Modeling of Recloser Operation Schemes under System Ground Fault Using EMTP-ATPDraw

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Abstract-**This paper simulates the operation of automatic circuit recloser under the system ground fault condition using MODELS language in transient digital simulation EMTP-ATPDraw. Any other recloser operation schemes such as two fast-one delay or one fast-one delay can be modeled. In this paper the recloser model has been tested with two fast and one time delay operation schemes for both temporary and permanent faults. The recloser model presented in this paper is the guideline for modeling the other recloser operation schemes including the other protective devices, such as fuse and overcurrent relay which have the similar time-current characteristics.**

Keywords—recloser; MODELS language; EMTP-ATPDraw; faults

I. INTRODUCTION

The automatic circuit recloser or recloser is an overcurrent protective device that automatically trips and recloses a preset number of times to clear temporary faults or isolated permanent faults [1] and providing continuity of electric service. The recloser may be classified as, single-phase recloser, three-phase recloser and triple-single recloser [2] and can contain oil or vacuum circuit interruption mechanisms. Hydraulic control for older feature or electronic control for newer. The recloser sizes are specified in terms of the maximum continuous current rating. Reclosers are used in conjunction with fuses in order to avoid permanent outages due to temporary faults call “fuse-savings”. The recloser may be used to coordinate with recloser itself or coordinate with other protective devices such as fuse and overcurrent relay [1], [2].

The time domain model of any protective devices can be represented using the MODELS language in the ATP [3] and also in ATPDraw [4] versions of EMTP. MODELS is a general technical description language or a programming language targeted to time-domain simulation, and is used as a tool for describing the dynamic behavior of complex physical systems [5], [6]. In EMTP-ATPDraw, it can be used for describing the operation of circuit components and of control components [5]. It can also be used for generating signals or for analyzing measurements from the circuit and can be used as the interface between EMTP-ATPDraw and outside programs [5].

In this paper, the recloser is modeled using MODELS language with inverse time operating curves which is settled with two inverse time curves, one fast and one delay time curves [2]. The other recloser operation scheme may have three inverse time curves, two different fast and one delay time curves [1], [2]. The recloser model presented in this paper can be taken as the guideline leading to further modeling of the other recloser operation schemes or protective devices for example those have the similar time-current characteristics, such as fuse and time overcurrent relay.

II. SYSTEM MODELING

The purpose of this study is to simulate the operation schemes of the recloser under the system ground fault condition using MODELS language in EMTP-ATPDraw. The distribution system for testing of recloser operation scheme has been modeled using digital simulation EMTP-ATPDraw as shown in Fig. 1 and the detailed models in EMTP-ATPDraw are as follow.

A. Distribution System Model

The radial distribution system of 22 kV has been modeled with the source impedance of 500 Ω and 1 mH in parallel [7]. The distribution line model, pi section of 1 mH with 0.002 μF [7], between source and loads (LOAD1-LOAD6). The line to ground fault has been occurred on load line 6 (LOAD6) as shown in Fig. 1. To protect each load, fuse is added in each feeder if required.

B. Ground Fault Model

Ground fault model has been simulated using switch, TACS-controlled type 13 [8] which received signal from MODELS called “fault (FAULT TYPE)”. To simulate faulted starting time including faulted time interval, both for temporary and permanent faults, fault starting and ending time are required so the fortran1 TACS type 98 [8] has been added (Fstart and Fend) as shown in Fig. 1.

C. Load Model

To get the normal load current through the recloser, LOAD1-LOAD6 have been represented with branch linear. The resistor of 400 Ω and inductor of 1 mH have been used

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for load modeling [7]. Any changes in these two components which connected in series can affect the current flowing through the recloser in normal operation.

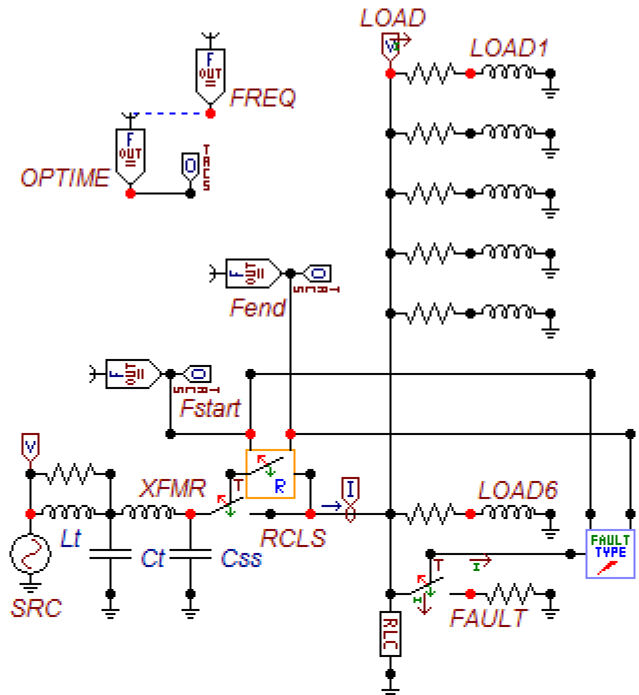

Fig 1. Simulation circuit in EMTP-ATPDraw for modeling and testing of recloser operation scheme under system ground fault condition.

D. Recloser Model

Unfortunately there is no recloser or any protective devices models available within the program so the recloser model has to be made using MODELS language in EMTP-ATPDraw. Reclosers have time current curves which are similar to fuses. To get the recloser model including any other protective devices, two components (recloser.sup and recloser.mod) are required. The recloser current time characteristics, fast and time delay curves, have been shown in Fig. 2 [1], [2]. The fault type model has been linked with recloser model as shown in Fig. 1.

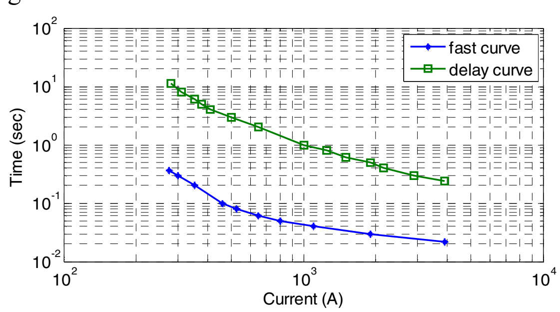

Fig. 2. Typical curves for fast and delay curves of recloser.

The recloser operation scheme can be selected, for example the recloser of two fast (instantaneous) ; nFast=2 and one time delay trip operations prior to lockout ; nDelay=1 in EMTP-ATPDraw (recloser.sup) has been shown in Fig. 3. The other operation scheme, for example one fast and one delay can be modeled as, nFast=1 and nDelay=1. Part of the other component (recloser.mod), fast scheme, has been shown in Fig. 4. The delay scheme has also be shown in Fig. 5. The others variables (DeltT, Step, CntF and CntD) are for the program integration purpose.

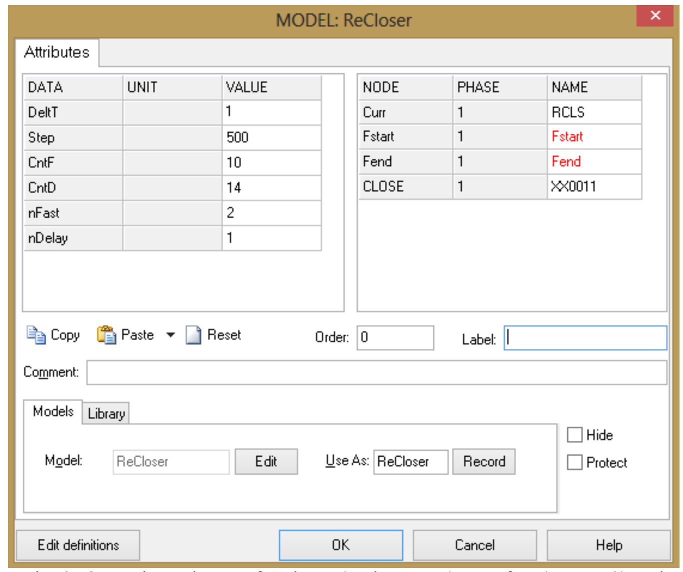

Fig. 3. Operation scheme of recloser (recloser.sup), two fast (nFast : 2) and one time delay (nDelay : 1).

```
-- FAST OPERATION
 FOR k:=0 TO CntF-1 DO
  IF (I>FINITF) THEN
   IF (I>FSTC[0..k]) THEN
     Cnt:=k
     Tst1:=FSTT[k]              -- Fast Recloser Operating Time
     Tf1:=Fstart+Tst1           -- Fast Recloser Start Operating
   ENDIF
     IF Tf1<Fend THEN           -- Fast Recloser Operated
       IF TTT=Tf1 THEN
         CLOSE:=0               -- Switch Opened
       ENDIF
     ENDIF
     IF Tf1>Fend THEN           -- Fast Recloser Not Operated
       IF TTT=Tf1 THEN
         CLOSE:=1               -- Switch Stay Closed
       ENDIF
     ENDIF
  ENDIF
 ENDFOR
-- End of FAST Scheme
```

Fig. 4. Operation scheme of recloser (part of recloser.mod), fast scheme.

```
-- DELAY OPERATION
 FOR m:=0 TO CntD-1 DO
    IF (I>FINITD) THEN
     IF (I>DLYC[0..m]) THEN
       Cnt:=m
       Tst3:=DLYT[m]            -- Delay Recloser Operating Time
       Tf3:=Top2+Tst3           -- Delay Recloser Start Operating
     ENDIF
      IF Tf3<Fend THEN          -- Delay Recloser Operated
        IF TTT=Tf3 THEN
          CLOSE:=0              -- Switch Opened
        ENDIF
      ENDIF
      IF Tf3>Fend THEN          -- Delay Recloser Not Operated
        IF TTT=Tf3 THEN
          CLOSE:=1              -- Switch Stay Closed
        ENDIF
      ENDIF
    ENDIF
 ENDFOR
 -- DELAY Recloser Start Reclosed
     Top3:=Tf3+TxD             -- Time for Recloser Start Reclosed
      IF TTT=Top3 THEN
       CLOSE:=1                 -- Delay Recloser Reclosed
      ENDIF
 -- End of DELAY Scheme
```

Fig. 5. Operation scheme of recloser (part of recloser.mod), delay scheme.

III. RESULTS

The recloser model in EMTP-ATPDraw has been tested by choosing recloser operation scheme of two fast and one time delay (nFast=2 and nDelay=1 in Fig. 3). The fault location is between recloser and LOAD6 as shown in Fig. 1 with the fault resistance of 1 **Ω**. Assumed the fault starting and ending time are at 0.015 and 0.035 s respectively. In order to model the recloser operation schemes under system ground fault condition correctly, the recloser operation time (open, close) including fault and load currents when temporary and permanent faults occurred have to be performed and tested which are as follow.

E. Temporary Fault

The fault location is between recloser and LOAD6 with the fault resistance of 1 **Ω**. If the temporary fault has be gone earlier, assumed the fault starting and ending time are at 0.015 and 0.035 s recpectively as shown in Fig. 6. From Fig. 2 the operating time for fast curve is 0.022 s, so recloser will start operate at 0.015+0.022=0.037 s. For fast operation, recloser will stay open for 2 cycles and recloser must close again at 0.037+0.04=0.077 s and the normal load can be supplied again from the source because of the fault is disappear as shown in Fig. 7. Only the first fast operation will operate in this fault condition. The switch status and recloser operating time (open : 0 and close : 1) are shown in Fig. 8.

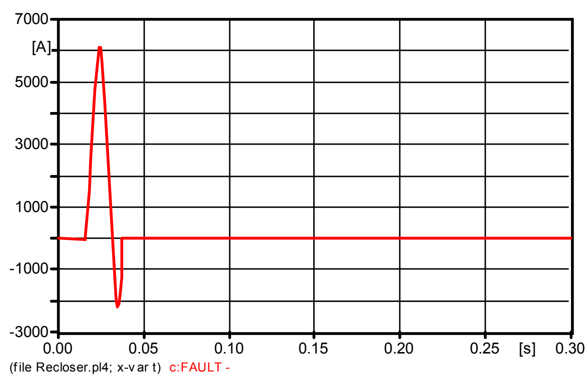

Fig. 6. Fault current when temporary fault occurred ; fault end at 0.035 s.

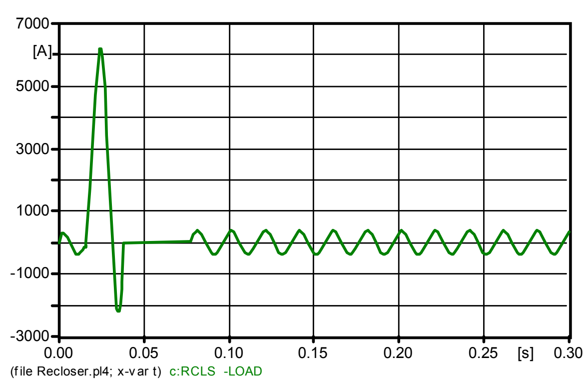

Fig. 7. Current through recloser for temporary fault ; fault end at 0.035 s. and recloser (one fast operation) reclose at 0.077 s.

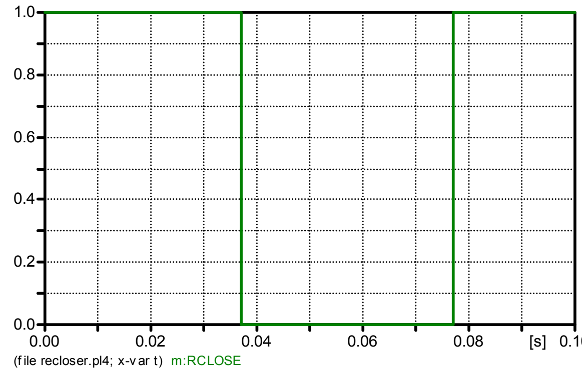

Fig. 8. Recloser operating time and status ; starting time at 0.037 s. (open : 0) and one fast reclose at 0.077 s (close : 1).

If the temporary fault stayed longer and assumed that the fault starting and ending time are at 0.015 and 0.20 s recpectively as shown in Fig. 9. From Fig. 2 the operating time for fast operation is 0.022 s, so recloser will start operate (open) at 0.037 s. For the first fast operation, recloser will stay open for 2 cycles and recloser must close again (reclose) at 0.077 s and the normal load cannot be supplied from the source because of the fault is not disappear as shown in Fig. 9. At this moment the second fast operation is required, the recloser will start to operate again (open) at 0.077+0.022=0.099 s and then reclose at 0.099+0.04=0.139 s. At this moment the fault is still exist for 0.061 s and disappear at 0.20 s which no need for delay operation to operate because the delay operation need 0.24 s to operate. The normal load can be supplied again from the source because of the fault is disappear as shown in Fig. 10. Only the first and second fast operations will operate in this fault condition.

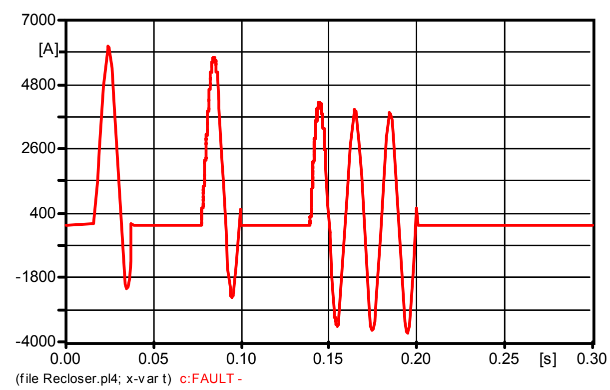

Fig. 9. Fault current when temporary fault occurred ; fault end at 0.2 s.

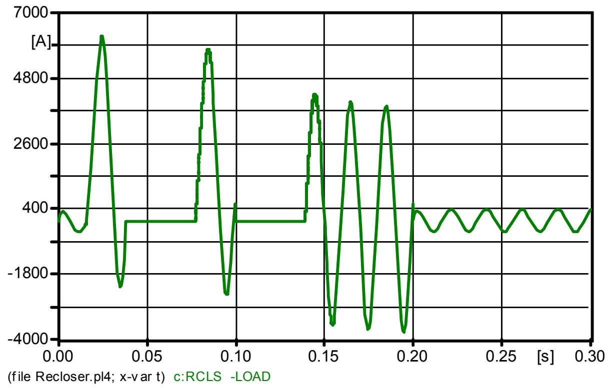

Fig. 10. Current through recloser for temporary fault ; fault end at 0.2 s. and recloser (two fast operation) reclose at 0.077 s., and 0.139 s.

F. Permanent Fault

If the permanent fault occured and assumed that the fault starting and ending time are at 0.015 and 0.90 s recpectively as shown in Fig. 11. From Fig. 2 the operating time for fast and delay operations are 0.022 and 0.24 s respectively, so recloser will start operate (open) at 0.037 s. For the first fast operation, recloser will stay open for 2 cycles and recloser must close again at 0.077 s and the normal load cannot be supplied from the source because of the fault is not disappear as shown in Fig. 11. At this moment the second fast operation is required, the recloser will start to operate again (open) at 0.099 s and then reclose at 0.139 s. At this moment the fault is still exist for 0.131 s and disappear at 0.90 s which the delay operation is required. The normal load cannot be supplied from the source because of the fault is continue as shown in Fig. 11. The delay scheme recloser will start operate (open) at 0.139+0.24=0.379 s and reclose again at 0.379+0.4=0.779 s. Assumed that the recloser will operate within 1 cycle if the fault is still be there. In this case the recloser will open or lockout at 0.779+0.02=0.799 s as shown in Fig. 12. The first and second fast and delay operations will operate in this fault condition. As before, the normal load cannot be supplied from the source because of the recloser lockout.

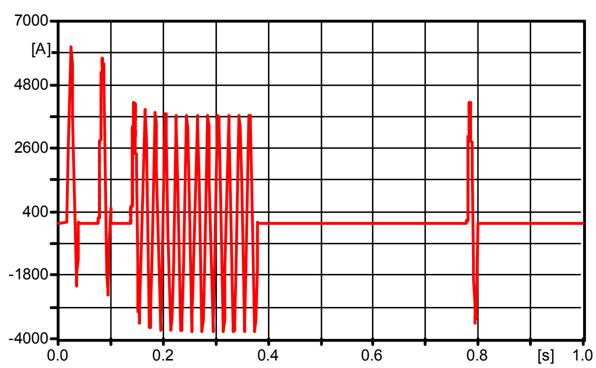

Fig. 11. Fault current when permanent fault occurred.

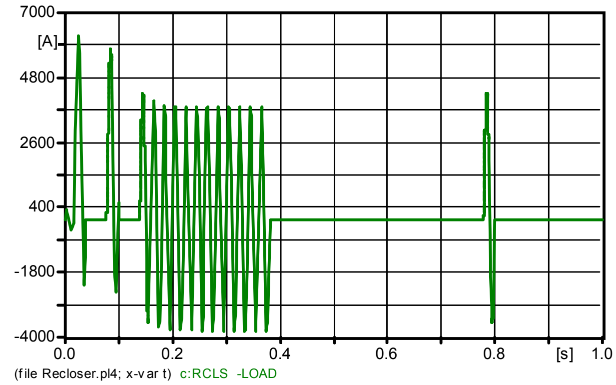

Fig. 12. Current through recloser for permanent fault ; recloser (two fast operation) reclose at 0.077 s., and 0.139 s.; recloser (one time delay) reclose at 0.779 s. and lockout at 0.799 s.

For temporary fault, the fault time interval would determine the operation of recloser. Only the first fast opeartion will operate if the fault end before the first reclose time. Both two fast operations will operate if the fault stay longer and end before the delay operation begin. The recloser operating time for permanent fault, open and close time which corresponds to fault condition are shown in Fig. 13 and 14.

For permanent fault, the fault time interval would determine the operation of recloser as for the temporary fault but the delay operation will operate after both two fast operation operated. If in case of the fault stay longer than the delay operation finished then the recloser lockout and there is no more current has been supplied from the source.

Under system ground fault condition, both for temporary and permanent faults, the recloser model can operate correctly which can be taken as the guideline leading to further modeling of the other recloser operation schemes or protective devices for example those have the similar time-current characteristics, such as fuse and time overcurrent relay.

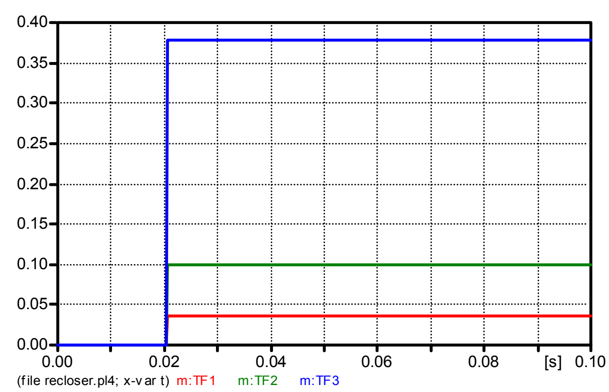

Fig. 13. Recloser open time ; starting at 0.022 s. one fast open at 0.037 s two fast open at 0.099 s and one time delay open at 0.379 s.

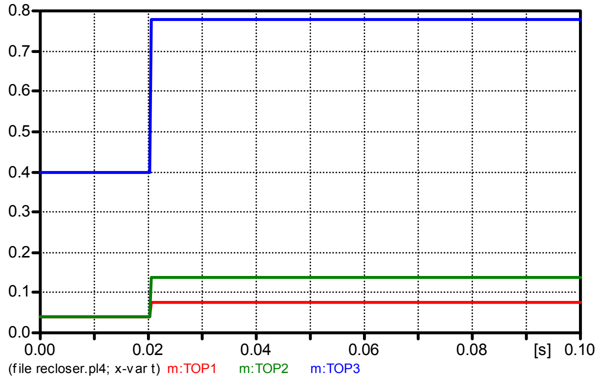

Fig. 14. Recloser reclose time ; starting at 0.022 s. one fast reclose at 0.077 s. two fast reclose at 0.139 s. and one time delay reclose at 0.779 s.

IV. CONCLUSIONS

The operation of recloser under the system ground fault condition has been simulated. By using MODELS language which is available in EMTP-ATPDraw, the recloser model including operation schemes can be done. The recloser operation scheme, two fast and one time delay, has been tested as the example which covered both temporary and permanent faults. The other operation schemes, for examples ; one fast and one delay or two fast and two delay can also be done if required.

The recloser which is modeled in this paper can be taken as the guideline leading to further modeling of the other recloser operation schemes or protective devices for example those have the similar time-current characteristics, such as fuse and time overcurrent relay.

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