


EEE4227: POWER SYSTEM PROTECTION TERM: MID-TERM



Lecture 04

Switching of circuit breaker



Topics to be covered

- ❖ Resistance switching
- ❖ Current chopping
- ❖ Switching of capacitor bank
- ❖ Switching of unloaded transmission line



Resistance switching

Things to be known-

- ❖ What is resistance switching?
- ❖ What are the objectives?
- ❖ How does it work?
- ❖ How is the connection made?
- ❖ How the value of the resistance is chosen?
- ❖ What are critical damping resistance and opening resistance?

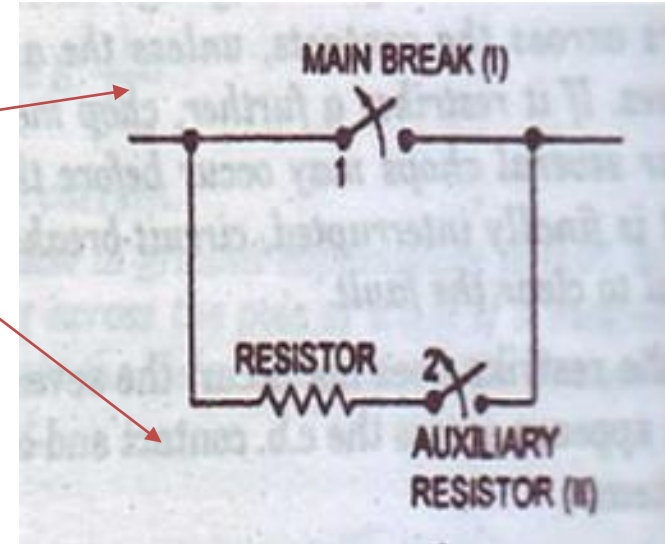
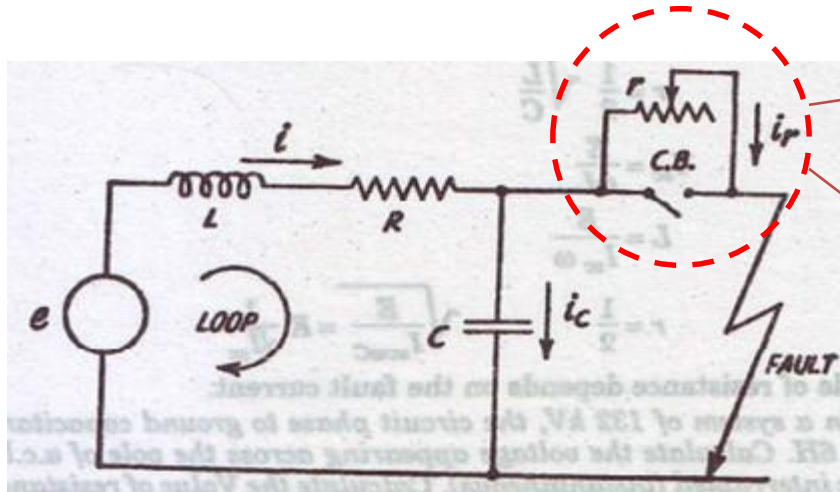


Resistance switching

- ❖ What is resistance switching?
 - ❖ A deliberate connection of a resistance in parallel with the contact space (arc) is called resistance switching. Resistance switching is used in circuit breaker having high post zero resistance of contact space like Air Blast CB.
- ❖ What are the objectives?
 - ❖ It is used to extinguish the frequency of re-striking voltage
 - ❖ Keep R.R.R.V within limit
 - ❖ To divert the arc current
 - ❖ To reduce or damp out the TRV
 - ❖ Interrupting the magnetizing current and capacitive current

Resistance switching

Connection-





Resistance switching

Working process-

- ❖ Opening resistors, also called switching resistor, are fitted in parallel with the main break
- ❖ The resistor is placed in series with the auxiliary resistance switch. The opening resistor comes into the circuit prior to the opening of the main break by closing the resistor switch-2.
- ❖ The resistance switch (ii) may be formed by the moving parts in the interrupter depending upon the design of the breaker.
- ❖ Before opening main contact, auxiliary contact will remain close.
- ❖ During arc extinction process the auxiliary contact will remain close.
- ❖ The auxiliary contact will open with a certain delay after opening of the main contact.



Resistance switching

❖ Magnitude of opening resistance:

$$r = \frac{1}{2} \sqrt{\frac{L}{C}}$$

❖ Critical damping resistance and opening resistance:

- ❖ The value of resistance at which the frequency of T.R.V becomes zero is called the “Critical damping resistance”.
- ❖ The resistance connected in parallel with the circuit breaker for opening operation is called “Opening resistance”.



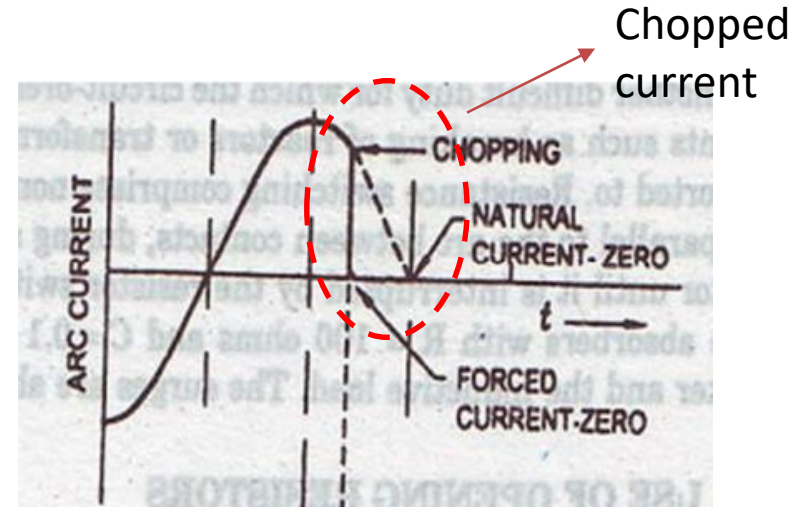
Current chopping

Things to be known-

- ❖ Why happen and what happen?
- ❖ Where does it happen?
- ❖ What is the after effect of current chopping?
- ❖ What is the remedy?

Current chopping

- ❖ Why happen and what happen?
 - ❖ When interrupting low inductive currents such as magnetizing currents of transformer or shunt reactor, the rapid deionization of contact space and blast effect may cause the current to be interrupted before its normal zero. This phenomenon is called current chopping.
 - ❖ In other words-If the fault occurs at such location that system inductance is negligible, the arc will be extinguished as soon as the contact gap is large enough such that the system voltage can not maintain the arc before current crossing natural zero, this occurrence is called current chopping.





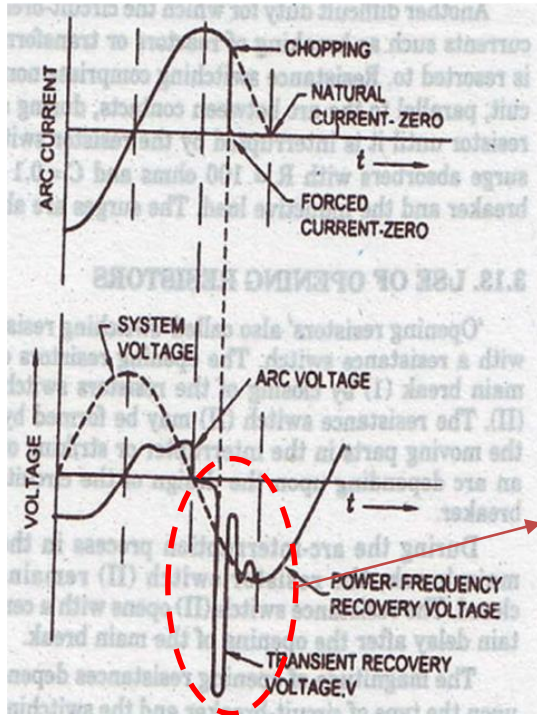
Current chopping

❖ Where does it happen?

- ❖ Current chopping is applicable in infinite bus where equivalent fault path reactance is almost zero.
- ❖ Current Chopping is mainly observed in Vacuum Circuit Breaker and Air Blast Circuit Breaker. There is no such phenomena in Oil Circuit Breaker.

Current chopping

❖ After effect of current chopping-



High
TRV

- ❖ Due to this current chopping transient voltage will be having high R.R.R.V appears across the contacts, unless the arc continues.
- ❖ If a restrike occurs, a further chop may take place or several more chops may occur before the current is finally interrupted. The CB may fail to clear the fault.
- ❖ If restrike does not occur, a severe voltage appears across the CB contact and on the system.
- ❖ The energy stored in the inductor for the value of current I , is diverted to the capacitance at the moment of current interruption-

$$\frac{1}{2}LI^2 = \frac{1}{2}CV^2$$

- ❖ Voltage appearing across contacts of circuit breaker-

$$V = i \sqrt{\frac{L}{C}}$$



Current chopping

❖ Remedy-

❖ Resistance switching might be used to overcome this effect of over voltage due to current chopping.

❖ Amount of resistance to be used-

$$r = \frac{1}{2} \sqrt{\frac{L}{C}}$$



Mathematical problem

Problem 1-

In a system of 132 kV, the phase to ground capacitance is $0.01\mu\text{F}$. The inductance is 6H. Calculate the voltage appearing across the pole of CB if magnetizing current of 10 A is interrupted. Calculate the value of the resistance to be used across the contact gap to eliminate the restriking voltage transient.

Solution:

$$\frac{1}{2}Li^2 = \frac{1}{2}CV^2$$

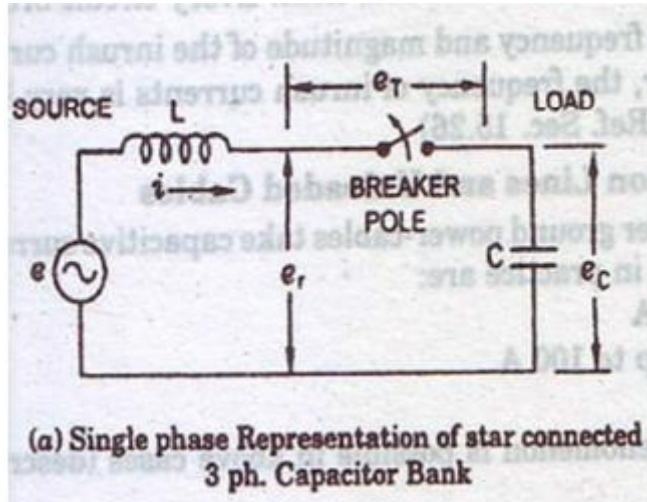
$$V = i\sqrt{\left(\frac{L}{C}\right)} = 10\sqrt{\frac{6}{0.01 \times 10^{-6}}} = 245 \text{ kV}$$

$$r = \frac{1}{2}\sqrt{\left(\frac{L}{C}\right)} = \frac{1}{2} \times \sqrt{\frac{6}{0.01 \times 10^{-6}}} = 12.25 \text{ k}\Omega$$

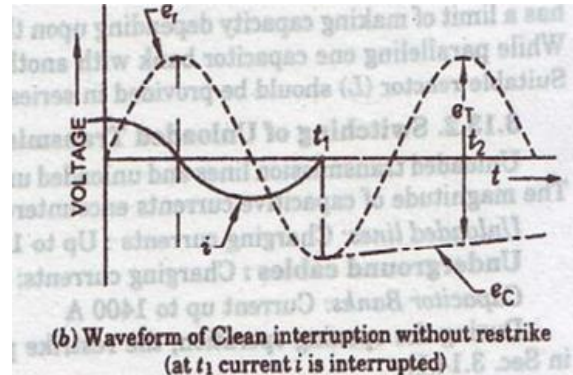
Switching of capacitor bank

- ❖ During opening of a capacitor bank the reignition and restriking can occur in an interrupter.

If we consider the following network-

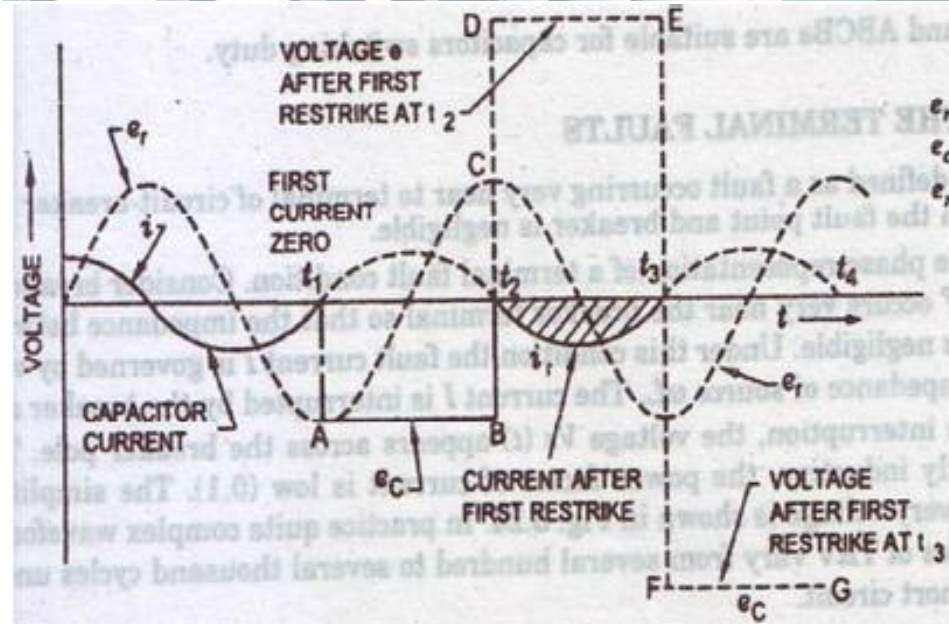


- ❖ The current drawn or supplied to the capacitor is generally of small order and the CB can interrupt such small current invariably at first current zero.



- ❖ Due to 90° phase difference, the voltage across the capacitor is at maximum value (e_c) at this instant t_1 and the capacitor remains charged at this voltage till t_2 .

Switching of capacitor bank



- ❖ After another cycle t_2 , the recovery voltage of approximate magnitude $e_r(\max)$ appears across the CB and the total voltage across the contact gap is the sum of the two voltages.

i.e.

$$e_T = e_r(\max) + e_c$$

- ❖ Thus the transient recovery voltage of the order of 2 E_{\max} might appear across the CB at the instant of t_2 , after the cycle from current zero.
- ❖ After effect:
 - ❖ A restrike may occur and this can cause damage to the system.



Switching of unloaded transmission line

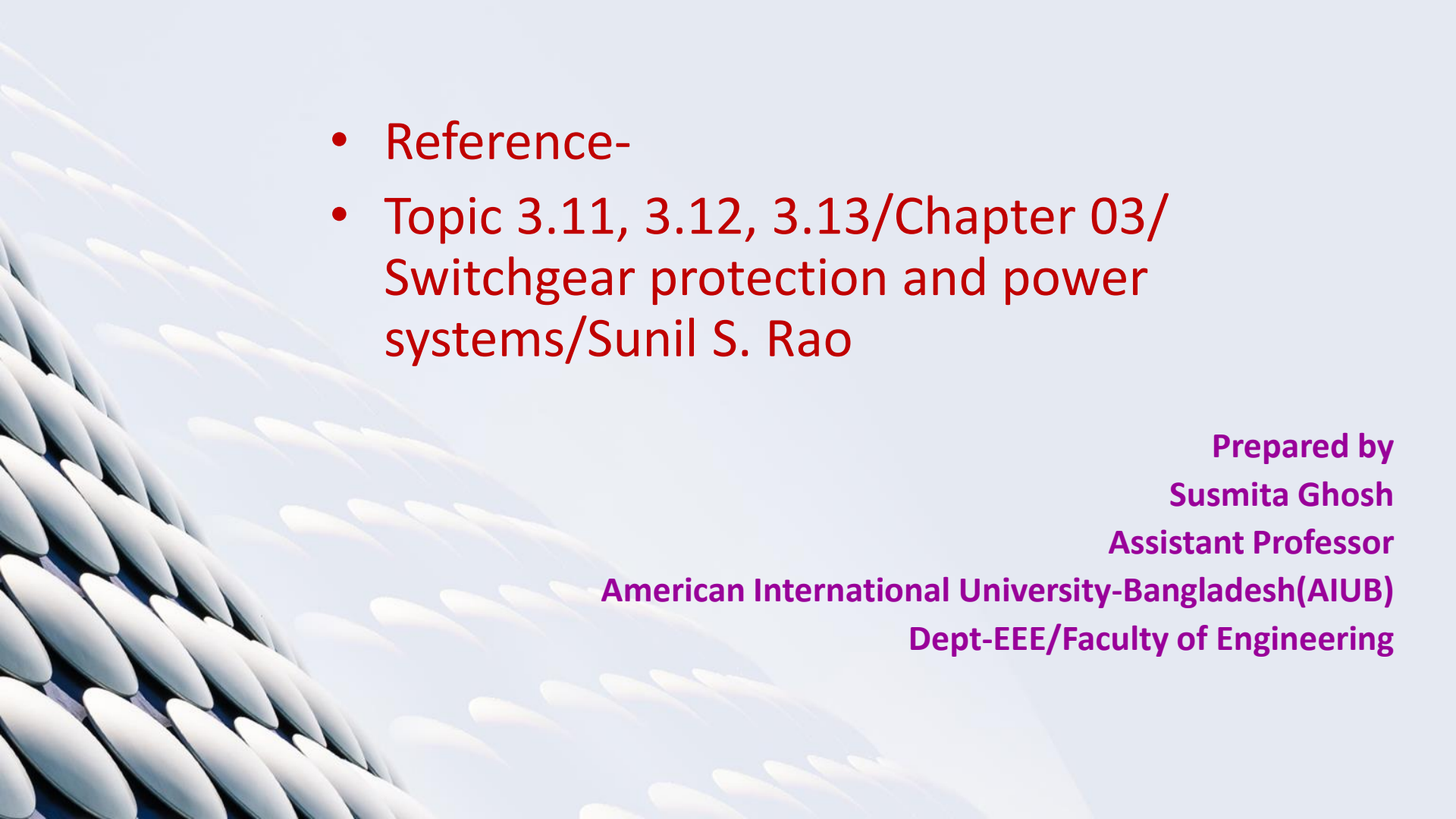
- ❖ When charging current of a line is to be interrupted, the current gets interrupted while the trapped voltage on the line remains leaking away slowly.
- ❖ The same thing will happen here as in the case of a capacitor bank. i.e. after one cycle from the arc interruption when the voltage from the supply side has reached positive peak, the voltage across the contact of the breaker is almost twice the normal value. if the insulation of the breaker gap is insufficient, a restrike occurs.
- ❖ The whole energy $\frac{1}{2}CV^2$ is discharged through arc. This may shatter the arc control devices in the interrupting chamber. Overvoltage of 3.5 times the normal voltage can be developed in the cable.



Switching of unloaded transmission line

❖ Remedies-

- ❖ Earthed neutral
- ❖ Use of lightning arrestor
- ❖ Use of switching resistor

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- Reference-
 - Topic 3.11, 3.12, 3.13/Chapter 03/
Switchgear protection and power
systems/Sunil S. Rao

Prepared by
Susmita Ghosh
Assistant Professor
American International University-Bangladesh(AIUB)
Dept-EEE/Faculty of Engineering