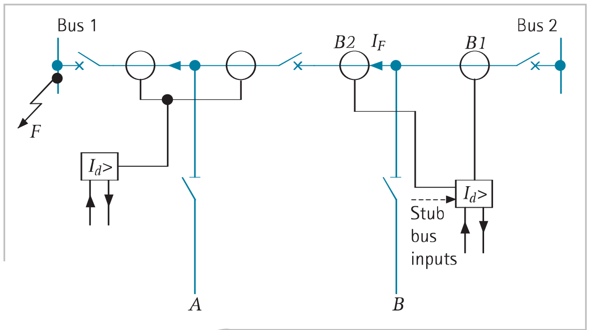

Figure 10.10: Breaker and a half switched substation

In the case of a through fault as shown, the relay connected to Feeder *A* theoretically sees no unbalance current, and hence will be stable. However, with the line disconnect switch open, no bias is produced in the relay, so CT's need to be well matched and equally loaded if maloperation is to be avoided.

For Feeder *B*, the relay also theoretically sees no differential current, but it will see a large bias current even with the line disconnect switch open. This provides a high degree of stability, in the event of transient asymmetric CT saturation. Therefore, this technique is preferred.

Sensing of the state of the line isolator through auxiliary contacts enables the current values transmitted to and received from remote relays to be set to zero when the isolator is open. Hence, stub-bus protection for the energised part of the bus is then possible, with any fault resulting in tripping of the relevant CB.

10.9 CARRIER UNIT PROTECTION SCHEMES

In earlier sections, the pilot links between relays have been treated as an auxiliary wire circuit that interconnects relays at the boundaries of the protected zone. In many circumstances, such as the protection of longer line sections or where the route involves installation difficulties, it is too expensive to provide an auxiliary cable circuit for this purpose, and other means are sought.

In all cases (apart from private pilots and some short rented pilots) power system frequencies cannot be transmitted directly on the communication medium. Instead a relaying quantity may be used to vary the higher frequency associated with each medium (or the light intensity for fibre-optic systems), and this process is normally referred to as modulation of a carrier wave. Demodulation or detection of the variation at a remote receiver permits the relaying quantity to be reconstituted for use in conjunction with the relaying quantities derived locally, and forms the basis for all carrier systems of unit protection.

Carrier systems are generally insensitive to induced power system currents since the systems are designed to operate at much higher frequencies, but each medium may be subjected to noise at the carrier frequencies that may interfere with its correct operation. Variations of signal level, restrictions of the bandwidth available for relaying and other characteristics unique to each medium influence the choice of the most appropriate type of scheme. Methods and media for communication are discussed in Chapter 8.

10.10 CURRENT DIFFERENTIAL SCHEME – ANALOGUE TECHNIQUES

The carrier channel is used in this type of scheme to convey both the phase and magnitude of the current at one relaying point to another for comparison with the phase and magnitude of the current at that point. Transmission techniques may use either voice frequency channels using FM modulation or A/D converters and digital transmission. Signal propagation delays still need to be taken into consideration by introducing a deliberate delay in the locally derived signal before a comparison with the remote signal is made.

A further problem that may occur concerns the dynamic range of the scheme. As the fault current may be up to 30 times the rated current, a scheme with linear characteristics requires a wide dynamic range, which implies a wide signal transmission bandwidth. In practice, bandwidth is limited, so either a non-linear modulation characteristic must be used or detection of fault currents close to the setpoint will be difficult.

10.10.1 Phase Comparison Scheme

The carrier channel is used to convey the phase angle of the current at one relaying point to another for comparison with the phase angle of the current at that point.

The principles of phase comparison are illustrated in Figure 10.11. The carrier channel transfers a logic or 'on/off' signal that switches at the zero crossing points of the power frequency waveform. Comparison of a local logic signal with the corresponding signal from the remote end provides the basis for the measurement of phase shift between power system currents at the two ends and hence discrimination between internal and through faults.

Current flowing above the set threshold results in turn-off of the carrier signal. The protection operates if gaps in the carrier signal are greater than a set duration – the phase angle setting of the protection.

Load or through fault currents at the two ends of a protected feeder are in antiphase (using the normal relay convention for direction), whilst during an internal fault the (conventional) currents tend towards the in-phase condition. Hence, if the phase relationship of through fault currents is taken as a reference condition, internal faults cause a phase shift of approximately 180° with respect to the reference condition.

Phase comparison schemes respond to any phase shift from the reference conditions, but tripping is usually permitted only when the phase shift exceeds an angle of typically 30 to 90 degrees, determined by the time delay setting of the measurement circuit, and this angle is usually referred to as the Stability Angle. Figure 10.12 is a polar diagram that illustrates the discrimination characteristics that result from the measurement techniques used in phase comparison schemes.

Since the carrier channel is required to transfer only binary information, the techniques associated with sending teleprotection commands. Blocking or permissive trip modes of operation are possible, however Figure 10.11 illustrates the more usual blocking mode, since the comparator provides an output when neither squarer is at logic '1'. A permissive trip scheme can be realised if the comparator is arranged to give an output when both squarers are at logic '1'. Performance of the scheme during failure or disturbance of the carrier channel and its ability to clear single-end-fed faults depends on the mode of operation, the type and function of fault detectors or starting units, and the use of any additional signals or codes for channel monitoring and transfer tripping.

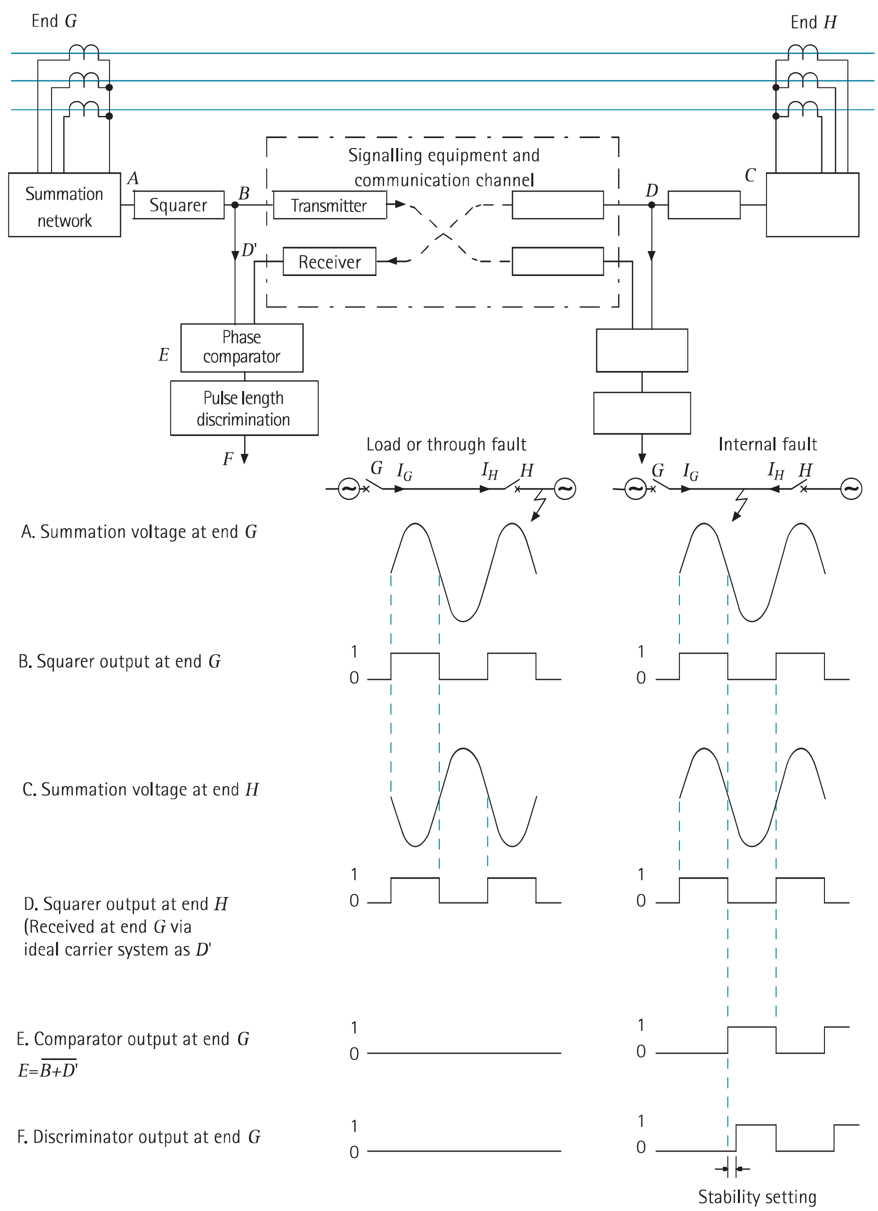

Figure 10.11: Principles of phase comparison protection.

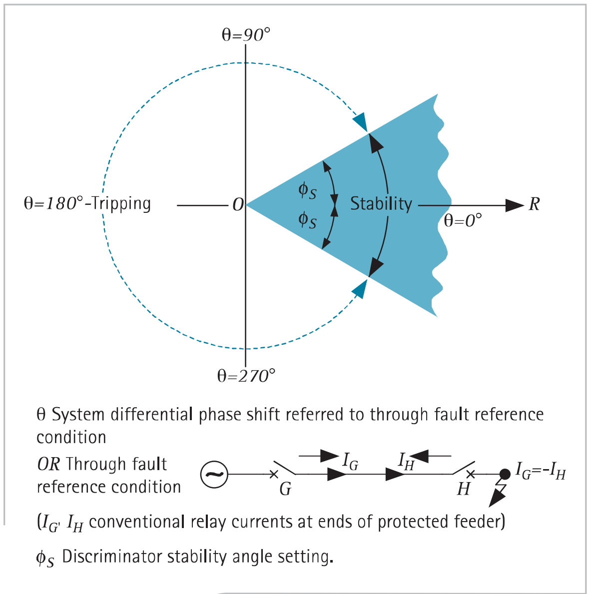

Figure 10.12: Polar diagram for phase comparison scheme

Signal transmission is usually performed by voice frequency channels using frequency shift keying (FSK) or PLC techniques.

Voice frequency channels involving FSK use two discrete frequencies either side of the middle of the voice band. This arrangement is less sensitive to variations in delay or frequency response than if the full bandwidth was used. Blocking or permissive trip modes of operation may be implemented. In addition to the two frequencies used for conveying the squarer information, a third tone is often used, either for channel monitoring or transfer tripping dependent on the scheme.

For a sensitive phase comparison scheme, accurate compensation for channel delay is required. However, since both the local and remote signals are logic pulses, simple time delay circuits can be used, in contrast to the analogue delay circuitry usually required for current differential schemes.

The principles of the Power Line Carrier channel technique are illustrated in Figure 10.13. The scheme operates in the blocking mode. The 'squarer' logic is used directly to turn a transmitter 'on' or 'off' at one end, and the resultant burst (or block) of carrier is coupled to and propagates along the power line which is being protected to a receiver at the other end. Carrier signals above a threshold are detected by the receiver, and hence produce a logic signal corresponding to the block of carrier. In contrast to Figure 10.11, the signalling system is a 2-wire rather than 4-wire arrangement, in which the local transmission is fed directly to the local receiver along with any received signal. The transmitter frequencies at both ends are nominally equal, so the receiver responds equally to blocks of carrier from either end. Through-fault current results in transmission of blocks of carrier from both ends, each lasting for half a cycle, but with a phase displacement of half a cycle, so that the composite signal is continuously above the threshold level and the detector output logic is continuously '1'. Any phase shift relative to the through fault condition produces a gap in the composite carrier signal and hence a corresponding '0' logic level from the detector. The duration of the logic '0' provides the basis for discrimination between internal and external faults, tripping being permitted only when a time delay setting is exceeded. This delay is usually expressed in terms of the corresponding phase shift in degrees at system frequency φ_s in Figure 10.12.

The advantages generally associated with the use of the power line as the communication medium apply namely, that a power line provides a robust, reliable, and low-loss interconnection between the relaying points. In addition dedicated 'on/off' signalling is particularly suited for use in phase comparison blocking mode schemes, as signal attenuation is not a problem. This is in contrast to permissive or direct tripping schemes, where high power output or boosting is required to overcome the extra attenuation due to the fault.

The noise immunity is also very good, making the scheme very reliable. Signal propagation delay is easily allowed for in the stability angle setting, making the scheme very sensitive as well.

10.11 PHASE COMPARISION PROTECTION SCHEME CONSIDERATIONS

One type of unit protection that uses carrier techniques for communication between relays is phase comparison protection. Communication between relays commonly uses PLCC or frequency modulated carrier modem techniques. There are a number of considerations that apply only to phase comparison protection systems, which are discussed in this section.

10.11.1 Lines with Shunt Capacitance

A problem can occur with the shunt capacitance current that flows from an energising source. Since this current is in addition to the load current that flows out of the line, and typically leads it by more than 90°, significant differential phase shifts between the currents at the ends of the line can occur, particularly when load current is low.

The system differential phase shift may encroach into the tripping region of the simple discriminator characteristic, regardless of how large the stability angle setting may be. Figure 10.14 illustrates the effect and indicates techniques that are commonly used to ensure stability.