NOTES

Programme Code: Electrical Engineering | **Year/Scheme:** EE3K | **Semester:** 3rd

Course Title: Fundamentals of Power Electronics | **Course Abbr.:** FPE | **Course Code:** 313335

Subject Teacher :- Ms. H.A.Badgujar

UNIT-04 – (10 MARKS)

DC-DC Converters

CO Coverage: - Test the performance of given chopper.

Unit -04 Content (Syllabus)

4.1 Basic terminologies: duty ratio, turn on period, turn off period, chopping period.

4.2 Control strategies of chopper: Constant frequency system, variable frequency system.

4.3 Step up chopper: circuit diagram, working, waveforms and output voltage equation.

4.4 Step down chopper: circuit diagram, working, waveforms and output voltage equation.

4.5 Buck-Boost chopper: circuit diagram, working, Waveforms and output voltage equation.

4.1 - Basic Terminologies :-

* Chopper :- The chopper circuit is power electronic circuit that converts fixed DC voltage at it's input into a variable DC output voltage. Hence a chopper is known as DC to DC converter.

1) Duty ratio :- (Duty Cycle) :-

Duty ratio of a chopper is defined as the ratio of turn ON period (T_{on}) and the total time (T)

i.e. Duty cycle = $\frac{T_{on}}{T}$

where, $T = T_{on} + T_{off}$.

2) Turn ON period :- (T_{ON}).

Turn ON time of chopper is defined as the time for which output voltage remains low. It is denoted by T_{off}.

3) Turn off period :- (Toff) The turn off time of chopper is defined as the time of which output voltage remains low. It is denoted by Toff.

4) Chopping Period :- It is defined as reciprocal of chopping frequency that means the frequency at which chopper is turn ON and off.

* 4.2 Control strategies of Chopper :-

The average output voltage can be controlled by following methods :-

1) Pulse width modulation (PWM) / Constant frequency.
2) Ferequency modulation or variable frequency system.

* Pulse width modulation technique :-

→ In this controlled technique of chopper the total time period or frequency is constant. And we can vary the ON time of chopper to get a variable output voltage.

→ The average output voltage is directly proportinal to the ON time of the chopper

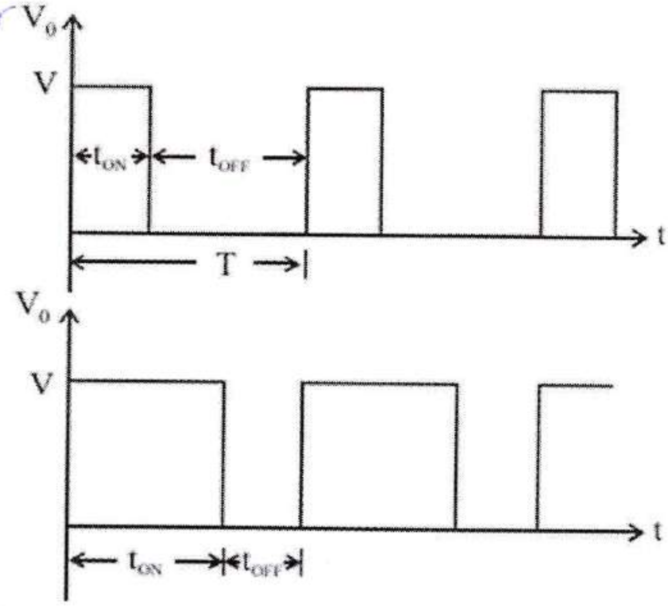


Fig. Pulse Width Modulation Control

→ In this technique we change the ratio of on time of the chopper to the total time. Hence it is also called as time ratio controlled (TRC) technique.

→ Fig. shows the output voltage waveforms for different ON times.

→ In PWM the pulse width (t_{ON}) of the output waveform is varied keeping chopping frequency 'f' and hence chopping period 'T' constant. Therefore output voltage is varied by varying the ON time, t_{ON}.

* **Variable frequency system or frequency modulation :-**

→ In this method, the ON time of chopper kept constant and variation in the average output voltage is obtained by varying the total time or chopping frequency.

→ In this technique the ratio of T_{ON} divided by T. or Duty cycle is change by changing the T_{OFF} time of the chopper.

→ This technique is called as frequency modulation technique.

→ This type of control generated harmonics at unpredictable frequencies and the fulter design would be difficult.

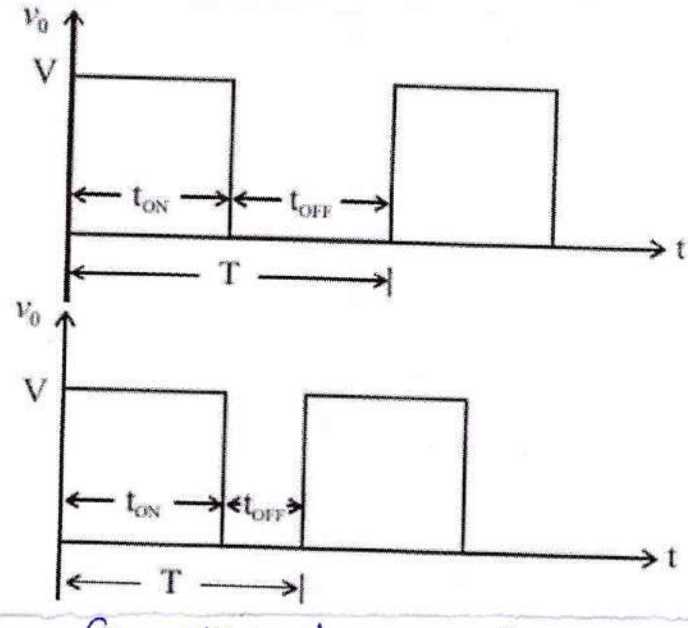


Fig. O/P voltage waveform

→ Fig. shows the output voltage waveforms for a constant t_{ON} and variable chopping period (T).

* **4.3 - Step up chopper :-**

Step up chopper is a type of chopper where output DC voltage is higher than I/P DC voltage. Step-up-chopper is also called as Boost chopper and it is classified as class B chopper.

* **Operation :-** When the average output voltage is greater than the ~~chopper~~ input voltage is called as step up chopper.

→ fig ① shows step up chopper and fig ② shows waveforms of step up chopper.

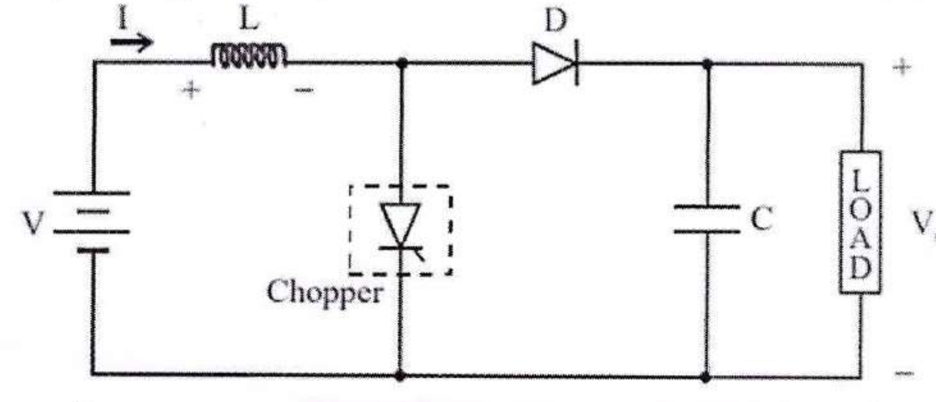


Fig. Step-up Chopper

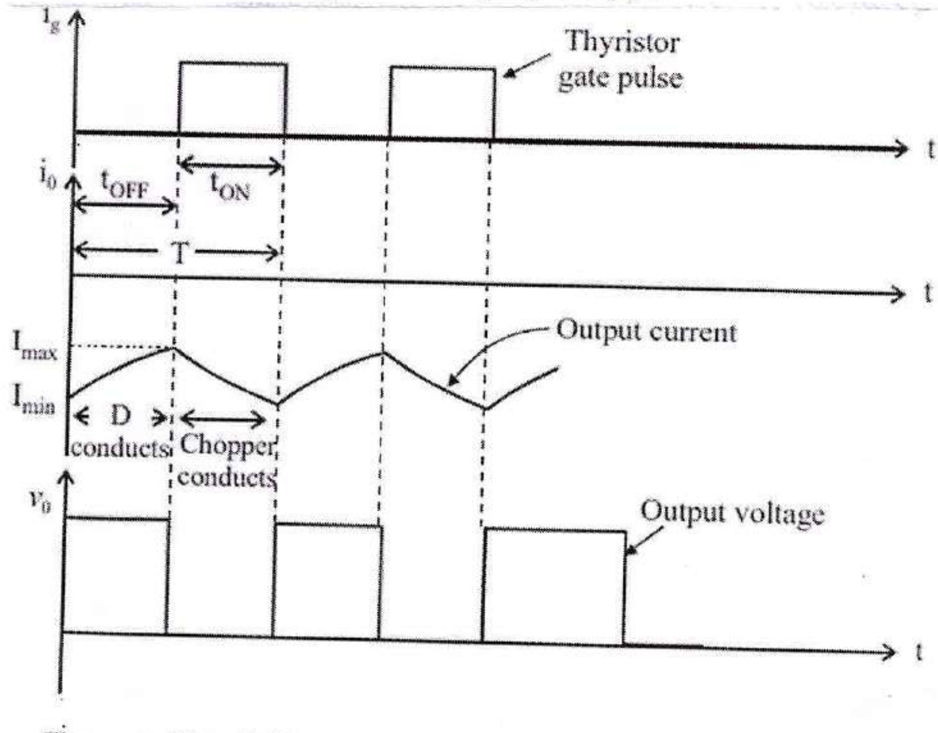


Fig. : Class B Chopper - Output Voltage and Current Waveforms

→ In this chopper large inductor L in series with source voltage Vs essential as shown in fig.

→ When the chopper CH is on the close path for current is input voltage source to the inductor to the chopper and back to the source.

→ During this period the inductor stores large amount of energy for Ton time.

→ When chopper is off, diode D conducts, $V_o = V$ and a part of energy stored in inductor L is returned to the supply.

→ As a result, the voltage across load is not only the source voltage Vs but also the inductor voltage $L \cdot \frac{di}{dt}$ (Discharging of inductor energy) i.e $V_0 = V_S + L.\frac{di}{dt}$

→ Hence, we can say, the output voltage is more than the input voltage V_S.

$V_0 = V_S + e_i$, ... [e_i = inductor stored energy]

i.e $V_0 = V_S + L.\frac{di}{dt}$ ∴ $V_0 > V_S$

where V_S = input voltage.
V_0 = output voltage.

$$V_0 = \frac{V}{\left[1 - \frac{T_{ON}}{T}\right]} = \frac{V}{[1-D]}$$

* 4.4. Step down chopper :-

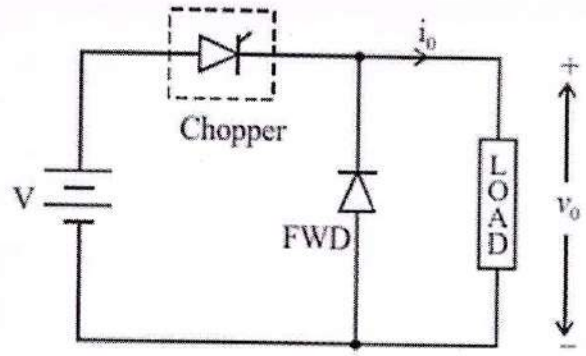


Fig. Class A Chopper

→ Above fig. shows the circuit diagram for step down chopper with R-Load. This chopper circuit is also called as class A chopper.

→ This chopper works in first quadrant. i.e. The output voltage and output current is always positive.

*operation :-

→ At $t = t_0$, the chopper switch is closed. This connects the input dc voltage across the load resistance.

→ Switch S is remains closed for time Ton. The input voltage V_S appears across the load.

→ The load current = $\frac{V}{R}$ and has the same shape as that of load voltage.

→ At $t = DT$, the chopper switch is turned OFF. This will disconnect the input DC source from the load, makes reducing the load voltage and load current to the zero.

→ If the switch remains off for the period of T_{off} time. No output voltage and current will be there at the load.

→ The sum of T_{ON} & T_{off} gives the total time of the chopper.

→ At $t = T$, where, the switch is turned on again and the operation repeats itself.

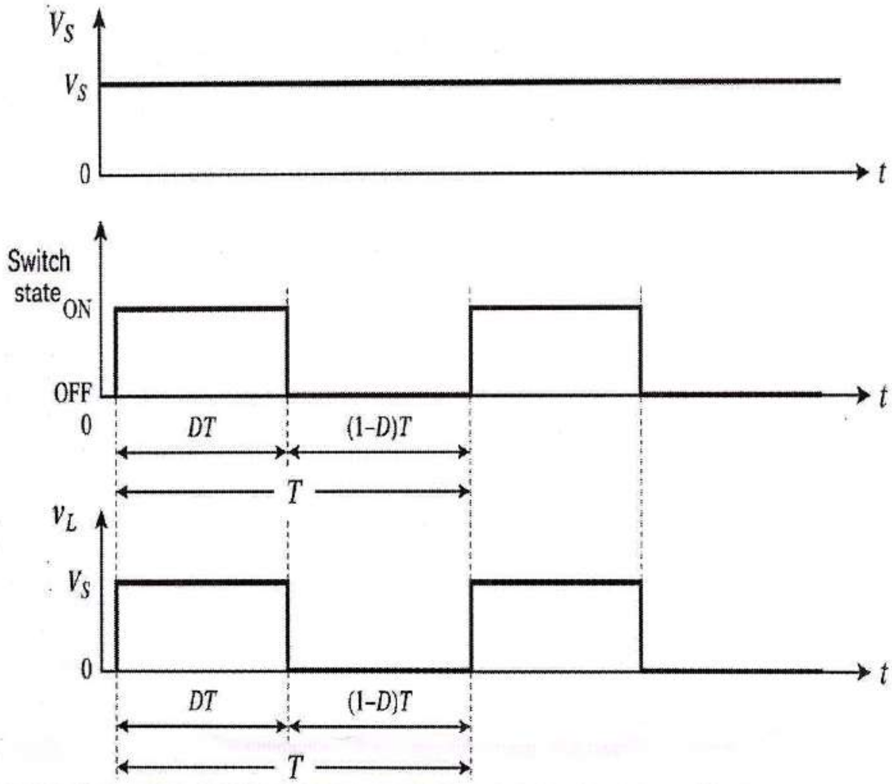


fig. class A chopper o/p waveform.

→ Average output voltage :-

$$V_{LDC} = \frac{1}{T}\int_0^{T_{ON}} V_S \cdot dt.$$

$$= \frac{V_S}{T}[t]_0^{T_{on}} = \frac{V_S}{T}[T_{ON} - 0]$$

$$= \frac{V_S}{T} \cdot T_{on} = \frac{T_{on}}{T} \cdot V_S.$$

$$\therefore V_{LDC} = D \cdot V_S$$

→ Average output current :-

$$I_L = I_o = \frac{V_{LDC}}{R} = \boxed{I_o = \frac{DV_S}{R}}$$

* 4.5 - Buck Boost Chopper :-

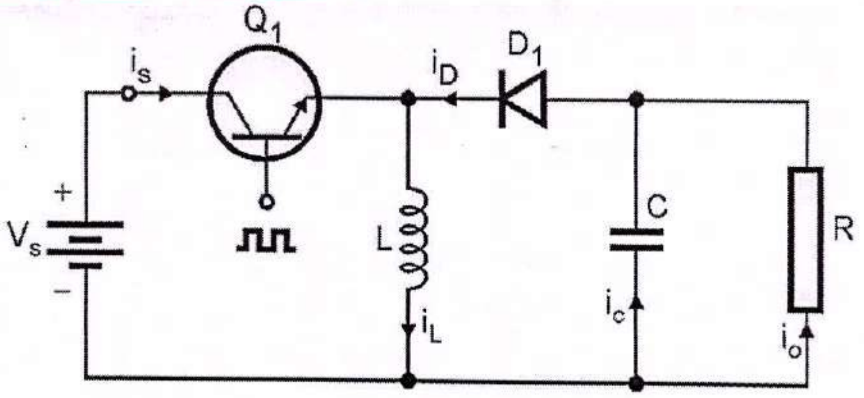
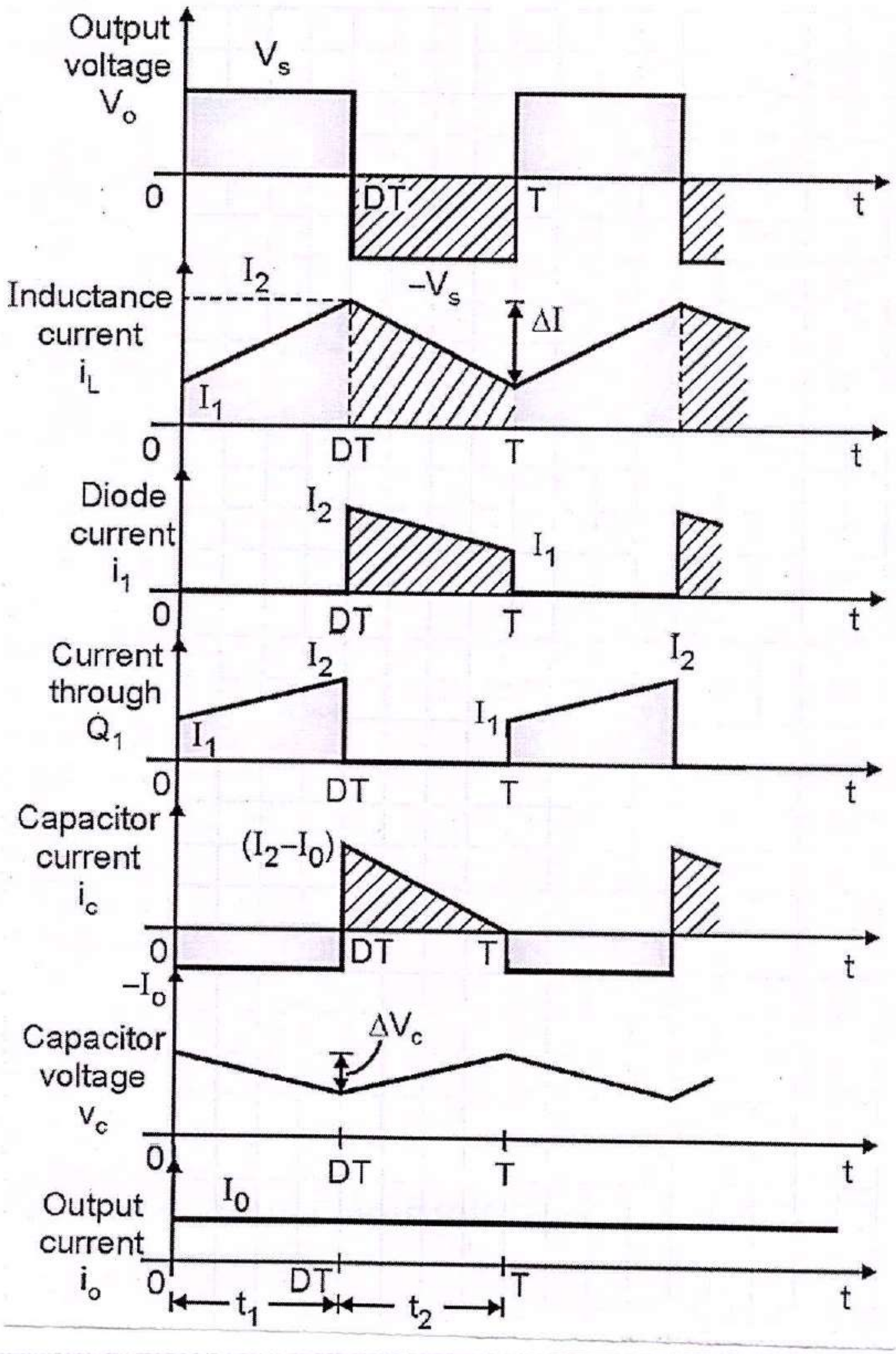


Figure 1: Circuit Diagram of Buck Boost Converter.



→ The circuit diagram of buck-boost chopper is as shown in fig. (1)

→ The buck boost switching regulator is non isolator type converter & also known as inverting chopper.

→ The bulk-boost chopper is a type of flyback converter whose operation is very similar to boost regulator.

→ A bulk boost chopper provides an output voltage that can be either less than or greater than DC input voltage Vs.

→ Hence the name given to it is buck boost. The O/P voltage polarities is opposite to that of I/P voltage. Therefore it is also known as inverting chopper.

→ A power BJT is used as switching device, but it is possible to use either MOSFET or IGBT in the place of power BJT.

* Operation :→ mode-1 [Q_1-ON, D_1-OFF]

→ At T=0, Vs gets connected across the inductance L and the diode D_1 is reverse biased.

→ The inductor current starts increasing linearly from I_1 to I_2.

→ The energy get stored in the inductor during this mode of operation.

* Mode-2 [Q_1-OFF, D_1-ON]

→ Q_1 is turn off at $t = t_1$, the current through inductor L is interupted abruptly.

→ A negative voltage is induced into L which forward biased the diode D_1.

→ The load current starts flowing through D_1, C & L. Note that this current is negative with respect to load.

→ The capacitor charges with it's lower plate +ve w.r.t. upper plate.

→ During this mode the energy stored in L is delivered to the load, and inductor current decreases from I_2 to I_1 linearly until transistor Q_1 is turned on again.

→ This mode comes to an end when Q_1 is turned on again in the next cycle of operation.

* Comparision between Boost & Bulk chopper.

Parameters	Boost	Bulk
1. Range of output voltage	V_s to above V_s	0 to V_s volts
2. Position of chopper switch	In parallel with Load	In series with Load
3. Expression for output voltage	$V_o = \frac{V_s}{(1-D)}$ volts	$V_o = V_s D$ volts
4. Quadrant of operation	2^{nd} quadrant	1^{st} quadrant
5. External inductance	Required for Boosting the output voltage	Not required
6. Application	Voltage Boosters	Motor speed control

* Features of Buck Boost Chopper :-

1) This circuit produces -ve output voltage.
2) It's efficiency is high.
3) Input current is discontinuous.
4) It's easy to implement short circuit protection.
5) High peak current flow through transistor.

* Applications of chopper :-

1) DC motor speed control
2) DC Voltage boosting.
3) Battery operated in electric cars.
4) Battery chargers.
5) Battery operated appliances.

QUESTION BANK/ASSIGNMENT -04

Course & Code: EE-3K
Name of Subject: Fundamentals of Power Electronics

Semester: Third
Subject Code: 313325

Que. No.	Unit 4 DC-DC Converters (10 Marks)	Exam	Marks
1	Define: (i) Duty cycle (ii) Chopping period w.r.t. chopper	W-24	2
2	List any two applications of chopper.	W-24 W-25	2
3	Explain operation of step-up chopper with neat circuit diagram.	W-24	4
4	Describe working of step-down chopper with neat circuit diagram and waveforms. Also write formula for O/P voltage.	W-24 W-25	6
5	State the need for pulse width modulation used in inverter and list its types.	W-25	4
6	Draw and explain the operation for step down chopper.	W-25	4
7	Explain the terms related to Chopper : (i) Turn on period (TOn) (ii) Turn off period (TOff)	S-25	2
8	Define a photovoltaic (PV) cell.	S-25	2
9	Compare Step up and Step down chopper	S-25	2
10	Explain variable frequency control strategy of a chopper along with output waveform	S-25	4
11	Draw the block diagram and explain the operation of a wind power generation system	S-25	4
12	Describe working of step down chopper with neat circuit diagram and waveforms. Also write equation for output voltage.	S-25	4

*****