34

Station Bus-Zone Protection

Introduction — Method of Protection — Use of Overcurrent/Impedance relays — Differential protection of buses — High impedance circulating current protection — High impedance voltage differential system — Check feature — Monitoring of Secondary Circuit — Autoreclosure — Interlock overcurrent protection — Bus transfer schemes — Summary.

34.1. INTRODUCTION

Buses are essential in both the power system and industrial switchgear. Busbar protection needs careful attention because,

- — fault level at busbars is very high.
- — the stability of the system is affected by fault in bus zone.
- — the fault on busbar causes discontinuation of power to a large portion of the system.
- — a fault on busbar should be interrupted in shortest possible time, *e.g.*, (60 ms), in order to avoid damage to the installation due to heating of conductors. Internal bus faults are less frequent than line faults. A bus fault tends to be appreciably more severe, both with respect to the safety of personnel, system stability and the damage. A major system shut-down can be caused by the lack of adequate bus protection.

The **desirable features** of bus protection include the following :

- — high speed (less than 3 cycles).
- — stability for external faults.
- — discrimination between fault in its protected section and fault elsewhere.
- — freedom from unwanted operation.
- — no operation due to CT saturation or power swings.
- — separate control of trip circuit of each circuit-breaker.
- — 'main' and 'check' protection to assure the disconnection only when desirable.
- — interlock overcurrent protection to trip generator unit if bus-zone protection operates.
- — non-autoreclosure, no single pole tripping of circuit-breakers for bus-fault.

The bus-zone faults are generally single line to ground faults. However phase to phase faults can occur for medium and mediumhigh voltage buses. The **causes** of bus zone faults can be the following :

- — failure of support insulator resulting in earth fault.
- — flashover across support insulator during overvoltages.
- — heavily polluted insulator causing flashover.
- — failure of connected equipment.
- — earthquake, mechanical damage, etc.

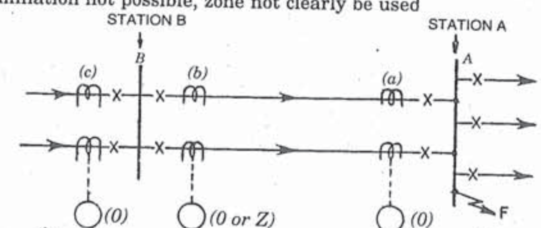
Table 34.1. Methods of Bus Zone Protection

Method	*Particulars*	*Remarks*
Bus-protection by overcurrent relays, of connected circuits.	High-set instantaneous overcurrent relays and earth fault relays, or definite time relays.	Used in distribution system (6—33 kV) with transformers feeder supply to bus bars. Time of the order to 100—400 ms.
Bus-protection by differential protection.	— High impedance circulating current differential protection. — High impedance differential protection based on voltage drop. — Biased differential protection.	Used in major stations. — High impedance connected in series with relay coil to improve stability. — Voltage drop across impedance is measured for discrimination. — Biased coil gives restrain for external faults.
Frame-leakage earthfault protection.	The metal frame of switchgear (lightly insulated from earth) earthed only through a CT. Earth fault relay connected to secondary of the CT.	Earth fault protection of metal clad switchgear (Ref. Sec. 27.10).
Static protection.	Rapid reliable, no problems of CT saturation.	Preferred in modern installations.
Back-up protection	Overcurrent protection or Distance protection.	The zone of primary protection of feeders is extended to cover bus-zone.
Overvoltage protection	Inverse overvoltage relays.	Connected to bus-VT
Surge voltage protection	Surge arresters	Connected phase to ground for line and for transformers

34.2. BUS PROTECTION BY OVERCURRENT RELAYS OF CONNECTED CIRCUITS

The graded overcurrent and earth fault protection on incoming feeders can provide bus-protection. Such bus protection is provided as primary protection only when no other primary bus zone protection is applied. In case other primary (main) bus zone protection is applied, the overcurrent and earth fault protection of incoming circuits act as a back-up protection to the bus-bar. Fig. 34.1 illustrates this principle. The fault on bus *A* can be sensed by overcurrent relay (*O*) of the incoming circuit, and is disconnected by opening of incoming circuit. The overcurrent protection of incoming feeder gives protection to the bus. The disadvantage of such system is :

- — delayed action.
- — disconnection of more circuits in case there are two or more incoming lines.
- — exact discrimination not possible, zone not clearly be used



(*b*)
Overcurrent or impedance protection of incoming lines at remote station (as back-up protection to bus A)

(*a*)
Overcurrent protection of incoming lines as local primary protection to bus 'A')

Fig. 34.1. Bus-protection at station A by (*a*) local overcurrent protection on incoming lines as primary protection. (*c*) Overcurrent or impedance protection at remote station (B) as a back-up to (*b*).

To isolate the bus fault all incoming lines connected to the bus must be opened. Since such disconnection may include generating sources as well as transmission lines, it is important to have correct operation of bus zone protection for internal faults only. Hence bus protection by overcurrent relays of other zones is not a satisfactory solution. It is used only distribution systems. However, such a protection always provides a back-up protection for bus-zone. The primary protection being generally differential protection.

34.3. BUS PROTECTION BY DISTANCE PROTECTION OF INCOMING LINE AS A REMOTE BACK-UP

Referring to Fig. 34.1 again, the Bus *A* is covered in the second step of distance protection *B*. Thus, for a fault *F* on bus *A*, the distance protection *B* will operate. The operating time of the second step can be of the order of 0.4 seconds. In this system also, the protection is slow and there can be unwanted disconnection of all incoming parallel circuits. Distance protection is widely used in protection of transmission lines, hence it is often economical to use the same for bus protection. However, due to the limitations mentioned above, it is not desirable for important buses.

Referring to Fig. 34.1, considered the protection of bus-zone in station *A*.

(*a*) The local overcurrent protection at station *A* provides the primary protection to Bus-Zone *A*.

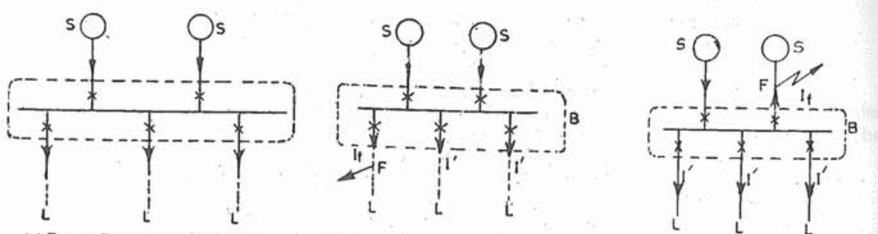
(*b*) The remote overcurrent protection or impedance protection at station *B* provides a back-up protection to bus-zone *A* so that if protection '*a*' fails, protection '*b*' gives a back-up.

(*c*) Local overcurrent protection of incoming lines at station *B* provide primary protection to bus *B*.

34.4. BUS-ZONE PROTECTION BY DIRECTIONAL INTERLOCK

Normally the busbars receive power from *source circuits*, and send power to *load circuits*. For internal faults within the bus-zone, the power will flow towards busbars from all circuits. For external fault in one of the circuits, the power will flow from busbar towards that circuit. Thus, if direction of power flow in each source and load circuit is sensed by respective directional relay, it should be possible to discriminate between internal fault and external fault for Bus-zone protection.

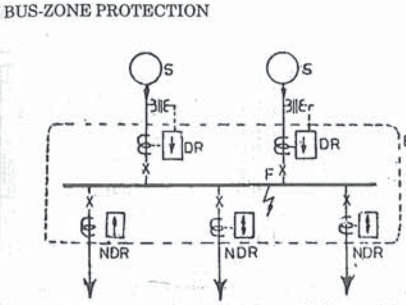
Ref. Fig. 34.2 (*b*) During the external fault on load circuit Direction of power flow from source circuits remains unchanged. However direction of power flow from load circuits is likely to be reversed. For a severe fault, the overcurrent relays of load side may operate but the directional relays on source circuit do not operate.



(*a*) Power flow-normal condition. (*b*) External fault in load circuit. (*c*) External fault in source circuit.
Fig. 34.2. Bus-zone protection Directional Interlock. (Ref. *d* for symbols)

For external fault on source circuit the directional relay of that circuit will operate. (Fig. 34.2 *c*) and current flowing in load circuit is substantially reduced.

The principle of *Directional Comparison* was adopted in earlier schemes. The scheme comprised directional relays in source circuits and overcurrent relays in load circuits. The contacts of these



B : Buszone
S : Source
L : Load
F : Fault
I_f : Fault current
I': Reduced load current
DR : Directional overcurrent relay
NDR : Non-directional overcurrent relay

(*d*) Internal fault.
Fig. 34.2. Bus-zone protection by directional interlock.

relays are suitably *interlocked* in such a way that if power flows towards the busbar from the source circuit and the current flowing away from the busbars (*I'*) is sufficiently low, the entire bus-zone protection acts and all the circuit-breakers on load side and source-side are tripped. (Fig. 34.2. *c*)

The contact system of such protection is quite complex. Hence such system was adopted only for earth fault protection. The system was too slow. Hence the directional comparison scheme is not preferred for busbars of high fault power and important sub-stations. It is used in distribution systems to achieve selectivity in bus-zone protection. (Ref. Sec. 43.8 for static Directional Comparison).

Phase Comparison Protection

In this method, two instantaneous relays are connected in rectifier bridge circuit. During internal faults, the contacts of both relays close and the trip circuit is closed. For external faults, the contacts of both relays do not close and trip circuit is not energized. This type of protection was tried during 1940's.

34.5. BUS-ZONE PROTECTION BY DIFFERENTIAL PRINCIPLE

The 'differential protection' is a wide term applied to protections which responds to vector difference between two or more similar electrical quantities. A simple method of bus bar protection is by comparing the vector-sum of currents entering and leaving the bus-zone. *In absence of internal fault,* the vector sum of currents entering the bus-zone is equal to the vector sum of currents leaving the bus-zone. In other words,

$$\Sigma I_n = \bar{I}_1 + \bar{I}_2 + \bar{I}_3 + \dots \bar{I}_n = 0$$

where $\bar{I}_1, \bar{I}_2 \dots \bar{I}_n$ etc. are currents in the circuits connected to the bus bar (Ref. Fig. 34.3).

During internal fault the vector sum of currents in the circuits connected to bus bar is equal to fault current, *i.e.*

$$\bar{I}_1 + \bar{I}_2 + \bar{I}_3 + \bar{I}_4 + \dots \bar{I}_n = \bar{I}_f$$

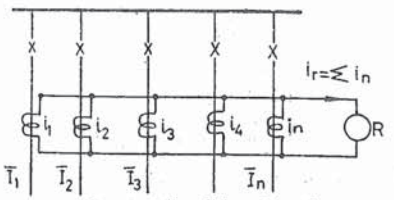
The out of balance current flows through the fault.

In differential protection of busbar, CT's are connected is each circuit connected to busbar. The secondaries of these CT's are connected in parallel with due considerations to polarity and phase.

The relay coil is connected across the pilot wires in such a way that the summation current of secondaries passes through the relay.

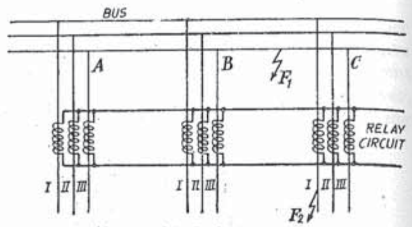
Referring to Fig. 34.3, the normal condition or external fault, the summation of secondary currents $\Sigma i_n = 0$.

For internal faults $\Sigma i_n \neq 0$.



For normal condition : Σ in = 0
for internal fault : Σ in $\neq$ 0

Fig. 34.3. Bus-zone protection based on differential principle. (Single line diagram).

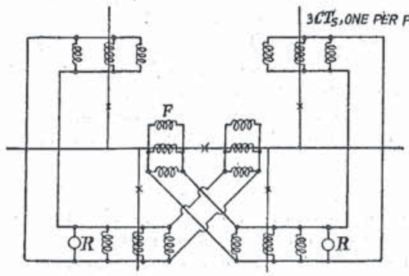


I, II, III : Phases of $A/B/C$
A, B, C : Incoming/Outgoing Circuits.
F_2 : External fault F_1 : Internal fault.

Fig. 34.4. Connections of CT's for simple earth fault protection.

The Σi_n flows through relay coil.

CT connections depend upon type of protection desired. For example, in simple earth fault protection scheme the CT connections are as follows (Fig. 34.4). The primaries are connected in each incoming and outgoing circuit (one in each phase). The secondaries are connected in parallel and are connected to the measuring relay. For external fault (F_2), or for healthy conditions, the sum of currents entering the bus is equal to sum of current leaving the bus, (Kirchhof's Law). Hence the secondary currents sum up to zero and relay gets no current.



R = high impedance relay.

Fig. 34.5. Earth fault protection of sectionalised bus by circulating current differential.

The connections of CT's for protection of sectionalized bus are illustrated in Fig. 34.5. The CT's are arranged on both sides of busbar sectionalizing breaker so the protections overlap and no 'dead holes' are left in the busbar.

To obtain phase fault and earth fault protection, the four pilot wire scheme (Fig. 34.6) can be employed.

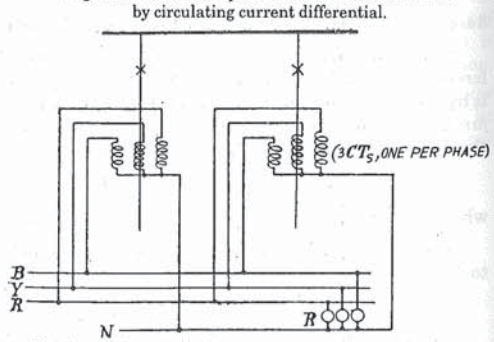


Fig. 34.6. Pilot wire scheme for protection against phase faults and earth faults.

In the schemes described above, stabilising resistors are used in series with instantaneous measuring element in order to avoid wrong operation of the relay on spill currents. The spill current can be caused by saturation of a CT.

34.6. PROBLEMS IN BUS-ZONE DIFFERENTIAL PROTECTION

The basic problems are the following :

— Large number of circuits, different current levels for different circuits for external faults.

— Saturation of CT cores due to d.c. component and a.c. component in short circuit current. The saturation introduces ratio-error.

— Sectionalising of bus makes the circuit complicated.

— Settings of relays need a change with large load changes.

34.7. SELECTION OF CTS FOR BUS-ZONE PROTECTION

In the protective schemes requiring close balance of secondary currents in various phase circuits, the CT ratio error should be low. The CTs for such protection should be selected such that the balance is maintained for maximum through fault current in primary of any of the phase under transient conditions and also steady conditions.

The large power system have a large X/R ratio. The d.c. component of fault current decays slowly and the CT cores remain saturated for longer duration (5 to 30 ms) since CT core gets magnetized with unidirectional component of fault current. The residual flux present in the core has a direction which depends on the instantaneous condition at the end of earlier switching. The residual flux also depends upon the remanance of CT core material. The total flux is caused by d.c. component, residual flux, a.c. component. If residual flux is in same direction as that of d.c. component, the core may saturate and harmonic spill current will flow through the relay coil.

The following aspects are considered while selecting CT's for differential bus-zone protection.

1. Use of identical CT's in which saturation occurs at large short-circuit currents.
2. Increasing CT ratio 'n' (Ref. Sec. 35.10) so as to decrease. The ratio of Ish/I'_1, Ish is fault current and I_1, is rated primary current.
3. Selecting as large core as economically and technically suitable thereby increasing limiting value of secondary current (i_n) for saturation of core.
4. Reducing the burden on CT's by using pilot wires of lesser resistance, static relays.
5. Use of intermediate CTs (Ref. Fig. 35.11) with gapped core.

When an internal bus fault occurs, the magnitude of the fault current and its d.c. component may be so large that the line CTs (current transformers) saturate within 2.4 ms. In such cases it is essential that the bus differential protection operates and seals in within 2 ms, *i.e.*, prior to the saturation of the line CT's. This high speed is necessary because when a line CT saturates its output e.m.f. tends to drop to zero.

In the event of an external fault, just outside the line CT's of a relatively small feeder, the fault current may in an extreme case be as large as 500 times the rating of the feeder. The lines CT's of the faulty feeder are then likely to saturate at higher speed. If the remanance in the core from a previous fault has an unfavourable polarity. The response of the restraint circuit to the differential relay must therefore be of atleast the same high speed as that of the operating circuit, if mal-operation is to be avoided.

Ref. Ch. 35 for stability of differential protection, the spill current through the relay should be less than the relay setting. *i.e.*

$$Ieb—Iea < Ir.$$

The CT error is minimum if the core does not get saturated for flux of the order of X/R times the normal current flux where X/R are ratios of equivalent reactance and resistance on source side of the fault. For large generating systems, equivalent X/R of source upto the fault point can be high as 20. Therefore, to avoid saturation, very large cores would be necessary. This makes the CT's prohibitively uneconomical. The CT's can be designed for higher value of a.c. component but they cannot transform the d.c. component.

Simple circulating current differential systems with low impedance attracted armature relay (operating time of 0.1 sec.) can operate during external faults due to the above mentioned reason. Induction type IDMT relays with time setting of several seconds do not operate for external faults because the transient component varnishes within a few hundred milliseconds and the relay gets reset. However, IDMT relays are slow and are not preferred for protection of buszone. However, busbar differential protection with IDMT relay unit was superior to the simple overcurrent protection described in sec. 34.2.

To overcome the problem of CT saturation and to improve the stability without intentional time delay, various modifications have been developed. These include the following :

— biased differential buszone protection.
— high impedance bus-zone protection.
— high impedance voltage differential bus-zone protection.

Note : 'High Impedance' refers to relay unit. This is quite different from impedance protection of transmission lines.

The principles of these schemes are described below :

34.8. BIASED DIFFERENTIAL BUS-ZONE PROTECTION

In biased differential protection, the relay element has a restraining coil in addition to the operating coil. The circulating current flows through the restraining coil and the spill current flows through the operating coil. For external faults, the restraining current is more and the relay does not operate. For internal faults operating current is more and the relay operates.

34.9. HIGH IMPEDANCE CIRCULATING CURRENT DIFFERENTIAL BUS-ZONE PROTECTION

By inserting a resistance in series with relay operating coil of differential protection the spill current through the relay can be reduced. The resistance connected in series is called stabilizing resistance. The relay is called *High Impedance Relay.* High impedance differential protection is an alternative to biased differential protection. It is simpler and effective. The basic principle of high impedance protection is same as that of differential protection. The circuit connections are also similar. (Figs. 34.4, 34.5, 34.6 etc.).

High impedance relay unit is the attracted armature type instantaneous relay with setting of the order of 25 mA. A relatively high stabilizing resistance is connected in series.

In some high impedance relays a capacitor and resistances are connected in series with the relay operating coils. The capacitors blacks the d.c. component and makes the relay insensitive to the d.c. component in short-circuit current.

34.10. HIGH IMPEDANCE DIFFERENTIAL PROTECTION BASED ON VOLTAGE DROP (Fig. 34.8)

This relaying is based on differential principle. During normal condition the vector sum of currents in the arrays is zero. During fault on bus-bar the balance is disturbed. The out of balance current I flows through the high impedance Z_H producing voltage drop V_{ZH}. This voltage is supplied to relay measuring unit M through transformer T. During faults on bus-bars the trip circuits of all the circuit breakers are closed by the same relay, thereby the bus-bar is rapidly disconnected.

If the relay measuring system responds to voltage drop instead of circulating current, the saturation of one of the CT's does not cause instability of protection.

During external fault, one of the CT's may saturate. Thereby its output will be reduced and the vector sum of secondary currents will not be zero. The resultant unbalance current would cause the relay operation. However the voltage drop across the CT under saturated condition will be limited by the IR drop in its secondary, IR drop in leads which is relatively low. However, the voltage drop across secondary of CT does not increase but approaches to zero under saturated condition. Hence V_{ZH} reduces.

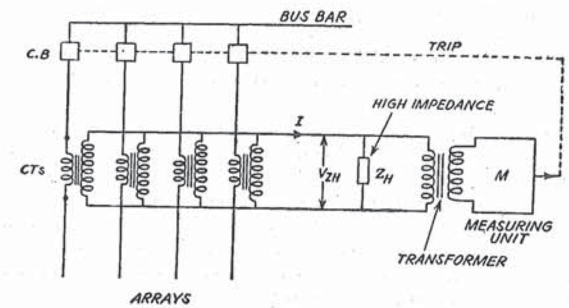


Fig. 34.7. High impedance bus-bar protection based on voltage drop.
Courtesy : Brown Boveri, Switzerland.

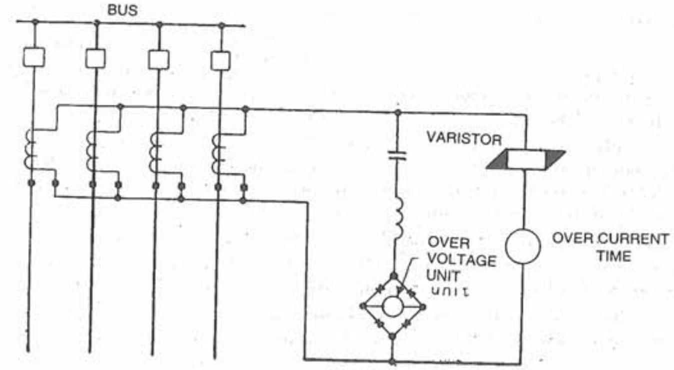


Fig. 34.8. Schematic of the High Impedance Voltage Differential System.
Courtesy : Westinghouse Electric Corporation (U.S.A).

However, during internal bus-fault all the secondaries will be feeding the current into the impedance Z_H. Hence voltage drop V_{ZH} increases and this increase is sensed by the relay.

34.11. HIGH IMPEDANCE-VOLTAGE DIFFERENTIAL SYSTEM

This scheme utilizes conventional CT's but the problem of saturation is avoided by high impedance relay unit. The basic principle is similar to that described in sec. 34.10. Resistance of the CT secondary circuits must be kept low. This limits the applications to bushing type current transformers only. These have a toroidally wound core where the leakage reactance is negligible, and hence, secondary impedance is low. It is further important to have all current transformers with the same ratio, to operate the bushings on full tap and to parallel the several transformers in the switchgear as near as possible to the current transformers. Auxiliaries to match ratios should not be used as all transformers must have the same ratios.

The discrimination between internal and external faults is made by the magnitude of the voltage applied to the relay. On internal faults, the voltage is high, approaching the open circuit voltage of the current transformer secondaries. Thus, the current transformer, leads and relay are subjected to voltages of the order of 1000 volts. On external faults, the voltage should be low and will be essentially zero unless unequal saturation of the current transformers exists. The maximum voltage occurs when one CT is completely saturated, with no saturation in the others, and will be the resistance drop of the theoretical secondary current through the leads and secondary winding of the saturated current transformer. The relay is set by calculating this maximum possible voltage and applying a safety factor of 2/1.

The relay unit shown in Fig. 34.8 is an instantaneous voltage plunger unit operated through a full-wave rectifier. The capacitance and inductance tune the circuit to fundamental frequency to reduce response to all harmonics. The impedance of this branch is around 3000 ohms, which means that CT secondaries and relay are subject to high voltages on a bus fault.

A thyrite voltage limiting unit is connected in parallel with the relay to limit the voltage to about 1500 volts. In series with this is an instantaneous overcurrent unit, set to operate at very high internal fault magnitudes. It must be set high to avoid operation on external faults. In addition contacts on the auxiliary tripping relay are used to short circuit all current transformers after the relay trips. The time of operation of the relay is three to six cycles for the voltage unit one to three cycles for the overcurrent unit.

34.12. CHECK FEATURES IN BUS PROTECTION

The methods of applying additional relays for increasing the reliability of bus differential schemes vary appreciably from one manufacturer to another. The unwanted opening of a CT secondary circuit has been of particular concern, because this may lead to maloperation of a bus protection during normal service condition resulting in embarrassment.

Some supply companies permit tripping of the bus zone protection if a CT secondary is open-circuited, whereas other companies require an alarm only, without tripping. The method which is adopted depends is often on scheme reliability of CT secondary wiring and whether tripping can be accepted from the system stability point of view.

Bus zone protection schemes should not be allowed to trip by the closing of one relay contact only. Two separately actuated relays, with their contacts in series are then required to operate simultaneously in order to achieve tripping. This is called check feature.

Since maloperation of a bus differential protection may lead to a complete system shut-down, the alarm relay is also normally arranged to disconnect the main tripping relay after a time delay of about 5 seconds.

It is desirable to be doubly sure about the fault in bus zone before de-energising the bus section. With this understanding, check feature is generally added to the differential bus protection in important and large power stations. Both main protection and check-feature can be of circulating current type or check feature can be overcurrent starter. Check feature operates from separate current transformers. The trip-circuit is controlled by connecting the main protection contacts and check feature contacts in series. Thereby, the trip circuit is closed only if check feature and main protection operate.

34.13. LOCATION OF CT'S

The location of CT's determines the boundaries of protective zones. CT's for bus protection are generally arranged such that circuit breakers are also covered by the protection and are not left unprotected. (Ref. Sec. 25.3).

34.14. MONITORING OF SECONDARY CIRCUITS

CT secondaries should not be open circuited, and there should be no open circuit in continuity of pilots. For this purpose an alarm relay is provided to monitor the continuity. If discontinuity occurs, the alarm relay gets actuated and gives and alarm, after some delay it may trip the bus circuit-breakers.

34.15. INTERLOCKED OVERCURRENT PROTECTION FOR BUSZONE AND GENERATOR-UNIT ZONE

The boundaries of the bus-zone protection and protection of generator-transformer are determined by location of CT's of respective differential protections. (Ref. Fig. 34.9).

The busbar protection will act for faults, internal to bus-zone such as a fault shown in the figure.

The unit protection will act for faults upto the CT of the unit protection.

What happens for a fault between the circuit-breaker and the CT of unit protection? This fault (shown in the figure) comes in bus-zone protection and is detected by Bus-zone unit. Therefore bus zone protection will act and trip the circuit-breaker.

However the fault is not internal to the unit protection zone and will not cause shut down of the generator transformer unit. The generator will therefore keep on feeding the fault. A special overcurrent relay called Interlocked overcurrent relay (IOC) is used in such cases to trip the generator unit.

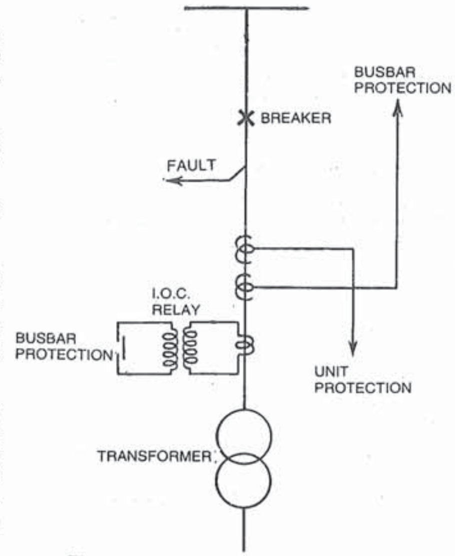


Fig. 34.9. Interlocked overcurrent protection.

Interlocked overcurrent protection is employed for discrimination between a busbar fault and a fault between CT and circuit-breaker.

Interlocked overcurrent relay (IOC) is energized by a set of CT's as shown in Fig. 34.9. Usually it is an induction disc relay with summation input winding and separately brought out secondary winding or shading winding. (Ref. Fig. 34.10).

For a fault shown in the figure, the busbar protection acts and closes the circuit of tuned shading coil of IOC relay. Thereby the IOC relay acts, and closes the contacts of generator trip circuit. (Ref. Fig. 34.9 and 34.10).

For faults in generator-transformer unit zone, the unit protection will act. The fault is external to bus-zone. The bus-zone protection is not likely to operate.

The interlocked overcurrent relay (Fig. 34.10) acts when the operating coil current increases above pick-up value and the circuit of tuned shading coil is completed by operation

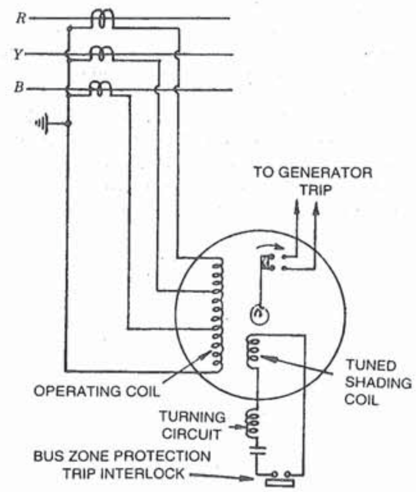


Fig. 34.10. Interlocked overcurrent relay.

of busbar protection trip interlock. (The interlock contacts of shading coil circuit are closed as the bus-bar protection operates.). Hence two conditions are to be satisfied :

— generator should supply overcurrent
— busbar protection should act.

Timelag of 0.1 to 0.5 sec may be provided when these two conditions are satisfied, the IOC relay of that generator-unit operates and closes trip circuit of that generator. Thereby the generator unit stops feeding the fault.

34.16. NON-AUTO RECLOSURE AND SIMULTANEOUS THREE-POLE OPERATION

The fault in bus-zone or generator transformer units are generally non-transient. After opening of circuit breaker, the cause of fault should be ascertained. Auto reclosure should not be carried out. Reapplication of voltage will cause further damage. Hence the generator-transformer protection and bus-zone protection should be non-autoreclosing type.

Single pole operation of circuit breaker for single line to ground fault bus zone will lead to unbalanced loads on generator units leading to damage of rotors (Ref. Ch. 33). Hence the protection and circuit breakers associated with bus-zone protection and generator protection must be arranged for

— non-autoreclosure
— three phase simultaneous operation

The autoreclosure and single pole operation is restricted to protection of overhead transmission lines, with stability considerations.

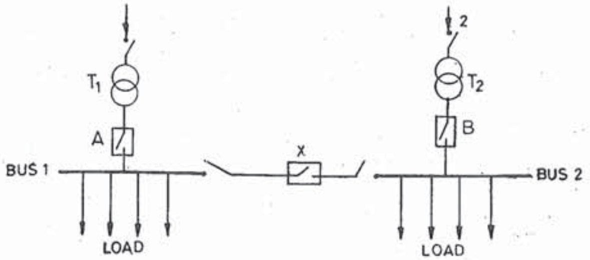
34.17. BUS TRANSFER SCHEMES FOR AUXILIARY SWITCHGEAR AND INDUSTRIAL SWITCHGEAR

In continuous process installations, momentary power failure can lead to serious losses or damage. If the incoming power is interrupted due to tripping incoming circuit-breaker, there should be a very quick (within few cycles) change over or transfer of load to an alternate source. Such schemes are known as Bus-transfer schemes or Transfer Schemes.

Manual transfer schemes are used in non-critical processes where shut down of several minutes can be allowed. The operator closes and trips circuit-breakers in a specific sequence so as to transfer the load to alternate source.

Ref. Fig. 34.11, in the event of loss of supply from circuit 1, circuit-breaker *A* is opened and circuit-breaker *X* closed, so as to transfer the load from source 1 to source 2.

In automatic bus-transfer schemes, the process of opening and closing the circuit-breakers *A*/*X*/*B* is much faster and automatic. The scheme depends upon the type of load, whether transformers T_1 and T_2 can be momentarily paralleled, timing of bus transfer etc.



(When supply voltage 1 is lost, breaker 1 is opened and breaker *X* closed to transfer the load from source 1 to source 2).
Fig. 34.11. Explaining bus transfer scheme.

Consider lighting load on the buses. The breakers *A* and *B* can be kept closed and *X* open. During failure of supply 1, breaker *A* is opened and *X* closed with a slight delay or simultaneously. The lighting load does not give current inrush and consequent voltage dip on the transformer bus.

If the loads are motors ; the transfer scheme becomes complicated because, as the breaker *A* is opened, the motors on bus 1, keep on rotating and generate voltage. This residual voltage makes faster closing of circuit-breaker *X* harmful. Such closing will cause high inrush currents. The breaker *X* should be closed when motor is still running and residual voltage has reduced. This will reduce the inrush currents sufficient magnitude.

Bus-transfer schemes are used in auxiliary switchgear in thermal power station (Ref. Sec. 17.3).

SUMMARY

Bus-zone protection should be stable for external faults and very fast for internal faults.

Circuit-breakers in incoming and outgoing circuits are also covered by bus zone protection.

In smaller installations, overcurrent or impedance protection of incoming circuits gives protection to busbars. However such system is slow and does not give satisfactory discrimination.

Differential protection is used as a primary bus-zone protection. CT's are connected in incoming and outgoing circuits. The high-impedance relay or biased differential relay is connected such that out of balance current during internal faults, flows through the relay.

The high impedance relay is an overcurrent relay with a series resistance. Such a relay remains stable against spill currents due to external faults or CT inaccuracies.

Selection of CT's is very important and difficult task in bus-zone differential protection.

Interlocked overcurrent protection is necessary to trip generator unit during a busbar fault.

The main protection is supplemented by check-feature in order to be doubly sure about bus-zone fault.

There is also a provision for monitoring CT secondary circuits.

Frame leakage protection is sometimes employed for metal enclosed switchgear.

HRC fuses are used for low voltage bus protection.

QUESTIONS

1. Discuss one of the following :-
   (*a*) Interlocked overcurrent protection.
   (*b*) Differential protection of bus-bars.
2. Explain the necessity of check feature in bus bar protection
3. Describe the earth fault protection of sectionalised bus.
4. Write short note on any one :
   (*a*) High impedance differential protection of bus.
   (*b*) Location of CT's with respect to CB location.
5. Discuss the protection of a bus bar as back-up from other station apparatus.
6. What are the likely causes of failures of outdoor bus bars?
7. How are the outdoor bus bars protected against lightning ?
8. Give a sketch of differential protection of station-bus.
9. Discuss the effect of short-circuits currents on CT performance. How does it effect the differential protection. What are the possible modifications to overcome the problem?
10. Describe the principle of high impedance differential protection based on voltage drop.
11. Describe the principle of bus bar protection based on voltage differential systems. How does it respond to saturation of CT's for external fault and internal fault?
12. Describe the interlocked overcurrent protection between generator and busbar. Explain its necessity.