CHAPTER 7

Auto-Reclosing

7.1 INTRODUCTION

It is well realized that the transient faults which are most frequent in occurrence do no permanent damage to the system as they are transitory in nature. These faults disappear if the line is disconnected from the system momentarily in order to allow the arc to extinguish. After the arc path has become sufficiently deionized, the line can be reclosed to restore normal service. The type of fault could be a flashover across an insulator. Reclosing could also achieve the same thing with semi-permanent faults but with a delayed action, *e.g.*, a small tree branch falling on the line, in which case the cause of the fault would not be removed by the immediate tripping of the circuit breaker but could be burnt away during a time delayed trip and thus the line reclosed to restore normal service. Now should the fault be permanent, reclosing is of no use, as the fault still remains on reclosing and the fault has to be attended personally. It simply means that if the fault does not disappear after the first trip and closure, double or triple-shot reclosing is used in some cases before pulling the line out of service. Experience shows that nearly 80% of the faults are cleared after the first trip, 10% stay in for the second reclosure which is made after a time delay, 3% require the third reclosure and about 7% are permanent faults which are not cleared and result in lockout of the reclosing relay. When a line is fed from both ends, the breakers at the two ends trip simultaneously on occurrence of the fault, the generators at the two ends of the line drift apart in phase, the breakers must be reclosed before the generators drift too far apart for synchronism to be maintained, such a reclosure increases the stability limit considerably.

In present day power systems, automatic reclosing finds wide application. It therefore follows that to effect fault clearance and subsequent reclosure, it is often necessary to operate sequentially several items of switchgear.

Recently logical design principles have been applied for the control of auto-reclose switching sequences in large substations.

7.2 DEFINITIONS AND AVAILABLE FEATURES

(*a*) *Operating time of protective relay:* Time from the inception of the fault to the closing of the tripping contacts.

(*b*) *Operating time of circuit breaker:* Time from the energizing of the trip coil until the fault arc is extinguished.

(*c*) *Dead time of circuit breaker or system:* Time between the fault arc being extinguished and the circuit breaker contacts remaking.

(*d*) *Dead time of auto-reclose relay:* The time between the auto-reclose scheme being energized and the completion of the circuit to the circuit breaker closing contactor. On all but instantaneous or very high speed reclosing schemes this time which is normally adjustable and marked on the calibrated dial is virtually the same as the circuit breaker dead time.

In multi-shot schemes the individual dead times may be the same or separately adjusted.

(*e*) *Closing impulse time of auto-reclose relay:* The time during which the closing contacts on the auto-reclose relay are made.

(*f*) *Reclaim time of auto-reclose relay:* The time from the making of the closing contacts on the auto-reclose relay to the completion of another circuit within the auto-reclose scheme which will reset the scheme or lock out the scheme or circuit breaker as required. This time may be fixed or variable or dependent on the dead time setting. In the multi-shot scheme the individual reclaim time may be the same or independently adjustable.

(*g*) *Reclosing time:* This is the time taken by the circuit breaker to open and reclose the line and is measured from the instant of energization of the trip circuit to the instant when the breaker contacts remake the circuit.

This period is made up of the circuit breaker time plus the system electrical dead time.

(*h*) *Lockout of circuit breakers:* A feature in the auto-reclose scheme to prevent further automatic closing of the circuit breaker after the chosen sequence of reclosures has been unsuccessful. From this position the circuit breaker must be reclosed manually.

(*i*) *Lockout of auto-reclose relay:* A feature in the auto-reclose scheme to prevent further automatic closing after the chosen sequence, regardless of whether the reclosure was successful or not.

(*j*) *Anti-pumping:* A feature incorporated in the circuit breaker or the reclose scheme whereby, in the event of a permanent fault, repeated operation of the circuit breaker are prevented when the closing impulse is longer than the sum of the protective relay and circuit breaker operating times.

(*k*) *Number of shots:* The number of attempts at reclosing which an auto-reclose scheme will make before locking out on a permanent fault. The number of shots may be fixed or adjustable.

(*l*) *Spring winding time:* On motor wound spring closed circuit breakers this is the time required for the motor to fully charge the spring after a closing operation.

(*m*) *Operation counter:* Usually an electromagnetically operated cyclometer type dial which is stepped round one digit each time the coil is energized. These are often incorporated in auto-reclose schemes to record the number of operations of the circuit breaker. This is necessary for maintenance purposes for in unattended substations the operations might not be logged in the usual manner.

(*n*) *Counting relay:* A relay usually of the electromagnetic type incorporating a ratchet arrangement which is driven forward one step each time the coil is energized. A contact is operated after a chosen number of steps and the mechanism may be manually or electrically reset.

Figure (7.1) illustrates auto-reclose cycle for a circuit breaker fitted with single shot auto-reclose scheme.

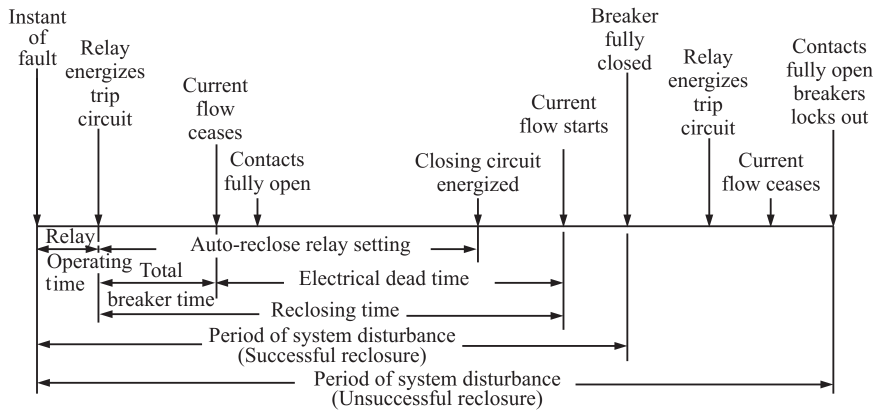

Figure 7.1: Auto-reclose cycle for a circuit breaker with a single shot auto-reclose scheme

7.3 AUTO-RECLOSING

The purpose of auto-reclosing has been discussed in section 7.1. The auto-reclosing can be broadly classified in two categories:

(*a*) *Medium voltage auto-reclose* where continuity of supply is the principal aim.

(*b*) *High voltage auto-reclose* where the main considerations are of stability and synchronizing.

These will now be discussed.

7.3.1 Medium Voltage Auto-Reclose

The obvious advantages are continuous supply except for short duration when tripping and reclosure operations are being performed, this renders the substation unattended. The success of rapid reclosure to a large extent depends on the speed of operation of the protections. This is so because high speed protection decreases the amount of damage incurred and thus increases the probability of successful operation of reclosing, consequently it renders the system less vulnerable to any fault which may occur later. In some cases application of automatic reclosing enables us to use very simple but high speed protections of the lines. With instantaneous protection being applied indiscriminate tripping of several circuit breakers is possible but the provision of auto-reclose makes it a selective operation. The principles of acceleration of the overcurrent protections by means of automatic reclosing is discussed below:

(*i*) *Overcurrent protection with acceleration prior to automatic reclosure:* In this case the provision of single shot auto-reclosure in a nonselective overcurrent high speed protection makes the protection selective. Consider the system shown in Fig. (7.2). Overcurrent protection with time delays located at breakers 1, 2 and 3 are provided so that $t_1 < t_2 < t_3$. The nonselective high speed overcurrent protection and automatic reclosure is located at breaker 3 only. The pickup current of this high speed protection is selected so that it only responds for faults occurring on the line sections *AB, BC* and on that part of section *CD* before the transformer bank. Therefore, for faults within the protected zone the high speed overcurrent protection trips breaker 3. After this the automatic reclosure immediately returns the line to service and at the same time the high speed overcurrent protection is removed for a time a little more than the operating time of overcurrent time delay relay (t_3) located at breaker 3, *i.e.*, $t_{out} > t_3$. This is necessary because if the fault persists after the reclosure, it should be cleared by overcurrent protections at 1, 2 or 3. The advantage is that only one automatic reclosing system on the head section of the line is required. Simplicity of the scheme for short distribution systems where the intermediate substations are not suited for automatic reclosing is an attractive feature of this scheme.

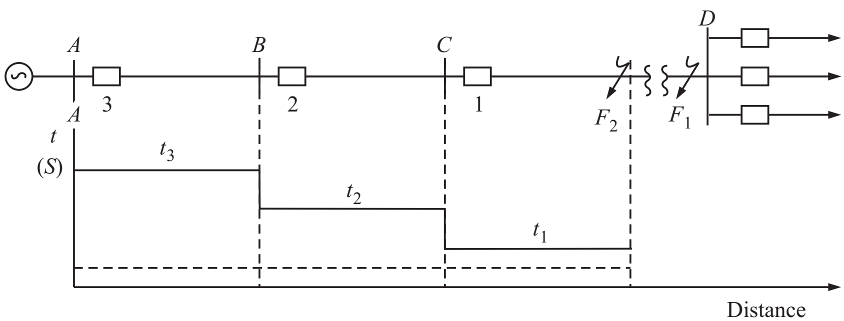

Figure 7.2: Time vs distance characteristic of overcurrent protection with acceleration prior to automatic reclosure

(*ii*) *Overcurrent protection with acceleration after the automatic reclosure:* In this case the fault is first cleared by overcurrent protection with stepped time delays. After this, automatic reclosure returns the line to service and if the fault is permanent, the high speed overcurrent protection operates and removes the line from service.

(*iii*) *Overcurrent protection with inturn automatic reclosure:* It enables us to realize high-speed protection of every section against transient as well as permanent faults. This is achieved by installing high speed nonselective overcurrent protections at all head parts of the sections. The pickup value for all such protections is selected for faults inside the full length of the given section and not for faults beyond the stepdown transformers if one such exists. Different zones of protection are shown in Fig. (7.3). Any nonselective operation of faults outside the given section is corrected by automatic reclosing. When the line is protected by composite overcurrent protection, the first stage of the protection can be employed as high speed nonselective overcurrent protection.

Consider a permanent fault at F_1, of system shown in Fig. (7.3). The high speed relays of breakers 1 and 2 will operate. Practically immediately the automatic recloser located at breaker 1 restores the section 1 to service. As the fault F_1 is located outside section 1 and breaker 2 is still open the high speed overcurrent protection of section 1 will not operate, although it was automatically removed from service for a little while. Now after a time delay t_{AR_2} the automatic recloser at breaker 2 closes.

$$t_{AR_2} = T_{AR_1} + \Delta t_{AR}$$

where t_{AR_2} = time delay of the automatic recloser at breaker 2

t_{AR_1} = inherent time delay of the automatic recloser at breaker 1

Δt_{AR} = time step $\simeq$ 0.5 second

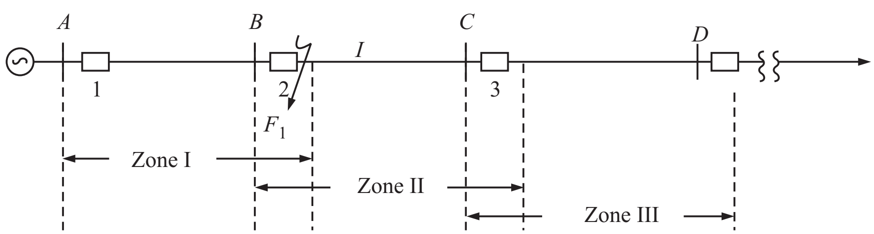

Figure 7.3: Overcurrent protection with 'inturn' automatic reclosure

As the fault of F_1 is permanent, the high speed overcurrent protection of section 2 opens breaker 2 once more and removes section 2 from service. This scheme has increasing clearing times as we proceed towards the far end of the line.

7.3.2 High Voltage Auto-Reclose

In the high voltage circuits where the fault levels associated are extremely high, it is essential that the system dead time be kept to a few cycles so that the generators do not drift apart. High speed protection such as pilot wire carrier or distance must be used to obtain operating times of one or two cycles. It is therefore desired that the reclosure be of the single shot type. High speed reclosure in high voltage circuits improves the stability to a considerable extent on single-circuit ties. On double circuit ties subjected to single circuit faults the continuity through the healthy circuit prevents the generators from drifting apart so fast and increase in the stability limit is thus moderate. Nevertheless, it is sometimes important. However, when the faults occur simultaneously on both the circuits the stability limit increases again considerably.

The successful application of high speed auto-reclose to high voltage systems interlinking a number of sources depends on the following factors.

(*i*) The maximum time available for opening and closing the circuit breakers at each end of the faulty line, without loss of synchronism.

(*ii*) The time required to deionize the arc at the fault, so that it will not restrike when the breakers are reclosed.

(*iii*) The speed of operation on opening and closing of the circuit breakers.

(*iv*) The probability of transient faults, that will allow high speed reclosure of the faulty lines.

It will be seen that some of these conditions are conflicting, *e.g.*, the faster the breakers are reclosed the greater the power that can be transmitted without loss of synchronism, provided that the arc does not restrike. But here the likelihood of arc restriking is greater. An unsuccessful reclosure is more detrimental to stability than no reclosure at all. For this reason the time allowed to deionize the line must not be less than the critical time for which the arc hardly ever restrikes. The reduction of reclosing time obtained by high speed relaying is however preferred as it reduces the duration of arc. Indeed, the increase in power limit due to reclosing is much greater with very rapid fault clearing than with slower fault clearing. For best results the circuit breakers at both ends of the faulty line must be opened simultaneously. Any time during which one circuit breaker is open in advance of the other represents an effective reduction of the breaker electrical dead time and may well jeopardize the chances of a successful reclosure.

To determine the electrical dead time for a circuit breaker used in a high speed auto-reclose scheme it is essential to know the time interval during which the line must be kept deenergized in order to allow for the complete deionization of the arc and ensure that it will not restrike when the line is reconnected to the system. The deionization time of an arc in open atmosphere depends on a number of factors such as: circuit voltage, conductor spacing or gap length, fault current, fault duration, wind velocity, etc.

Line voltage is the most important of all the factors affecting the arc deionization time. Typical values of deionization times for an arc in free air are:

Line voltage (kV)	Minimum deionizing time (seconds)
66	0.1
110	0.15
132	0.17
220	0.28
275	0.3

7.4 THREE-PHASE VERSUS SINGLE-PHASE AUTO-RECLOSE

Three-phase auto-reclosure is one in which the three phases of the transmission line are opened after fault incidence, independent of the fault type, and are reclosed after a predetermined time period following the initial circuit breaker opening. For a single circuit interconnectors between two power systems, the opening of all the three phases of the circuit breaker makes the generators in each group start to drift apart in relation to each other, since no interchange of synchronizing power can take place.

On the other hand single-phase auto-reclosure is one in which only the faulted phase is opened in the presence of a single-phase fault and reclosed after a controlled delay period. For multiphase faults, all three phases are opened and reclosure is not attempted. In case of single-phase faults which are in majority, synchronizing power can still be interchanged through the healthy phases.

In the case of single-phase auto-reclosing each phase of the circuit breaker has to be segregated and provided with its own closing and tripping mechanism. Also it is necessary to fit phase selecting relays that will detect and select the faulty phase. Thus single-phase auto-reclosing is more complex and expensive as compared to three-phase auto-reclosing. When single-phase auto-reclose is used the faulty phase must be deenergized for a longer interval of time, than in the case of three-phase auto-reclose, owing to the capacitive coupling between the faulty phase and the healthy conductors which tends to increase the duration of the arc. The advantage claimed for single-phase reclosing is that on a system with transformer neutrals grounded solidly at each substation, the interruption of one phase to clear a ground fault causes negligible interference with the load because the interrupted phase current now flows in the ground through neutral points until the fault current is cleared and the faulted phase reclosed. The main drawback is its longer deionizing time which can cause interference with communication circuits and, in certain cases maloperation of earth relays in double circuit lines owing to the flow of zero sequence currents.

QUESTIONS

1. What is the purpose of providing auto-reclosing? Discuss the main considerations for designing the auto-reclose scheme with particular reference to high-voltage system.
2. Distinguish between single-phase and three-phase auto-reclose. In which case is the duration of arc more, single-phase auto-reclose or three-phase auto-reclose and why? Clearly bring out their relative merits and drawbacks.
3. Define the following terms:
   (*i*) Dead time of circuit breaker.
   (*ii*) Reclosing time.
   (*iii*) Lockout of circuit breakers.
   (*iv*) Number of shots.