Unit 1.

Significance of Switchgear, Protection in Power system.

Electrical energy management system ensures supply of energy to every consumer at all times at rated voltage, rated freq. & specified waveform, at low cost & with minimum environmental degradation. The switchgear, protection and network automation are integral part of modern energy management sys. & national economy.

The electrical energy is supplied to to various consumers located in a vast geographical area with required quality at all times. The service continuity & high quality of power supply ~~is~~ is very imp. Switchgear & protection/control panels are installed at each voltage level at each switching point for,

i) normal routine switching, control and monitoring and,

ii) automatic switching during abnormal, and faulty operating conditions such as short circuit, undervoltage, overloads, etc.

Everyone knows about switches & rewirable fuses. A switch is used for opening & closing an electric circuit and fuse is used for overcurrent protection. Every electric ckt. needs switching & protective device. These devices are developed in various forms.

switchgear is a general term ~~used~~ which covers a wide range of equipment concerned with switching & protection.

The first function mentioned on earlier page is relatively simple as it involves normal currents which are easy to interrupt.

The second function is complex as the fault currents are relatively high & they should be interrupted automatically within a short time of order of few cycles. (1 cycle = 1/50 sec.) There are several types of faults and abnormal conditions. The fault current can damage the equipment and supply installation, if allowed to flow for longer duration.

In order to avoid such a damage, every part of the P.S. is provided with a protective relaying system and an associated switching device. The protective relays are automatic devices which can sense the faults and send the instruction to the associated C.B. to open.

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All equipment associated with the fault clearing process are covered by the term "switchgear". Switchgear is an essential part of a P.S. Switchgear includes switches, fuses, CBs, isolators, ~~fa~~ relays, control panels, lightning arresters, CTs, ~~PTs~~, etc.

Switchgears are necessary at every switching point in AC P.S. Betn the generating station & final load point, there are several voltage levels & fault

levels. Hence in various applications, the requirements of switchgear vary depending upon the location, ratings & switching duty.

Besides the supply n/w, switchgear is necessary in industrial works, industrial projects, domestic & commercial buildings, etc.

Faults and abnormal conditions.

A fault in an electrical equipment is defined as a defect in ~~the~~ its electrical circuit due to which the current is diverted from the intended path. Faults are generally caused by breaking of conductors or failure of insulation. The other causes include mechanical failure, accidents, excessive internal & external stress, etc.

The fault impedance being low, the fault currents are relatively high.

During the faults, the voltages of three phases become unbalanced. The power flow is diverted towards the fault & the supply to the neighbouring zone is affected.

For the purpose of analysis, A.C. fault can be classified as,

- single line to gnd.
- double line to gnd
- three ph. fault.
- three ph. to gnd.
- line to line
- open ckt. fault

The other abnormal conditions are --
- Vltg. & current unbalance
- over voltage
- reversal of power
- power swings
- under frequency
- instability, etc.

Some of the abnormal conditions are not serious enough for tripping of the C.B. In such cases protective relaying is arranged for giving an alarm. In more serious cases, the continuation of abnormal condition can be harmful. In such cases, the faulty part should be disconnected from the system without any delay.

During the fault, the current & voltage undergo a continuous change and the phenomena observed is called "transient phenomena." Transient means which lasts for a short duration of time. The fault current varies with time. During the first one to three cycles, the fault current is high but decreases very rapidly. The zone in which the current is high but decreases rapidly is called sub-transient zone. After the first few cycles, the decrease in the current is less rapid. This region of slow decrease in current is called the transient state. The transient state lasts for several cycles. After the transient

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state, steady state is reached. During the steady state, the rms value of the current remains almost constant.

The C-B. operates during the transient state.

The knowledge of fault currents is necessary for selecting the CBs of adequate rating, designing the sub-station equipment, determining the relay setting etc. The fault calculations provide the information about the fault currents & voltages at various points of the P.S. under diff. fault conditions. The p.u. sys. is normally used for fault calculations.

Fault clearing process

The protective relays are connected in secondary side of CTs and/or PTs. The relays sense the abnormal conditions And close the trip circuit of the associated CB. The CB opens its contacts. An arc is drawn betn the contacts as they separate. The arc is extinguished at a natural current zero of the AC wave by suitable medium & technique. After the final arc extinction & final current zero, a high voltage wave appears across the CB contacts tending to re-establish the arc. This transient voltage wave is called Transient Recovery Voltage (TRV). The TRV comprises a high freq. transient component superimposed on a power freq. recovery voltage.

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Harmful effects of faults--

1. Heavy current due to fault causes excessive heating which can result in fire.
2. Sometimes S.C. current takes the form of an arc that may cause damage to the elements in the P.S.
3. The stability of the P.S. can be adversely affected & even complete shut down of the P.S. may occur.
4. Damage to the other apparatus may be caused due to overheating & due to abnormal mechanical forces set up.

Faults can be minimised to some extent by taking following measures-

1. Improvement in the quality of machines, installation etc.
2. Improvement in system design, correct layout, choice of equipment.
3. Adequate & reliable protection schemes
4. Regular & detailed maintenance by trained personnel.
5. Trained personnel for operation & management of electrical plant.

Importance of Protective Relaying

Inadequate protection can lead to a major fault that could have been avoided. A damaged equipment needs time for repair & replacement. By adequate protection, the damage can be eliminated or minimized.

A fault in the equipment in the P.S. leads to disconnection of supply to a large portion of the system. If the faulty part is quickly disconnected, the damage caused by the fault is minimum and the faulty part can be repaired quickly and the service can be restored without further delay. Thus the protective relaying helps in improving service continuity.

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Protective Zones.

The protective relaying of a P.S. is planned along with the system design. The CBs are located at appropriate points such that any component of the P.S. can be disconnected for usual operation and maintenance requirements and also during abnormal conditions such as short circuits.

Depending upon the rating of the machines, its location, importance, probability of ~~fault~~ faults, etc. each P.S. component is covered by a protective zone. A part of the system protected by a certain protective scheme is called protective zone or zone of protection. The entire P.S. is covered by several protective zones & no part of the sys. is left unprotected.

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Fig. in PPT

Fig. above explains the meaning of protective zones. Each zone covers one or two components of P.S. Neighbouring zones overlap, so that no 'dead spot'

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~~is lesser~~

In the slide shown is R-S protection sch
Here each line is associated with overcurrent relay
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does the required job.

The backup protection is the second line of
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protection is essential for the proper working of
the sys.

Sometimes, the backup protection has low sensitiv
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are left in ~~the~~ the P-S.

The boundary of a protective zone is determined by the location of CTs - Hence CTs are located such that CBs are covered in the protective zones.

The zones can be precisely identified in unit systems. Unit system is one in which the protection responds to faults in the protected zone alone, and it does not respond ~~to~~ to through faults (faults beyond/outside the protected zone).

Primary & Backup Protection

Generally the protection given by the protective devices can be divided into two categories--

1. Primary
2. Backup

Primary protection is the first line of defense. It is the essential protection provided for protecting a P.S. component ensures fast & selective clearing of the fault within the boundaries of the ckt element, that is zone is required to be protected. Pri. protection is provided for each section of an electrical install It is very sensitive and the fault clearing ti is lesser.

In the slide shown is P.S. protection sch Here each line is associated with overcurrent relay If a fault happens on any line, it will be cleared by its relay & CB. This is called as pri. or main protection. The service record of pri. relaying is ver high & well over 90% of all operations are correct But sometimes the faults are not detected by pr relays due to problem in them. In such conditions, secondary or backup protection does the required job.

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The backup protection is the second line of defense which isolates the faulty section in case the main protection fails to operate. Backup protection is essential for the proper working of the sys.

Sometimes, the backup protection has low sensitiv and operated over limited backup zone.

Moreover, when we disconnect the pri. protection for testing or maintenance purpose, the back up protection will act as pri. protection.

The methods of backup protection can be classified as -

1. Relay back up - Same CB is used by both pri. & back up protection, but the protective systems (relays) are different. Separate trip coils may be provided for the same breaker.

2. Breaker back up - Different breakers are provided for main & back up protection.

3. Remote back up - The main & back up protection provided at different stations & are completely independent.

4. Centrally coordinated back up - The system having central control can be provided with centrally controlled back-up. Central control continuously supervises the load flow & frequency in the system. If one of the components in any part of the system fails, the central coordinating station receives information about the abnormal condition. The stored program in the digital computer determines the correct switching operation as per severity of fault. The main protection is at various stations, and

backup protection for all stations is at central control centre.

Desirable Qualities of Protective Relaying

Protective relaying should have certain qualities. They are:-

1. Selectivity & Discrimination:-

Selectivity is a quality of being selective. The protective relaying should select the faulty part of the system & should isolate only that part from the remaining healthy sys.

Discrimination is the act of finding difference between. This quality of relay enables it to distinguish between normal condition and abnormal condition. Also it can discriminate betn abnormal condition within the protective zone and outside the protective zone.

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The protective system should operate only during abnormal condition. Also it should be inoperative & stable during faults beyond its protective zone.

If the protective relaying is not selective and operates for faults beyond its protective zones, a larger portion of the system gets disconnected unnecessarily causing inconvenience.

2. Relay ~~speed~~, time and fault clearing time -

Fault clearing time is the time between the instant of fault and instant of final arc interruption in the CB.

Fault clearing time is the sum of relay time and CB time.

The relay time is the time between the instant of occurance of fault and the instant of closure of ~~CB~~ relay contacts.

The CB time is the total time taken by operating ~~on~~ mechanism to open the CB contacts and the arcing time.

Rapid Fault clearing time is important because,

- it minimises the damage
- it improves the P.S. stability

For this reason, the slow relays & slow CBs should not be preferred.

Though fast fault clearing is desirable, some time lag is purposely provided for following reasons -

- to permit discrimination betn main & backup protection
- to prevent operation of relay during transients, starting currents, permissible load fluctuations, etc.

The relay time of fast relays is of the order of a few ~~eg~~ cycles.

3. Sensitivity -

Sensitivity of a protective scheme refers to the smallest value of actuating quantity at which ~~protecting~~ protection starts operating

in relation with the minimum value of fault current in the protected zone. Sensitivity can be defined in terms of sensitivity factor K_s,

$$K_s = \frac{I_s}{I_o}$$

where, K_s – sensitivity factor
I_s – min short circuit current in the zone
I_o – min operating current of protection

The operation current should not be kept too small for following reasons –
- The protection should no operate on max. loads
- The protection should not operate under through fault condition.

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4. Stability –
Stability is defined as the quality of protective system due to which, the protective sys. remains inoperative & stable under certain conditions such as system disturbance, through faults, transients, etc.

5 Reliability –
Reliability means trustworthiness. The protective relay should not fail to operate in the event of faults in the protected zone. Secondly, there o there should not be

any fault in the components of protective system. Reliability of protective systems is assessed from statistical data.

The protective system is a teamwork of several components. A failure of any one of them can result in failure of the whole system. Hence the basic requirement of reliable protection is reliability of ~~cost~~ each component including CBs, CTs, PTs, Trip circuit, ~~cables~~ batteries, etc.

6. Adequateness –

The protection provided for any machine should be adequate. The adequateness is judged by following aspects –

- rating of protected m/c
- location of ——11——
- probability of abnormal condition due to internal & external causes.
- cost of the machine.
- continuity of supply as affected by failure of machine.

For example, for a low voltage equipment, at the remote end of the system an elaborate and costly protective system is not necessary. ~~Whereas~~ Whereas, for a large machine like generator, a very complex protective scheme is necessary.

The adequateness of protection should be assessed while planning the protection scheme.

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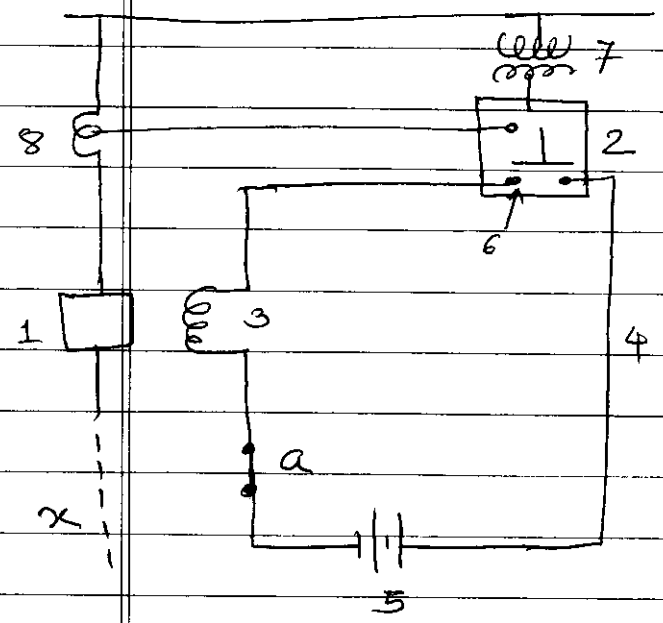
Basic Connection of Trip Circuit of C.B.

Fig. below shows the basic connection of C.B. trip circuit in the most simplified way, for the sake of understanding.



1 - C.B.
2 - Relay
3 - Trip Coil of CB
4 - Trip ckt.
5 - battery
6 - Relay contacts
7 - PT
8 - CT
a - auxiliary switch contacts
x - Protected element

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- The protected element is shown with a dotted line
- When the fault occurs, in the protected ckt, the relay connected to CT & PT actuates and closes its contacts.
- As the trip ckt. is closed, the current flows from the battery
- Due to this current, the trip coil of the CB is energized
- Because of energization of trip coil, the CB operating mechanism

is actuated and it operates for the opening operation, ie, CB opens its contacts & part X is disconnected from rest of the ckt.

Auxiliary switch is an imp. device in the trip Ekt of the CB. It is a multipoint switch (4 point, 6 point, 12 point, 24 point) which is mechanically interlocked with the operating mechanism of the CB. That is, when the CB opens, the auxiliary switch also opens, thereby disconnecting the trip ckt. The current in the trip ckt is interrupted by auxiliary switch & not by protective relay contacts. The relay contacts are light & delicate so that the weight of moving parts is low & consumption of relay is low.

Besides the trip ckt. connections, the indication ckt. (to indicate whether the CB is open or closed), ckt. of interlocking (between breakers, isolaters & other devices) and some control ckts. are also operated by auxiliary switch.