eliminated and filter inductance size is also low.
- In SMPS the transistor operate in switch mode. i.e.
  ON state – Saturation region
  OFF state – Cut-off region.
  Safe operating area is also more.
- The SMPS provides good quality of dc power supply which is more efficient and compact in size.
- With the availability of high speed devices like power MOSFET SMPS is efficiently used.
- Before SMPS we were using Linear power supplies where the transistor operates in the active region so losses were more. Linear power supplies are not efficient and occupy more space. Therefore linear power supplies are replaced by SMPS.

The principle used is:

$$\underset{50\ Hz}{AC} \xrightarrow{1} DC \xrightarrow{2} \underset{(50\ Hz\ to\ 200\ kHz)}{AC\ (increase\ frequency)} \xrightarrow{3} DC$$

Therefore SMPS is a three stage conversion. In stage 2 the devices employed are MOSFET and IGBT.

Types of SMPS

1. FLY BACK type
2. Forward Converter
3. PUSH PULL type

Flyback Converter

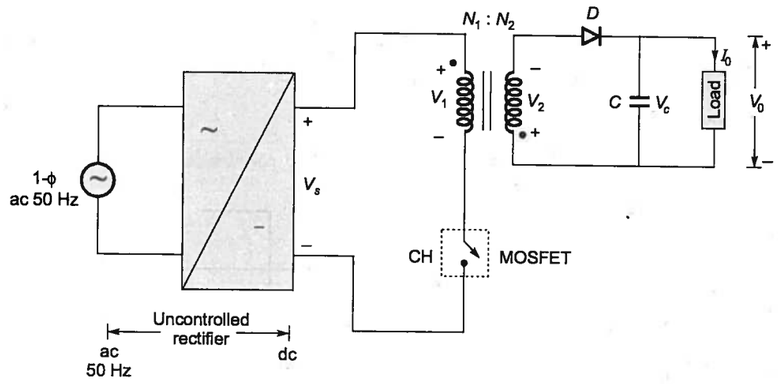


***Figure*-12.1**

1. Time interval $0 \le t \le T$ i.e. CH is ON

$$V_1 = V_s$$

$$V_2 = \frac{N_2}{N_1} V_1 = \mathbf{a} V_s$$

V_2 reverse biases the diode.

Diode remains in OFF state means the secondary is open circuited and it draws only the no-load current. So, the current magnetization increases from I_{min} to I_{max} because transformer stores energy in the form of magnetic field.

2. $T_{ON} \le t \le T$
   CH → OFF
   Diode D → ON

So the stored magnetizing current is discharge through the diode because primary is open.

$$\boxed{V_2 = -V_0}\ ; \quad \boxed{V_1 = -\frac{V_0 N_1}{N_2}}$$

In the second mode the transformer is releasing the stored energy to load. So I_m decrease.

As the operation of flyback converter is similar to Buck - Boost chopper whose

$$\boxed{V_0 = \frac{\alpha V_S}{(1-\alpha)}}$$

But, we have to replace inductor by the transformer.

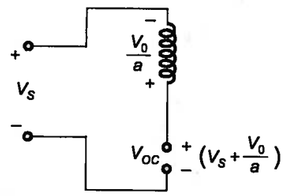
$$\boxed{V_0 = \frac{a\,\alpha\, V_S}{(1-\alpha)}}$$

Where as, a = turns ratio = $\frac{N_2}{N_1}$

The peak forwarded blocking voltage of the chopper (MOSFET) is

$$V_{OC} = V_1 + V_S = \frac{V_0 N_1}{N_2} + V_S$$

$$\boxed{V_{oc} = \frac{V_0}{a} + V_S}$$



Wave Forms of Flyback Converter SMPS

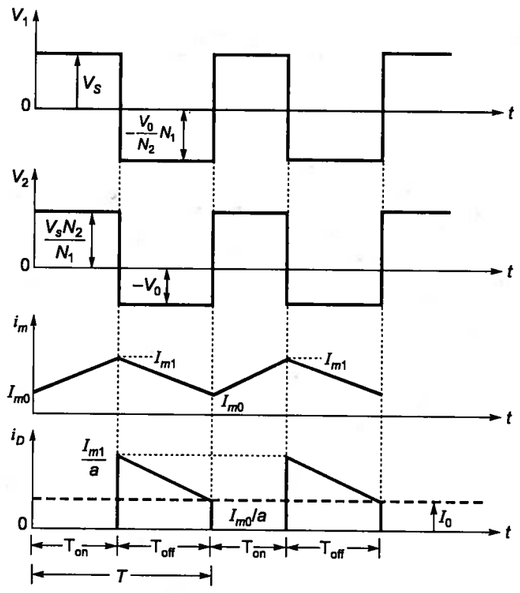


***Figure*-12.2**

- Because of chopper switch the polarities of voltage at primary reverse from + – to – + and so on, so it acts as ac for the transformer because frequency is high. So there is no case of applying dc to the transformer such that it is short circuited.
- Finally at output, filter is also provided to eliminate ripples that ranges around (0.01%) so a perfect dc output is obtained.
- This type of SMPS is used only for low power applications (i.e. less than 100 W)

Push Pull Converter

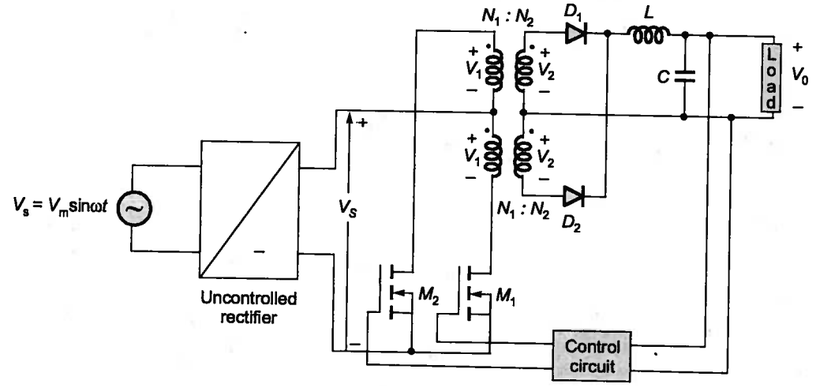


***Figure*-12.3**

SMPS with push pull configuration is shown above, it uses two power MOSFETs M_1 and M_2 and a transformer with mid taps on both primary and secondary sides. As in flyback converter, an uncontrolled rectifier feeds push pull SMPS. Inductor L and capacitor C are the filter components.

When M_1 is turned ON, V_S is applied to lower half of transformer primary, i.e., $V_1 = V_S$. As a result, voltage $V_2 = \frac{V_S N_2}{N_1}$ is induced in both the secondary winding. Voltage V_2 in the upper half secondary forward biases diode D_1, therefore load voltage V_0 is given by

$$\boxed{V_0 = \frac{V_S N_2}{N_1} = aV_S}$$

When M_2 is turned on, $V_1 = -V_S$ is applied to upper half of the primary winding. Consequently $V_2 = \frac{-V_S N_2}{N_1}$ is induced in both transformer secondaries. As V_2 is negative, diode D_2 gets forward biased and $V_0 = aV_S$

This shows that voltage on primary swings from $+V_S$ with M_1 on to $-V_S$ with M_2 on. Power MOSFETs M_1 and M_2 operates with duty cycle of 0.5. When M_1 is off, the voltage across M_1 terminal is $V_{OC} = 2V_S$. As both $M1$ and M_2 are subjected to open circuit voltage of $2V_S$, this configuration is suitable for low-voltage applications only.

The Main Advantages of SMPSs over Conventional Linear Power Supplies are

- For the same power rating, SMPS is of smaller size, lighter in weight and possesses higher efficiency because of its high frequency operation.
- SMPS is less sensitive to input voltage variations.

The Disadvantages of SMPS are

- SMPS has higher output ripple and its regulation is worse.
- SMPS is a source of both electromagnetic and radio interference due to high frequency switching.

- Control of radio frequency noise requires the use of filters on both input and output of SMPS.
  The advantages possessed by SMPS, for outweigh their short commings. This is the reason for their wide spread popularity and growth.

Example - 12.1 **In a switched-mode power supply (SMPS), after conversion of a.c. supply to a highly filtered d.c. voltage, a switching transistor is switched ON and OFF at a very high speed by a pulse width modulator (PWM) which generates very-high frequency square pulses. The frequency of the pulses is typically in the range of**

(a) 100 Hz-200 Hz
(b) 500 Hz-1 kHz
(c) 2 kHz-5 kHz
(d) 20 kHz-50 kHz

Solution: (d)

The frequency of the pulses is kept as high as possible to reduce the size of the pulse transformer.

Example - 12.2 **Which one of the following is used as the main switching element in a switched mode power supply operating in 20 kHz to 100 kHz range?**

(a) Thyristor
(b) MOSFET
(c) Triac
(d) UJT

Solution: (b)

MOSFET has lowest switching losses and operates at high frequencies (upto 100 kHz range).

Example - 12.3 **Which of the following devices should be used as a switch in a low power switched mode power supply (SMPS)?**

(a) GTO
(b) MOSFET
(c) TRIAC
(d) THYRISTOR

Solution: (b)

In SMPS, high frequency operation is required for such application, MOSFET is used as it has less switching losses.

Example - 12.4 **Which one of the following is the main advantage of SMPS over linear power supply?**

(a) No transformer is required
(b) Only one stage of conversion
(c) No filter is required
(d) Low power-dissipation

Solution: (d)

In SMPS filter required is easy to design there are multiple stage in SMPS transformer is also used in SMPS small physical size & less weight is main reason to wide spread use of SMPS's