EE493 Protection of Power Systems I

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1

Reclosers

A recloser is a device with the ability to detect phase-to-phase and phase-to-earth overcurrent conditions, to interrupt the circuit if the overcurrent persists after a predetermined time, and then to automatically reclose to re-energise the line. If the fault that originated the operation still exists, then the recloser will stay open after a preset number of operations, thus isolating the faulted section from the rest of the system. In an overhead distribution system between 80 to 95 per cent of the faults are of a temporary nature and last, at the most, for a few cycles or seconds. Thus, the recloser, with its opening/closing characteristic, prevents a distribution circuit being left out of service for temporary faults. Typically, reclosers are designed to have up to three open-close operations and, after these, a final open operation to lock out the sequence. The operating time/current characteristic curves of reclosers normally incorporate three curves, one fast and two delayed, designated as A, B and C, respectively. Figure 6.1 shows a typical set of time/current curves for reclosers.
However, new reclosers with microprocessor-based controls may have keyboard-selectable time/current curves which enable an engineer to produce any curve to suit the coordination requirements for both phase and earth-faults. This allows reprogramming of the characteristics to tailor an arrangement to a customer's specific needs without the need to change components.

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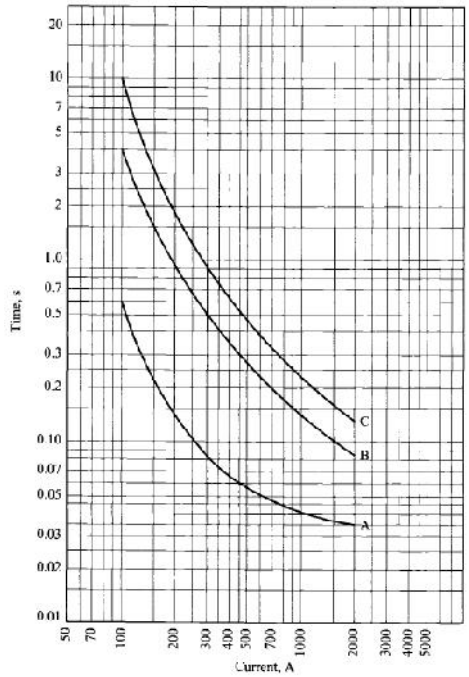

Figure 6.1 Time/current curves for reclosers

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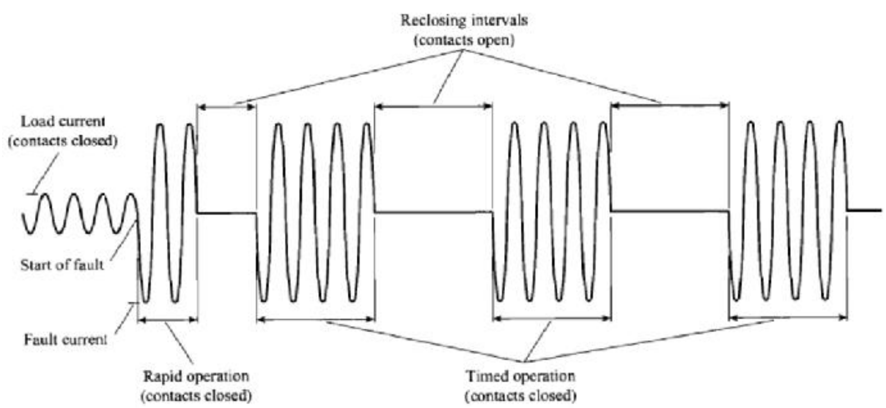

Figure 6.2 Typical sequence for recloser operation

A typical sequence of a recloser operation for a permanent fault is shown in Figure 6.2. The first shot is carried out in instantaneous mode to clear temporary faults before they cause damage to the lines. The three later ones operate in a timed manner with predetermined time settings (i.e. according to curves A, B, and C in Figure 6.1).

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Sectionaliser

A sectionaliser is a device that automatically isolates faulted sections of a distribution circuit once an upstream breaker or recloser has interrupted the fault current and is usually installed downstream of a recloser. Since sectionalisers have no capacity to break fault current, they must be used with a back-up device that has fault current breaking capacity. Sectionalisers count the number of operations of the recloser duringfault conditions. After a preselected number of recloser openings, and while the recloser is open, the sectionaliser opens and isolates the faulty section of line. This permits the recloser to close and re-establish supplies to those areas free of faults. If the fault is temporary, the operating mechanism of the sectionaliser is reset.

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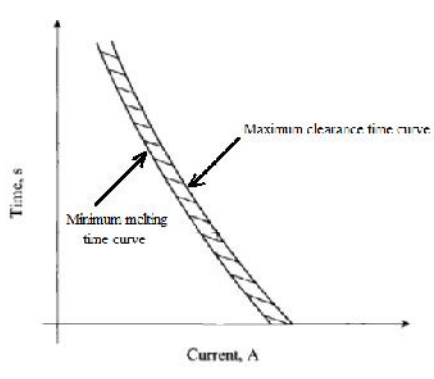
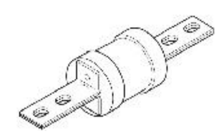
fuse

A fuse is an overcurrent protection device; it possesses an element that is directly heated by the passage of current and is destroyed when the current exceeds a predetermined value. A suitably selected fuse should open the circuit by the destruction of the fuse element, eliminate the arc established during the destruction of the element and then maintain circuit conditions open with nominal voltage applied to its terminals, (i.e. no arcing across the fuse element).





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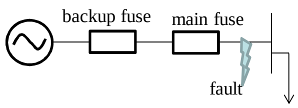
Criteria for co-ordination of time/current devices in distribution systems

Fuse-fuse co-ordination



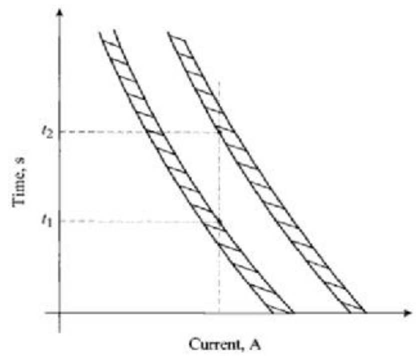


Figure 6.4 Criteria for fuse-fuse co-ordination: $t_1 < 0.75\, t_2$

The essential criterion when using fuses is that the maximum clearance time for a main fuse should not exceed 75 per cent of the minimum melting time of the backup fuse, for the same current level, as indicated in Figure 6.4. This ensures that the main fuse interrupts and clears the fault before the back-up fuse is affected in any way. The factor of 75 per cent compensates for effects such as load current and ambient temperature, or fatigue in the fuse element caused by the heating effect of fault currents that have passed through the fuse to a fault downstream but were not sufficiently large enough to melt the fuse.

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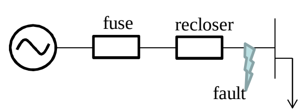
Recloser-fuse co-ordination

Fuse at the source side



When the fuse is at the source side, all the recloser operations should be faster than the minimum melting time of the fuse. This can be achieved through the use of multiplying factors on the recloser time/current curve to compensate for the fatigue of the fuse link produced by the cumulative heating effect generated by successive recloser operations. The recloser opening curve modified by the appropriate factor then becomes slower but, even so, should be faster than the fuse curve. This is illustrated in Figure 6.5.
The multiplying factors referred to above depend on the reclosing time in cycles and on the number of the reclosing attempts. Some values are reproted in Table 6.1.

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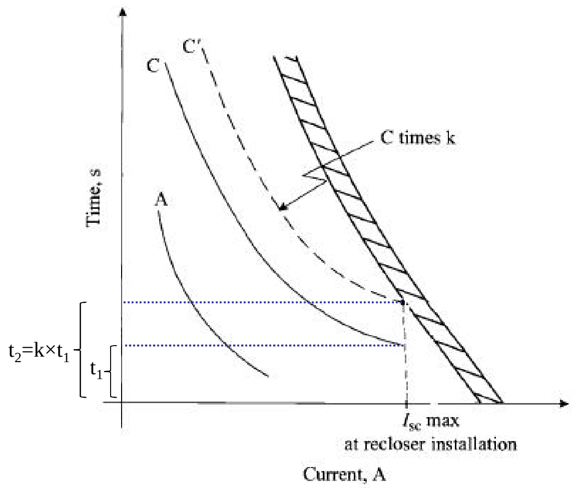

Figure 6.5 Criteria for source-side fuse and recloser co-ordination

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Table 6.1 k factor for source-side fuse link

Reclosing time in cycles	Multipliers for:		
	two fast, two delayed sequence	one fast, three delayed sequence	four delayed sequence
25	2.70	3.20	3.70
30	2.60	3.10	3.50
50	2.10	2.50	2.70
90	1.85	2.10	2.20
120	1.70	1.80	1.90
240	1.40	1.40	1.45
600	1.35	1.35	1.35

The *k* factor is used to multiply the time values of the delayed curve of the recloser.

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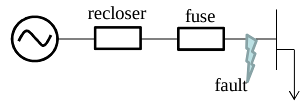
Fuses at the load side



The procedure to co-ordinate a recloser and a fuse, when the latter is at the load side, is carried out with the following rules:

- The minimum melting time of the fuse must be greater than the fast curve of the recloser times the multiplying factor, given in Table 6.2
- The maximum clearing time of the fuse must be smaller than the delayed curve of the recloser without any multiplying factor; the recloser should have at least two or more delayed operations to prevent loss of service in case the recloser trips when the fuse operates.

The application of the two rules is illustrated in Figure 6.6.
Better co-ordination between a recloser and fuses is obtained by setting the recloser to give two instantaneous operations followed by two timed operations.

In general, the first opening of a recloser will clear 80 per cent of the temporary faults, while the second will clear a further 10 per cent . The load fuses are set to operate before the third opening, clearing permanent faults. A less effective coordination is obtained using one instantaneous operation followed by three timed operations.

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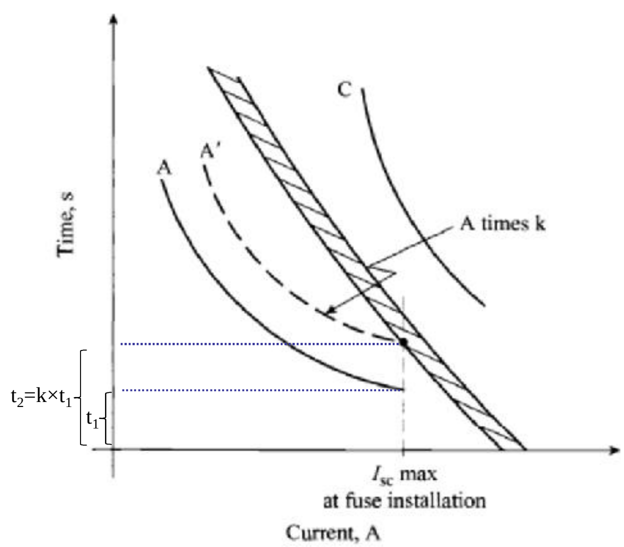

Figure 6.6 Criteria for recloser and load-side fuse co-ordination

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Table 6.2 k factor for the load-side fuse link

Reclosing time in cycles	Multipliers for: one fast operation	Multipliers for: two fast operations
25–30	1.25	1.80
60	1.25	1.35
90	1.25	1.35
120	1.25	1.35

The *k* factor is used to multiply the time values of the recloser fast curve.

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Figure 6.7 shows a portion of a 13.2 kV distribution feeder. The recloser chosen has two fast and two delayed operations with 90 cycles intervals. For a fault at the distribution transformer, its fuse should operate first, being backed up by the recloser fast operating shots. If the fault is still not cleared, then the branch fuse should operate next followed by the delayed opening shots of the recloser and finally by the operation of the feeder relay. The sectionaliser will isolate the faulted section of the network after the full number of counts has elapsed, leaving that part of the feeder upstream still in service.

As the nominal current of the 112.5 kVA distribution transformer at 13.2 kV is 4.9 A, because

$S=\sqrt{3}\times V\times I \rightarrow \quad 112.5\text{ kVA} = \sqrt{3}\times 13.2\text{ kV}\times I \rightarrow I=4.9$

a 6 fuse was selected on the basis of allowing a 20 per cent overload. The fast curve of the recloser was chosen with the help of the following expression based on the criteria already given

$t_{recloser} \times k < t_{MMT}$ of branch fuse (6.1)

where t_{MMT} of branch fuse is the minimum melting time.

At the branch fuse location $1.5\times I_{normal}$=40 Amp, so a 40 A fuse was selected for branch fuse. At fuse location, the short-circuit current is 2224 A, which results in operation of the branch fuse in 0.02 s. From Table 6.2, the k factor for two fast operations and a reclosing time of 90 cycles is 1.35. With these values, from eqn. 6.1 the maximum time for the recloser operation is (0.02 /1.35)= 0.0148 s. This time, and the pick-up current of the recloser (i.e $1.5\times I_{normal}$=240 Amp), determines the fast curve of the recloser.

The feeder relay curve is selected so that it is above that of the delayed curve of the recloser

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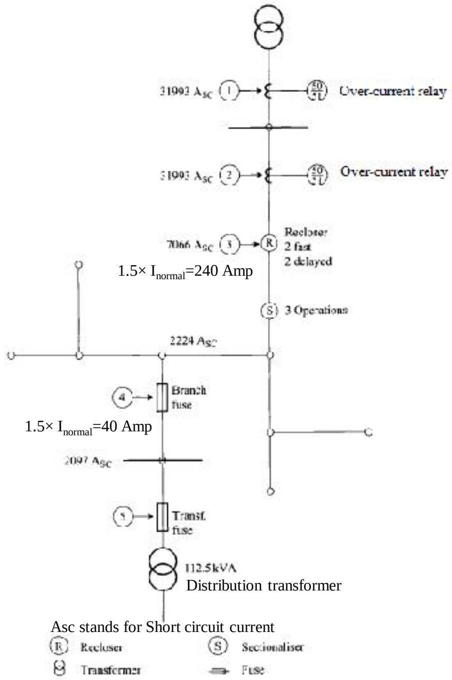

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Figure 6. 7 Portion of a distribution feeder

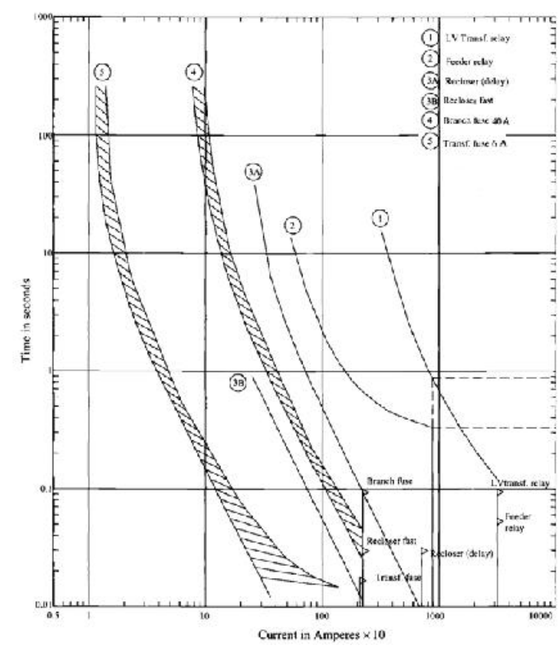

Figure 6.8 Phase-current curves

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