

Module 7 : Out of Step Protection

Lecture 26 : Power Swing Detection, Blocking and Out-of-Step Relays

Objectives

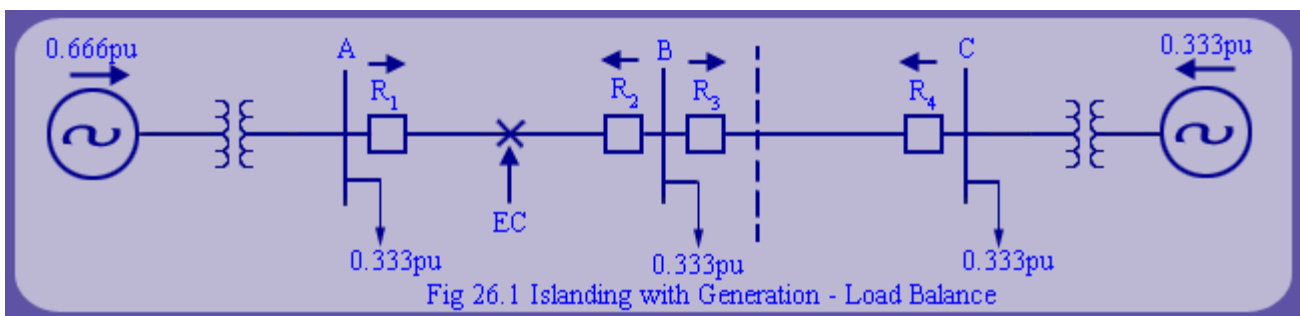
In this lecture, we will

- Discuss the effect of unstable power swings in a two area system.
- Explain different methods for detecting power swings such as:
 - 1) Out of step blocking relays.
 - 2) Out of step tripping relays.
- Discuss the guidelines for setting out of step blocking relays and out of step tripping relays.

Introduction

We have so far seen that power swings can be classified as either stable or unstable. Basically, a relay which is expected to issue trip decision on a fault should not pick up on a swing (either stable or unstable). When a power swing is a consequence of stable disturbance, unwanted line tripping can aggravate disturbance and lead to instability. On the other hand, when the power swing is a consequence of disturbance, classified as unstable, then interconnected operation of the system is simply not possible.

This implies that the system has to be split into multiple islands each of which can have independent existence i.e. each island can maintain synchronism of generators. Now to achieve stable operation in each island, generator load balance has to be ascertained. If an island has excess generation, it should be shelved and similarly if an island has excess load then load shedding is required. Load shedding is usually initiated by underfrequency relays, as excess load tends to pull the frequency down. However, to minimize the loss of service to consumers, the boundary of islands has to be selected carefully. To illustrate this point, consider a simple two area system as shown in fig 26.1.



Now consequent to a disturbance, let the system be unstable and let the location of electrical center be on line AB. Recall that at the electrical center, voltage zero point is created when the two generators are out of step. Alternatively, electrical center appears when the power swing intersects the transmission line characteristics. This implies that relays located at the two ends of the transmission line, perceive the out of step condition as a bolted three phase fault on the transmission line. Consequently, relays R₁ and R₂ will issue a trip decision, thereby islanding the system. Now, the generator at A ($P_G = 0.666$ pu) islands with a load of 0.333pu and generator at B ($P_G = 0.333$ pu) islands with a load of 0.666pu. The resulting loss of load is 0.333pu in island B and loss of generation in island A is 0.333pu.

However, if we had islanded the system by tripping line BC then an ideal solution of zero load or generation shedding would have been achieved. This suggests that during unstable swings, we should block the relays from operation. Consequently, more selective tripping can be initiated to achieve the

desirable islands. We now, arrive at a thumb rule that under out of step condition, distance relays should be blocked from operation on swings.

Introduction (contd..)

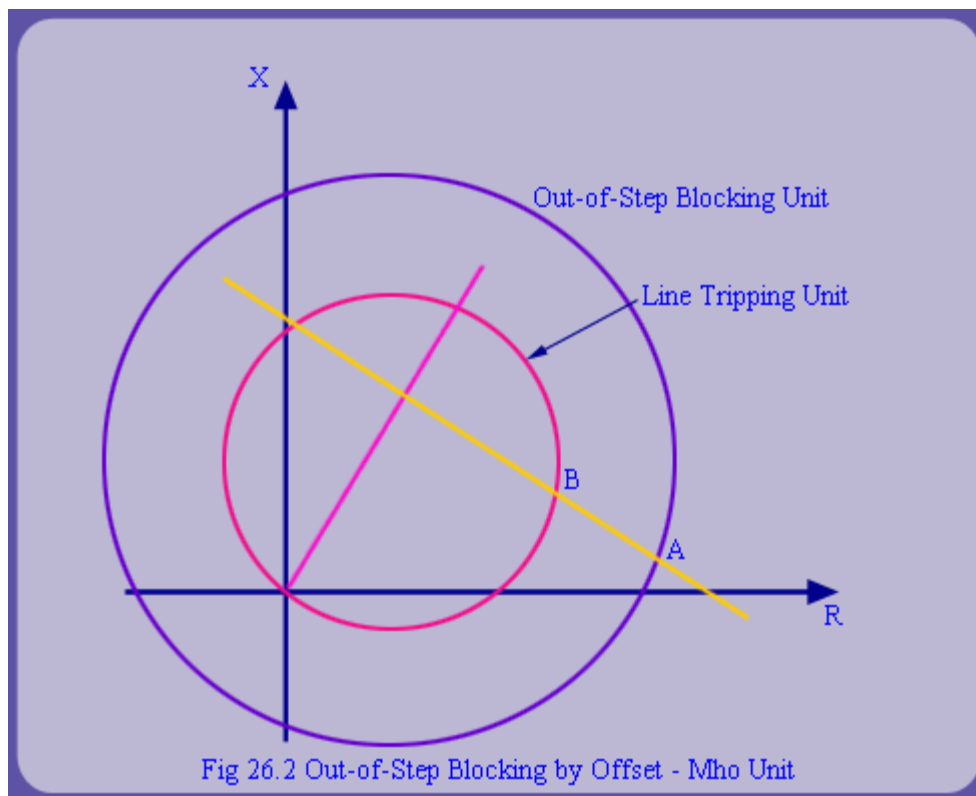
Let us now re-look, the case of a stable power swing. The resulting movement of apparent impedance seen by relay on the R-X plane may encroach Z_2 or Z_3 of a relay. If the swing stays inside the zone for long enough time, then the relay will issue a trip command. This is also not desirable. Hence, even under stable swings, the distance relays have to be blocked from tripping.

To conclude this discussion, it is not desirable for distance relay to trip on power swing whether the swing is stable or not. This implies that distance relay should be equipped with swing detection and blocking mechanism. This aspect is elaborated in this lecture.

Power Swing Detection

The basic idea in detecting a power swing is that change in apparent impedance seen by relay (ΔZ) due to fault occurrence is instantaneous. In contrast, the change in ΔZ due to power swing is a slow process limited by inertia of generators. Thus, this time discrimination can be used to distinguish swings from faults.

Out-of-Step Blocking Relays



Based upon the above principle, fig 26.2 shows out of step blocking scheme with an offset Mho unit.

The out-of-step blocking unit is similar to the Mho unit. It is a circle concentric to mho - tripping characteristic but it has a larger radius. In other words, the tripping characteristic is embedded inside the blocking unit. This ascertains that any power swing which enters tripping will first enter the out-of-step blocking characteristic. For the swing locus, shown in fig 26.2, this happens at point A. After a short while, it reaches the tripping characteristics and enters tripping region at point B.

Introduction (contd..)

Out-of-Step Blocking Relays (contd..)

If the transit time, from point A to B is larger than a preset interval of the order of few cycles, the out of step blocking unit will operate auxiliary relays to block tripping of phase

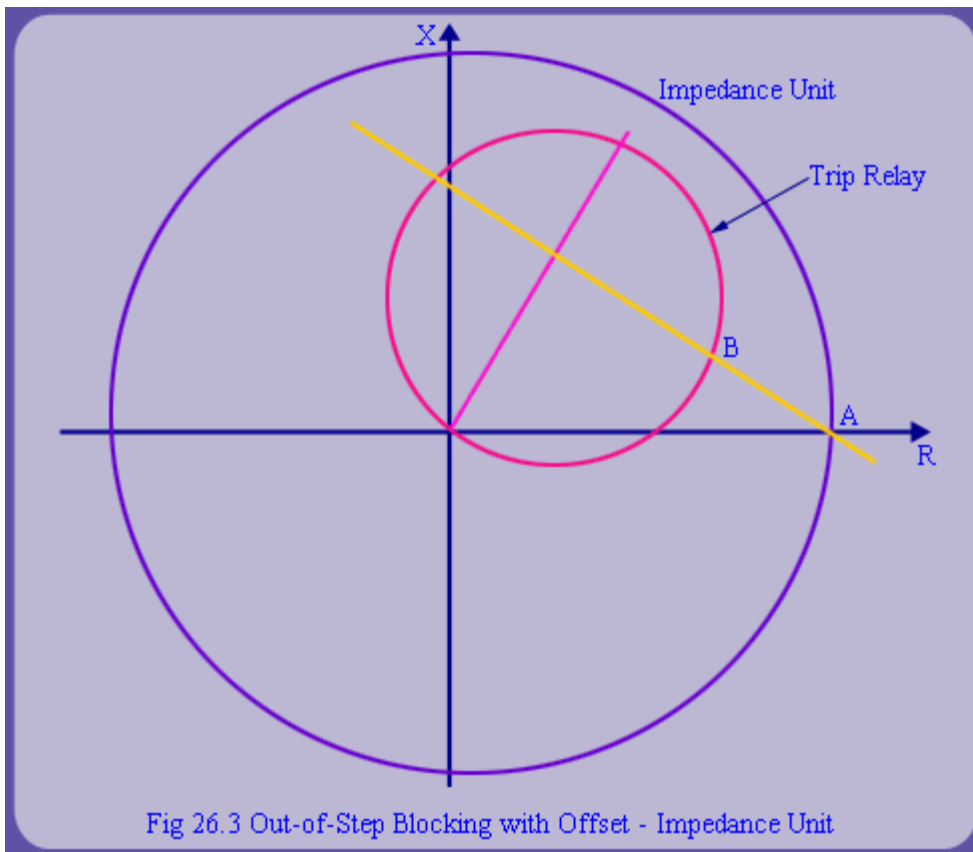


Fig 26.3 Out-of-Step Blocking with Offset - Impedance Unit

relays.

In case, only blocking of reclosing is required, the blocking unit will restrain automatic reclosing equipment. An out of step blocking scheme with an impedance starting relay having similar principle as described above is shown in fig 26.3.

Out-of-Step Tripping Relay

Out-of-Step tripping relay is required for controlled separation of the system into multiple islands. Out of step condition is detected by out of step tripping relay which detects presence of an unstable power swing. It then proceeds to either trip the local breaker or issue a transfer trip signal to remote breaker to separate the system at a more convenient point.

Introduction (contd..)

Out-of-Step Tripping Relay (contd..)

As shown in fig 26.4 the basic scheme consists of two modified reactance type units whose characteristics are set parallel to the system impedance characteristic SR with one on each side of line SR.

Consider an unstable swing PQ as shown in fig 26.2. It will cross the first unit at point X when it will pick up, and emerge from relay characteristic at X' . The two crossing, indicate that swing has crossed the impedance characteristic and hence is a loss of synchronism

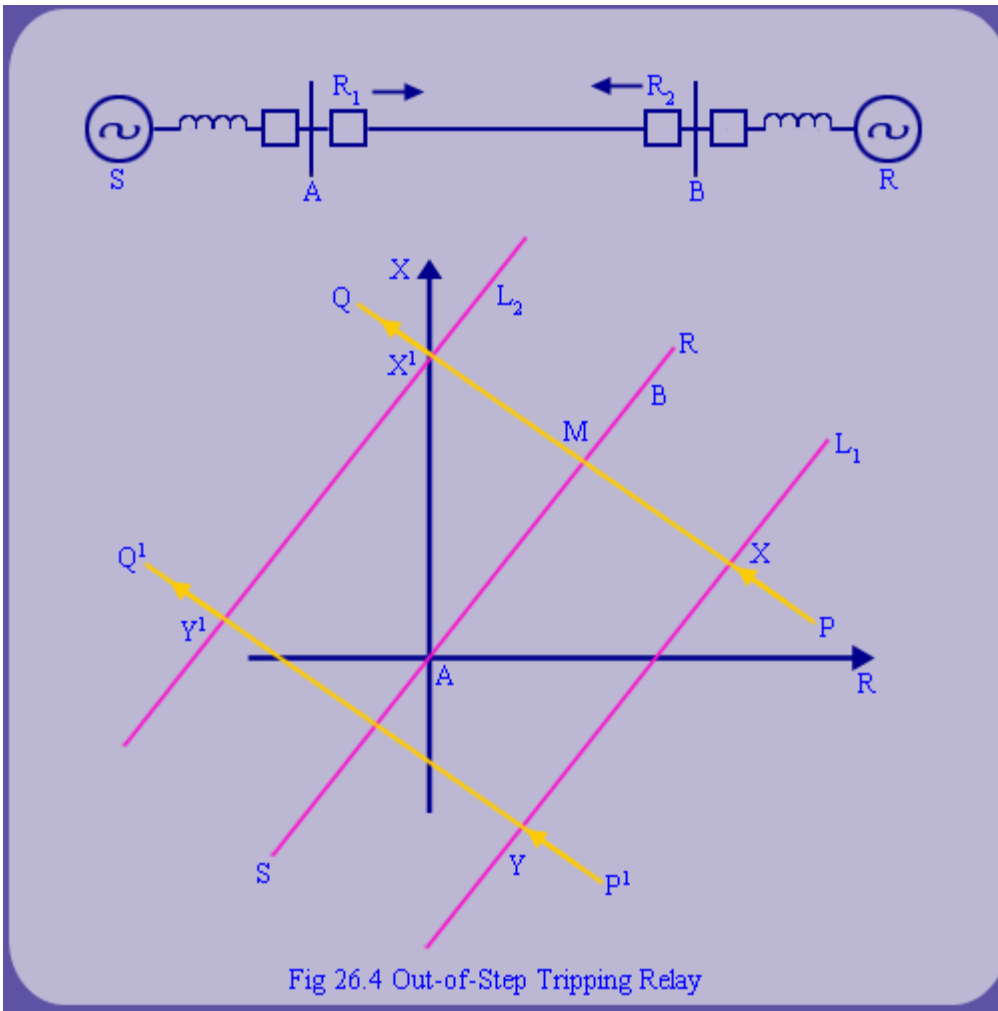


Fig 26.4 Out-of-Step Tripping Relay

condition, leading to an out of step trip decision. The scheme will equally well pick up if swing movement was from Q to P. The scheme would also pick up even if the unstable swing is behind the relay.

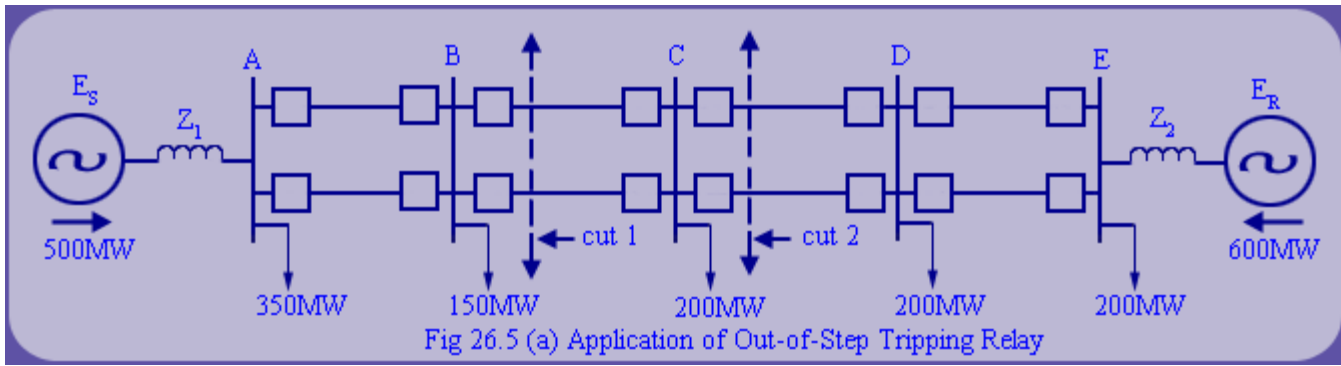
For example, a swing from P' to Q' . If the swing is far away from the line characteristic, then currents involved are quite less. It is then associated with very low power reversals which do not characterize unstable swings. To prevent tripping on such condition, the out of step relay is supervised by an overcurrent relay unit. If the current signal is below a preset value, it inhibits the tripping signal of out of step relay.

Introduction (contd..)

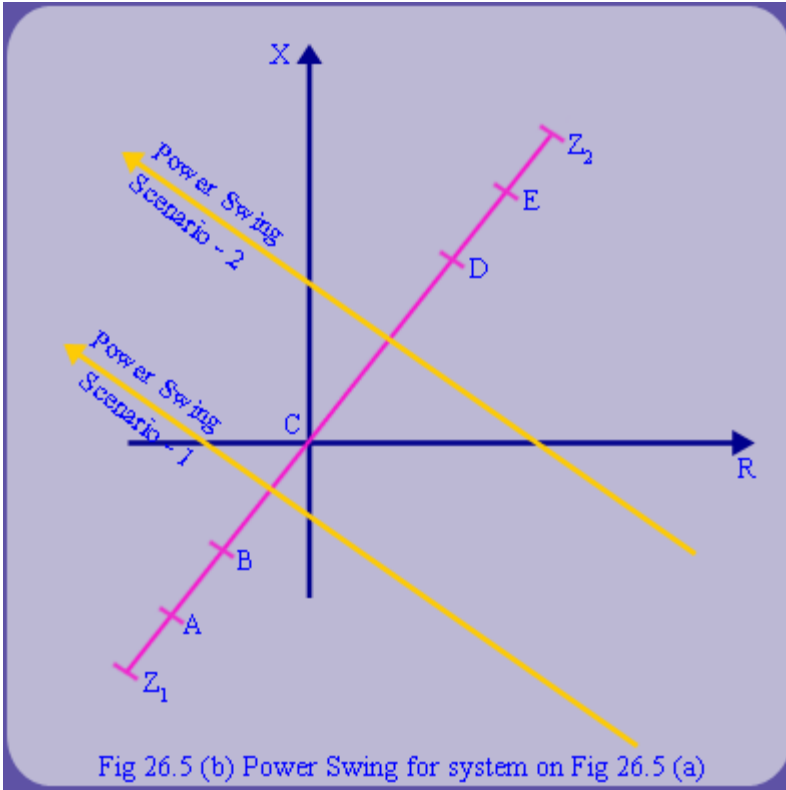
Guide lines for Setting Out-of-Step Tripping Relay

The primary question in setting the out of step relay discussed in previous section is to freeze the location of the line segments L_1 and L_2 . i.e. decide the perpendicular distance MX and MX' . In general, this setting should be such that the swing locus will remain between XX' for at least a preset interval usually 0.005sec. This time is the operating time of the auxiliary relays which evaluates the sequence of events and determines a loss of synchronism condition. Usually, this represents what is achieved in actual system and hence does not pose any series rejection. Also, the characteristics L_1 and L_2 should not be set so far apart to pick up on load conditions.

In other words, the angle subtended by X on R and S should be larger than 90° and as maximum loading condition will always have angle below 90° . The maximum rate of slip can be estimated by carrying out transient stability simulations.



Consider the system shown in fig 26.5a. In the case of out of step condition, optimum location to break the system into multiple islands is at bus-B.



If during out of step condition, the electrical center also appears in the line segment BC, then the required separation is achieved naturally. However, as we know the location of electrical center is not fixed and it depends upon system conditions like E_s , E_R , number of lines in service, Thevenin's impedances Z_{S1} and Z_{S2} etc.

Now, if due to system conditions, the electrical center location shifts to section CD, then uncontrolled system separation will take place at cut - 2, where generation load balance is not obtained.

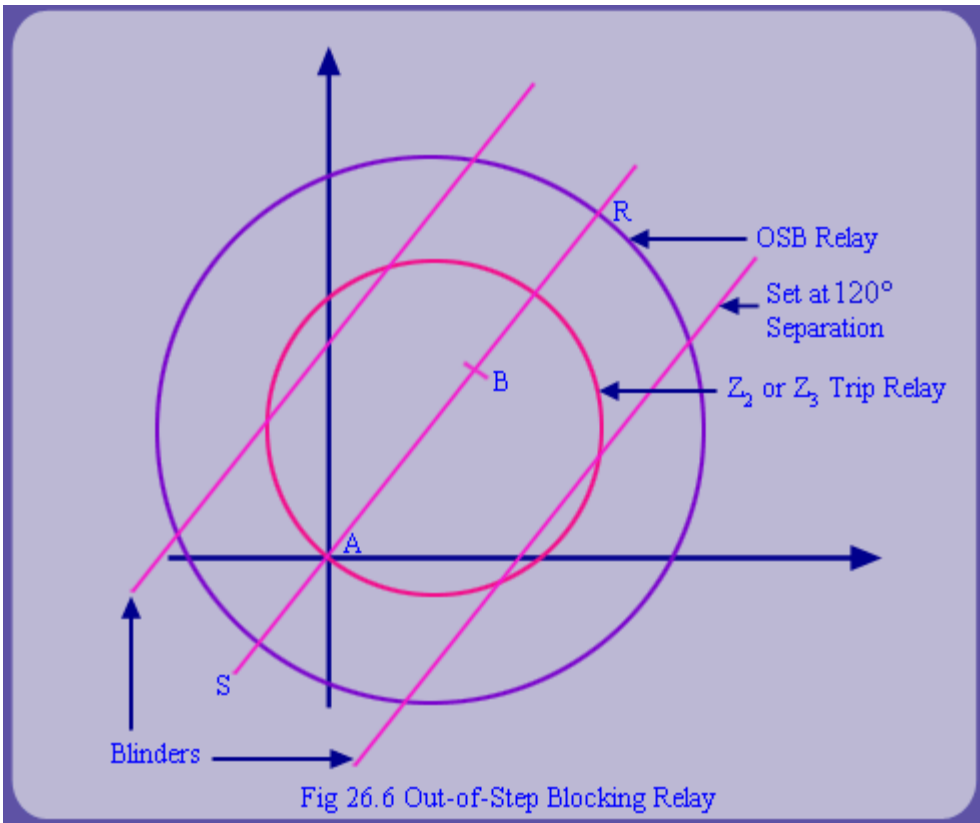
Hence, it is desirable to block distance relay operation on power swings and install an out of step tripping relay at Bus-C. The respective power swings are shown in fig 26.5b. Now, for this scenario, the loss of synchronism requires a transfer trip signal to be generated to breakers at bus B. In general, the point of best separation is not fixed and it depends upon loading and generating conditions.

Thus, supervising control with system operator intervention may be required to decide the islanding location. Now WAM (Wide Area Measurement) technology has opened up new options for system protection.

Introduction (contd..)

Setting of Out-of-Step Blocking Relays

The guidelines to set an out of step blocking relay is that with maximum slip between systems, it will take an impedance trajectory more than 4 cycles to traverse the distance from out of step characteristic to mho tripping curve. The 4 cycle time is the required pick up time of auxiliary relay which establishes blocking function. As in case if



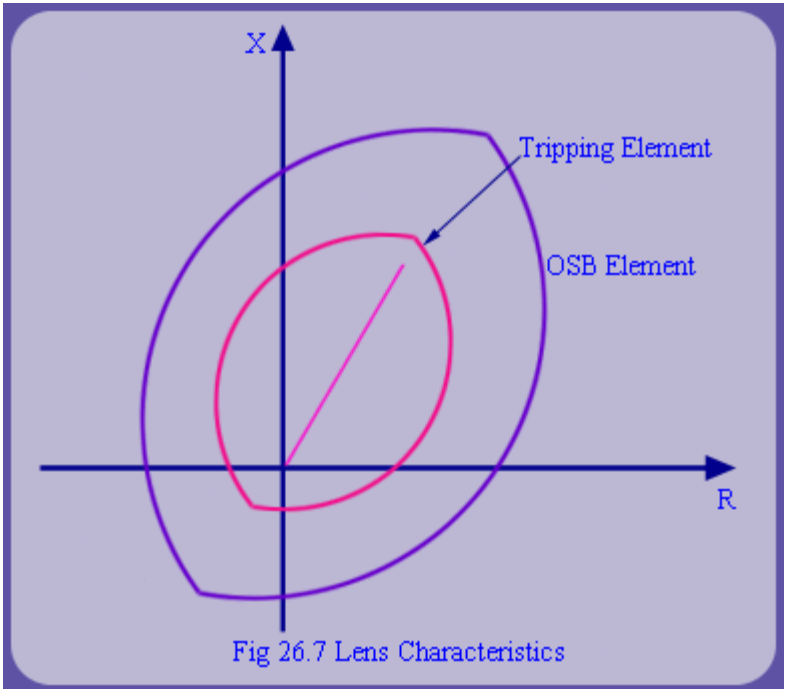
setting out of step tripping relays, precaution has to be taken that out of step blocking characteristic does not encroach the load impedance point and establish increment blocking of line tripping relays.

Usually, blocking is applied only to zone1 and zone2 and not to zone3.

This enables clearing of fault which may arise during power swing block condition. The blocking setting for reclose blocking condition is also similar to that described for trip blocking setting. Blocking automatic reclosing is a must for out of step condition. In case the OSB offset mho characteristic encroaches into the load region, then it has to be appropriately modified. This is achieved by using additional blinders, typically set at 120°. Separation angle is as shown in fig 26.6.

Introduction (contd..)

Setting of Out-of-Step Blocking Relays (contd..)



When additional blinders as shown in fig 26.6 are used, the 4 cycle travel time from OSB elements has to be monitored with respect to the blinder elements. To restrict the reach of relays, instead of blinders and mho relays, lens type characteristics as shown in fig 26.7 are also used. Many of these functions like tripping, blocking and fault detection can be easily integrated into a single numerical relay with a lot more flexibility to shape characteristics of numerical relays and upcoming WAM technology which use synchronized PMU provide many new options in out of step relaying. However, these developments are beyond the scope of this course.

Out of Step Protection for Generators

With large of generators, it is also likely that electrical center may lie within the generator. When

$$X'_d$$

such a situation is detected it is advisable to avoid the knee jerk reaction of tripping the generator. A more beneficial strategy would be to use transfer trip signal to achieve generator function with load generator balancing.

Monitoring the Circuit Breaker Tripping

To avoid stress on the circuit breaker, it is advisable to delay CB trip until after the 180° point of separation is crossed over and the voltages are coming in phase. Tripping circuit breaker close to out of step condition with separating phasors induces very large transient voltages on circuit breaker which is not very advisable.

Review Questions

1. How can we distinguish a power swing from a fault?
2. Why is it necessary for equipping distance relays with swing detection and blocking mechanism?
3. Explain the basic principle of working of:
 - 1) Out of step blocking relays
 - 2) Out of step tripping relays

Recap

In this lecture we have learnt the following:

- Disadvantages of stable and unstable power swings.
- Different types of power swing detection mechanisms.
- Guidelines for setting out of step tripping relays and out of step blocking relays.

