



R. C. Patel College of Engineering & Polytechnic, Shirpur



Department of Electrical Engineering

Name of Subject: - **SWITCHGEAR AND PROTECTION (SGP)**

Course Code: - **315334**

Scheme:- **EE-5K**

Semester:- **Fifth**

Unit No. 01- Fundamentals of Protection

CO1 - Recognize the different types of faults occurring in power system.

Unit	Title	COs	Learning hours	R Level	U Level	A Level	Total Marks
I	Fundamentals of Protection	CO1	8	2	4	6	12

THEORY SYLLABUS CONTENT

- 1.1 Protective system: Necessity, functions and components
- 1.2 Normal and abnormal conditions
- 1.3 Types of faults and their causes
- 1.4 Protection zones and backup protection
- 1.5 Short circuit fault calculations for symmetrical fault on busbars fed through generators
- 1.6 Current Limiting Reactors: Need, types, arrangements, comparative advantages and disadvantages

Subject Incharge
Mr. N. S. Borse

Unit - 1

Fundamentals of Protection (12M)

Introduction: The switching off the certain equipments automatically under fault condition and manually or remotely under normal condition, such equipment by which switching on & off operations are done are known as switchgear.

Necessity of protective system:

- 1) To provide continuous supply for overall growth of country.
- 2) It is essential to protect the entire power system from fault.
- 3) fault must be clear as early as possible to provide protection of the equipment.
- 4) This is achieved by switching off all equipment automatically under fault condition & manually under normal condition.
- 5) The equipment used for these purpose are known as switchgear.

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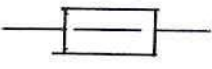
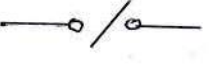
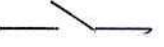
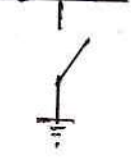
- 1) Ensure safety
- 2) prevent equipment damage
- 3) Maintain system stability.
- 4) Improve reliability & continuity
- 5) Reduce economic loss

* Functions of protective system:

- 1) quick operation: To minimize the damage to faulty part, switchgear must operate as quickly as possible after the occurrence of fault. If fault can pass for more time then there will be considerable damage to generator, transformer & other equipments.
- 2) Complete Reliability: The ability of system to ~~per~~ operate under the predetermined conditions is known as reliability. The protection is ineffectively & become liability without the reliability.
- 3) Discrimination: protective system should be capable of identifying the faulty section i.e. it must be able to discriminate betn faulty section & healthy sections. This will ensure the continuity of supply.
- 4) Provision for instruments: For metering purpose, there should be the provision for connecting instrument transformer to system.

- or
- 1) Detection / identification of fault
 - 2) Isolation of faulty section
 - 3) protection of equipment
 - 4) protection of personnel
 - 5) Maintaining system stability
 - 6) providing alarm & indication
 - 7) Reliable operation.

* components of protective system:-

Sr. No.	switching equipment	Symbol	function
1)	fuse		To protect ckt against over c/n & S.C. c/n
2)	circuit Breaker		To make & break the circuit manually or remotely under normal & fault condition
3)	Isolator		To disconnect the part of system
4)	Earthing switch		To discharge the Vtg after disconnecting line from live section
5)	Protective Relay		Detect fault and send trip signal to circuit breaker.

* Normal condition:

It is the state of network in which c/n flowing through it is rated or below rated path provided, that V_{lrg} & f_{avg} remains constant.

As long as c/n is not diverted to ~~the~~ other path then condition is said to be normal condⁿ.

or When c/n is not diverted to other path then condition is said to be normal condition.

* Abnormal condition:

If defect at any part of the power system due to which current is diverted from desired path with increase in a magnitude is called fault or abnormal condition.

* Types of fault:

Mainly fault are classified into two categories
A) Symmetrical fault
B) Unsymmetrical fault.

A) Symmetrical fault:

- 1) A fault which gives rise of symmetrical fault current (i.e. equal magnitude of fault current with 120° phase displacement) is called as symmetrical fault.
- 2) e.x. when all the three conductors of 3- ϕ line are brought together simultaneously into short circuit condition.
i.e. L-L-L fault, L-L-L-G fault.

B) Unsymmetrical fault:

- 1) A fault which gives rise to unsymmetrical fault current (i.e. with ~~e~~ unequal magnitude of fault ctn with unequal phase displacement) is called as unsymmetrical fault.
- 2) e.x. short circuit betⁿ any two conductor, one conductor with ground, two phase to ground,
i.e. L-L fault, L-G fault, L-L-G fault.

* Causes of Fault:

- 1) Mostly the faults are caused by failure of insulation, which results in short circuits
- 2) Faults are also caused due to breaking of conductor due to excessive heat or mechanical stress.
- 3) Most of the faults on transmission line is caused due to over voltage due to lightning or switching surges.
- 4) ~~Certain~~ Fault occurs due to the poor quality of system components or faulty system design.
- 5) Unbalance in flowing in rotating ~~etc~~ machine, which causes heating of machine.
- 6) Some times fault are occurs due to error in switching operations, testing or maintenance work
- 7) Over voltage and under voltage
- 8) Voltage and current unbalance
- 9) Temperature
- 10) Unstability
- 11) Environmental conditions

* protection Zone:

- 1) Area which is provided with protection system is protection zone.
- 2) protection zone is defined as the part of power system which is protected by a certain protective devices.
- 3) When fault occurs on any protection zone then only the circuit breaker within that zone will be open.

* Backup protection:

- 1) It is a second line of defence.
- 2) If a protection system fail to operate then backup protection is use to provide protection.
- 3) Generally backup protection is standby protection to the primary protection system.

* short circuit KVA calculation;

- 1) The fault occurs on system are most of leads to short circuit condition.
- 2) When such condition is occurs, heavy c/n is start flowing thro the equipment causes damage it.
- 3) Therefore, it is necessary to determine short circuit current under fault condition.
- 4) The choice of apparatus in power system depends on short circuit current.
- 5) The short ckt c/n is limited by impedance of system upto the point of fault.
- 6) for determination of short circuit current, it is important to know the impedance of equipment & ckt in the line of the system.
- 7) Percentage reactance of the equipment depends on it's KVA rating. Equipment used in power system have different ~~HA~~ KVA rating.
- 8) It is necessary to find percentage reactance of all the element on common KVA rating. common KVA rating known as Base KVA.
- 9) Base KVA maybe equal to that of largest plant or equal to total plant capacity.
- 10) Convert all the reactance into base kVA reactance.

$$\% \text{ reactance at base KVA} = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \% \text{ reactance at rated KVA}$$

* Steps for symmetrical fault calculation:

- 1) Draw single line diagram of given network
- 2) Indicate all the rating, voltage & percentage reactance (%X) of each element of network
- 3) select the base KVA
- 4) convert all %X to this base value, using

$$\frac{\%X \text{ at base KVA}}{\text{base KVA}} = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \frac{\%X \text{ at rated KVA}}{\text{rated KVA}}$$

- 5) Draw the reactance diagram corresponding to the single line diagram of network, showing one phase and neutral.
- 6) Indicate % reactance on base KVA in diagram.
- 7) calculate total % reactance upto the fault point.
- 8) Calculate full load c/n corresponding to the selected base KVA & normal system voltage at the fault point.
- 9) calculate short circuit current by

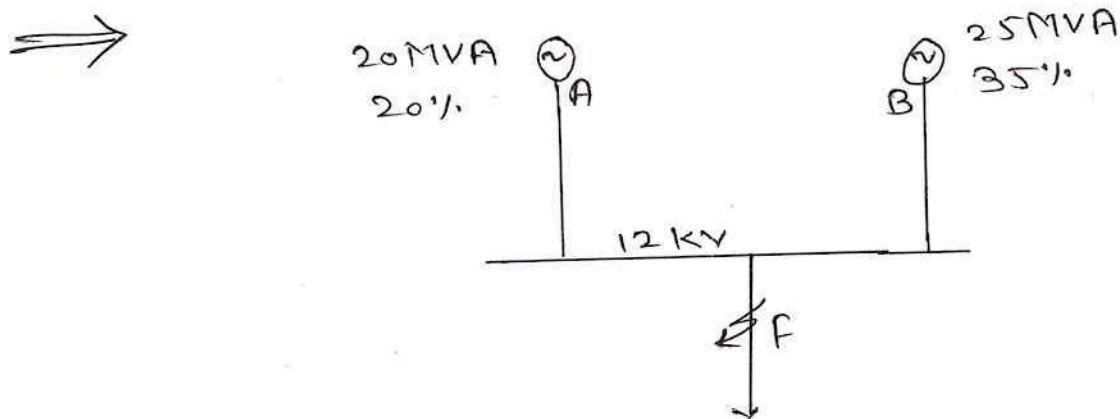
$$I_{sc} = I \times \frac{100}{\%X}$$

- 10) Calculate short circuit ~~kA~~ KVA by

$$S.C. \text{ KVA} = \text{Base KVA} \times \frac{100}{\%X}$$

Problem (1)

Q. Two alternator are connected to bus bar operating at 12 kV. The alternator A is of 20 MVA & having 20 % reactance. Alternator B is of 25 MVA & having 35 % reactance. Find short ckt ~~of~~ current that will flow in complete 3- ϕ s.c. if fault occurs at mid-point of busbar



- consider, Base kVA = 25 MVA = 25000 kVA
- calculate % Reactance of alternator A at the base kVA,

$$\% X_A = \frac{25000}{20000} \times 20$$

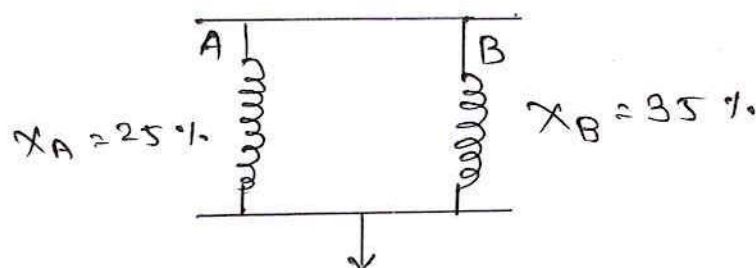
$$= 25 \%$$

% Reactance of Alternator B at the base kVA,

$$\% X_B = \frac{25000}{25000} \times 35$$

$$= 35 \%$$

- Draw reactance diagram



total percentage reactance

$$\begin{aligned} & \text{11 el resi} \\ & R_g = \frac{R_1 R_2}{R_1 + R_2} \end{aligned}$$

$$\%X = \%X_A \text{ parallel to } \%X_B$$

$$= \frac{25 \times 35}{25 + 35} = \cancel{60.4}\%$$

$$\%X = 14.58 \%$$

- calculate full load current by,

$$P = \sqrt{3} \cdot V \cdot I$$

$$I = \frac{P}{\sqrt{3} \times V} = \frac{25000 \times 10^3}{\sqrt{3} \times 12 \times 10^3}$$

$$I_{FL} = 1202.81 \text{ A.}$$

- calculate short circuit current (I_{sc})

$$I_{sc} = I_{FL} \times \frac{100}{\%X}$$

$$= 1202.81 \times \frac{100}{14.58}$$

$$I_{sc} = 8249.7 \text{ A.}$$

- calculate short circuit kVA

$$S.C. \text{ kVA} = \frac{\text{Base}}{\text{kVA}} \times \frac{100}{\%X}$$

$$= 25000 \times 10^3 \times \frac{100}{14.58}$$

$$S.C. \text{ MVA} = 25000 \times \frac{100}{14.58}$$

$$= 171467.7 \text{ MVA}$$

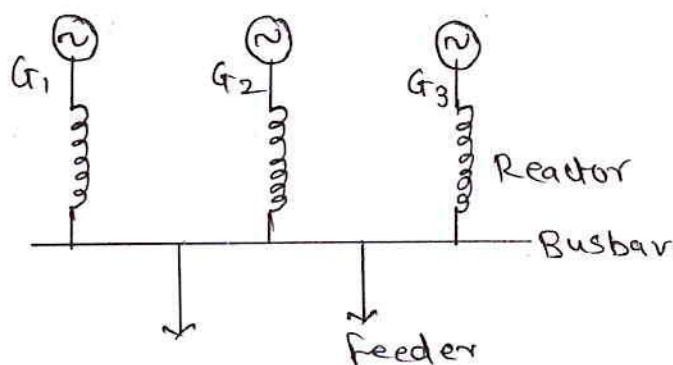
* current Limiting Reactor:

- 1) Reactance of the system under fault condⁿ is low & fault current increases rapidly.
- 2) It is necessary to limit the fault current.
- 3) In order to limit the short circuit c/n in the system additional reactance are connected in series with system at suitable point are known as Reactor.
- 4) Reactor is a coil having number of turns with the large inductance.

Types of reactor: Reactor are classified on the basis of location,

- a) In series with generator
- b) In series with feeder
- c) In series with Busbar.

a) Generator Reactor:

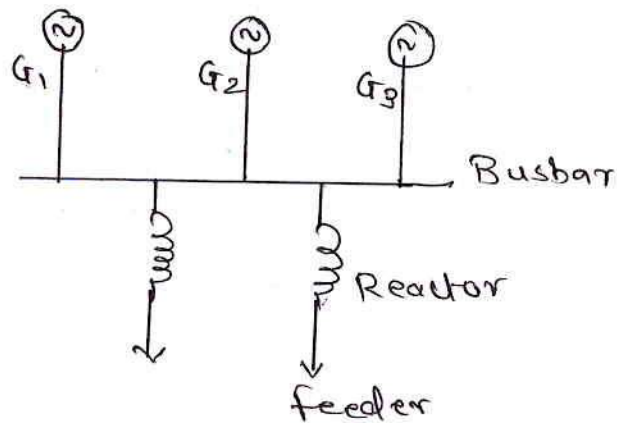


- The reactor are connected in series with generator are known as generator reactor.
- The function of generator reactor is to protect the generator incase of any short ckt. occurs beyond the reactors.

Disadvantages: $\rightarrow$ as the reactor are all time in the ckt, causes vltg & power loss.

2) Faults occurs on busbar, supply continuity is affected.

b) Feeder Reactor:



- The reactor are connected in series with each feeder are known as feeder reactor.

Advantages: 1) fault occur on feeder, busbar voltage is not disturb

2) fault on any one feeder does not affect on affect the other feeder, thus continuity is maintained

Disadvantages: 1) If fault on busbar then no protection provided for generator

2) Reactor all the time in circuit, causes constant vltg & power loss during normal operation

3) Increase in number of generator, size of feeder reactors increases to limit S.C. current.

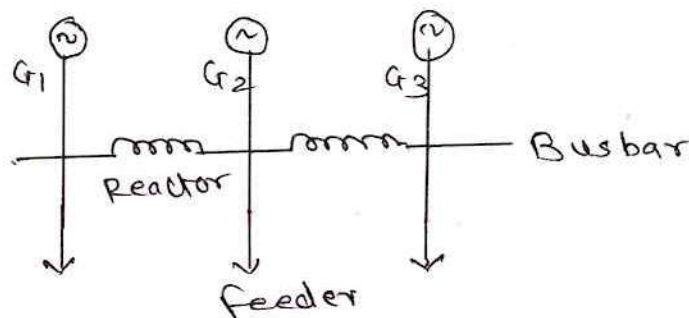
c) Bus bar Reactor:

In above methods, there is considerable vltg drop & power loss in normal condition, this disadvantages overcome as reactor connected with bus bar.

There are two methods of connection

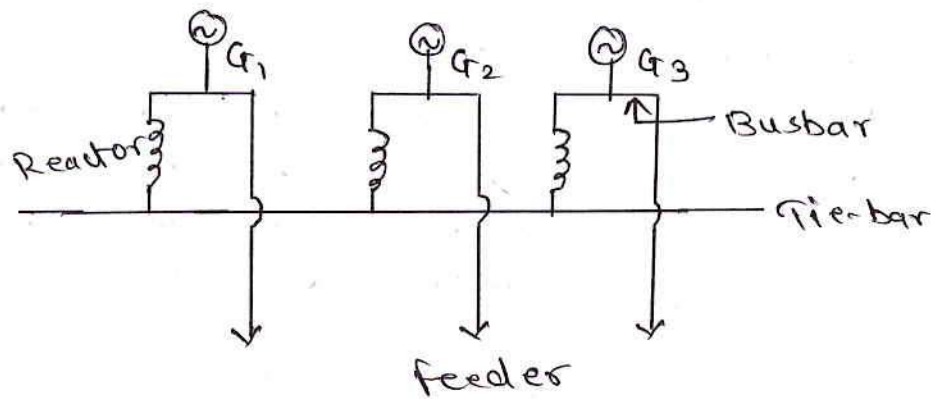
- i) Ring system
- ii) Tie-bar system

i) Ring system?



- In this system, normally one feeder is fed from one generator.
- Under normal operating condition, very small amount of c/n flows thro reactor, therefore vltg drop & power loss in reactor is low.
- In case of fault on any one feeder, only that generator disconnected from supply.
- Therefore heavy c/n & vltg disturbance is reduced.
- These reactor does not provide protection to the generator of faulty section.

ii) Tie-bar system:-



- This is the modification of above system, the vltg regulation betⁿ feeder section is improved than above system.
- In this system, generator are connected to common bus bar through the reactor bus. feeder fed from another side of reactor.

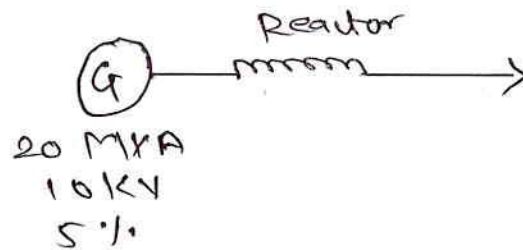
Advantages:- 1) Vltg regulation betⁿ feeder section is improved.

2) If number of sections increases, fault c/n will not exceed which is fixed by size of individual reactor

3) Modification are not required when new generator are being added into system.

Problem (2)

Q. A 3- ϕ , 20 MVA, 10 kV alternator has internal reactance of 5% & negligible resistance. Find the external reactance per phase to be connected in series with the alternator so that steady current on short circuit does not exceed 8 times the full load current.



- Assume base kVA = 20 kVA

$$\% X_A = \frac{\text{Base kVA}}{\text{Rated kVA}} \times \% X_{\text{at rated}}$$

$$= \frac{20,000}{20,000} \times 5 \Rightarrow 5\%$$

- Full load current (I_{FL}) by $P = \sqrt{3} \cdot V \cdot I$.

$$I = \frac{20 \times 10^6}{\sqrt{3} \times 10000}$$
$$= 1154.7 \text{ A}$$

- But in given, $I_{sc} = 8 \times I_{FL}$
 $= 9237.6 \text{ A}$

$\therefore \% X$ from I_{sc}

$$\% X = \frac{I}{I_{sc}} \times 100 = \frac{1154.7}{9237.6} \times 100$$

$$\% X = 12.5$$

$\therefore$ External reactance required

$$X_e = \% X - \% X_A$$
$$= 12.5 - 5$$
$$= 7.5\%$$

Question Bank

- 1) State the need of current limiting reactor
- 2) State the term percentage reactance, state its importance related to actual value of reactance in ohm. Also state the importance of base KVA.
- 3) Explain busbar reactor to control the S.C. current in the power system.
- 4) State the component used in protective system. State the importance of protection zones and backup protection.
- 5) List out any four causes of fault in electrical power system.
- 6) With the help of suitable diagram, state the importance of backup protection.
- 7) Draw neat circuit diagram of feeder reactor and generator reactor.
- 8) State four functions of protective system.
- 9) Explain step for short circuit calculations.
- 10) Define protection zone and backup protection.

- 11) Define normal and abnormal conditions in electrical power system.
- 12) State any four types of faults and their causes in electrical power system.
- 13) Problem on short circuit calculation.
- 14) Problem on calculation of fault current and fault MVA.



Subject Teacher
Mr. N.S. Borse


H.O.D.