Lecture-30  Classification of Choppers

7.4 Classification of Choppers
Choppers are classified as
• Class A Chopper
• Class B Chopper
• Class C Chopper
• Class D Chopper
• Class E Chopper

1. Class A Chopper

• When chopper is ON, supply voltage $V$ is connected across the load.
• When chopper is OFF, $v_O = 0$ and the load current continues to flow in the same direction through the FWD.
• The average values of output voltage and current are always positive.
• *Class A Chopper* is a first quadrant chopper.
• *Class A Chopper* is a step-down chopper in which power always flows form source to load.
• It is used to control the speed of dc motor.
• The output current equations obtained in step down chopper with $R-L$ load can be used to study the performance of *Class A Chopper*.
2. Class B Chopper

- When chopper is ON, \( E \) drives a current through \( L \) and \( R \) in a direction opposite to that shown in figure.
- During the ON period of the chopper, the inductance \( L \) stores energy.
- When Chopper is OFF, diode \( D \) conducts, and part of the energy stored in inductor \( L \) is returned to the supply.
- Average output voltage is positive.
- Average output current is negative.
- Therefore \textit{Class B Chopper} operates in second quadrant.
- In this chopper, power flows from load to source.
- \textit{Class B Chopper} is used for regenerative braking of dc motor.
- \textit{Class B Chopper} is a step-up chopper.
(i) Expression for Output Current

During the interval diode 'D' conducts voltage equation is given by

\[ V = \frac{L \, di_o}{dt} + Ri_o + E \]

For the initial condition i.e.,

\[ i_o \quad t = I_{min} \quad \text{at} \quad t = 0 \]

The solution of the above equation is obtained along similar lines as in step-down chopper with R-L load

\[ \therefore \quad i_o \quad t = \frac{V - E}{R} \left( 1 - e^{\frac{R}{L} t} \right) + I_{min} e^{\frac{R}{L} t} \quad 0 < t < t_{OFF} \]

At \( t = t_{OFF} \) \( i_o \quad t = I_{max} \)

\[ I_{max} = \frac{V - E}{R} \left( 1 - e^{\frac{R}{L} t_{OFF}} \right) + I_{min} e^{\frac{R}{L} t_{OFF}} \]

During the interval chopper is ON voltage equation is given by

\[ 0 = \frac{L \, di_o}{dt} + Ri_o + E \]

Redefining the time origin, at \( t = 0 \) \( i_o \quad t = I_{max} \)

The solution for the stated initial condition is

\[ i_o \quad t = I_{max} e^{\frac{R}{L} t} - \frac{E}{R} \left( 1 - e^{\frac{R}{L} t} \right) \quad 0 < t < t_{ON} \]

At \( t = t_{ON} \) \( i_o \quad t = I_{min} \)

\[ \therefore \quad I_{min} = I_{max} e^{\frac{R}{L} t_{ON}} - \frac{E}{R} \left( 1 - e^{\frac{R}{L} t_{ON}} \right) \]
For second quadrant operation, CH2 is ON or D1 conducts.

- When CH1 is ON, the load current is positive.
- The output voltage is equal to ‘V’ & the load receives power from the source.
- When CH1 is turned OFF, energy stored in inductance L forces current to flow through the diode D2 and the output voltage is zero.
  - Current continues to flow in positive direction.
- When CH2 is triggered, the voltage E forces current to flow in opposite direction through L and CH2.
  - The output voltage is zero.
- On turning OFF CH2, the energy stored in the inductance drives current through diode D1 and the supply
  - Output voltage is V, the input current becomes negative and power flows from load to source.
  - Average output voltage is positive
  - Average output current can take both positive and negative values.
  - Choppers CH1 & CH2 should not be turned ON simultaneously as it would result in short circuiting the supply.
  - *Class C Chopper* can be used both for dc motor control and regenerative braking of dc motor.
  - *Class C Chopper* can be used as a step-up or step-down chopper.
• Class D is a two quadrant chopper.

• When both $CH1$ and $CH2$ are triggered simultaneously, the output voltage $vO = V$ and output current flows through the load.

• When $CH1$ and $CH2$ are turned OFF, the load current continues to flow in the same direction through load, $D1$ and $D2$, due to the energy stored in the inductor $L$.

• Output voltage $vO = -V$.

• Average load voltage is positive if chopper ON time is more than the OFF time

• Average output voltage becomes negative if $tON < tOFF$.

• Hence the direction of load current is always positive but load voltage can be positive or negative.
5. Class E Chopper

![Class E Chopper Diagram]

Four Quadrant Operation

- Class E is a four quadrant chopper
- When CH1 and CH4 are triggered, output current \( i_o \) flows in positive direction through CH1 and CH4, and with output voltage \( v_o = V \).
- This gives the first quadrant operation.
- When both CH1 and CH4 are OFF, the energy stored in the inductor L drives \( i_o \) through D2 and D3 in the same direction, but output voltage \( v_o = -V \).
- Therefore the chopper operates in the fourth quadrant.
- When CH2 and CH3 are triggered, the load current \( i_o \) flows in opposite direction & output voltage \( v_o = -V \).
- Since both \( i_o \) and \( v_o \) are negative, the chopper operates in third quadrant.
- When both CH2 and CH3 are OFF, the load current \( i_o \) continues to flow in the same direction D1 and D4 and the output voltage \( v_o = V \).
- Therefore the chopper operates in second quadrant as \( v_o \) is positive but \( i_o \) is negative.
**Effect Of Source & Load Inductance**

- The source inductance should be as small as possible to limit the transient voltage.

- Also source inductance may cause commutation problem for the chopper.

- Usually an input filter is used to overcome the problem of source inductance.

- The load ripple current is inversely proportional to load inductance and chopping frequency.

- Peak load current depends on load inductance.

- To limit the load ripple current, a smoothing inductor is connected in series with the load.