

AUTOCOORDINATION OF PROTECTION SETTINGS OF SERIES RECLOSERS

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Abstract

The paper deals with the problem of coordination of reclosers installed in series in overhead line. Existing practice is based upon set of rules that require human interference. This may lead to errors and incorrect operation of protection. We have developed a set of algorithms that allow determining settings of protection elements providing protection against short circuit and sensitive earth faults. Network parameters and grading margins serve as input data for the mentioned algorithms. The algorithms have been tested with the aid of network computer models. The tests proved applicability of the algorithms for field application.

Introduction

Introduction of microprocessor relays provided power utilities with a lot of capabilities not available in the past:

- high accuracy
- low power consumption
- ability to monitor line parameters
- ability to provide self-monitoring
- utmost flexibility.

At the same time in many cases mentioned flexibility creates substantial application problem: it is not easy to program for particular application relay designed for meeting all possible requirements.

Side effects of this problem are substantial training expenses and growth of percentage of human errors [1].

Moreover in many cases customers do not employ even minor fraction of the capabilities offered by microprocessor relays [2]. Table 1 summarises results of survey [2] with regard to applicability of advanced protection practice for distribution overhead lines.

The same survey indicates that only limited number of utilities takes into considerations all important considerations when designing protection settings (Table 2).

On this basis one can notice substantial gap between existing protection practice and capabilities of the modern microprocessor relays.

The goal of the present paper is to close this gap for the particular case: series reclosers installed in overhead line. This goal shall be

achieved with the aid of autocoordination algorithm that shall allow automatic calculation of the protection settings on the basis of line parameters and selected grading margins.

Table 1

Advanced relay function	Percentage of utilities using advanced function
Distance protection	4%
Directional protection	2%
Negative sequence protection	8%
Automatic back feed restoration	8%

Table 2

Consideration used at designing protection settings	Percentage of utilities taking relevant consideration into account
Coordination with load	44%
Conductor thermal limit	51%
Coordination with downstream device	63%
Coordination with upstream device	65%
Reach (fault current at line end)	39%

Available technology

New type of flexible time-current characteristic (TCC) has been designed in order to support autocoordination algorithm. This characteristics (named TEL A - "TEL Automatic") is supported by the new generation of Tavrída Electric recloser controls (RC02). It delivers minimum possible tripping times if TCC's for downstream devices as well as time and current grades are known. Fig. 1 illustrates typical example of plotting TEL A characteristic.

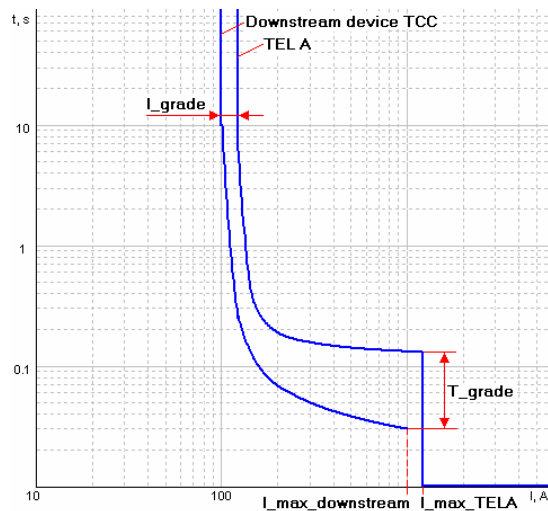


Fig. 1 – Example of plotting TEL A characteristic over TCC of downstream device.

Task formalisation

The following input parameters are taken into account while calculating the shape of the TEL A time-current curve:

- the structure of the feeder: the lengths of lines sections, the points of branching, fuses and reclosers locations, physical and geometric parameters of the lines
- the data on the load connection points and on the load power
- maximum clearing and minimum melting time-current characteristics of the applied fuses
- maximum phase-to-phase and phase-to-ground fault resistance, which must be treated by the protection as a fault
- peak load coefficient
- cold load coefficient
- maximum arcing time limiting duration of fault clearance (even sacrificing coordination with the downstream fuse)
- grade margins for current and time between neighboring reclosers as well as between reclosers and downstream fuses.

The following limitations are applied for calculation of protection settings:

- all reclosers shall provide protection against faults located at all sections located immediately below next downstream reclosers(s) (if any)

- all reclosers shall be insensitive to maximum possible load current at the point of installation
- all slow curves of all reclosers shall allow clearance of the downstream fuses (if fuse clearance time at particular current does not exceed maximum arcing time)
- all fast curves of all reclosers shall provide maximum possible current range where fuse saving is effective
- tripping times of all reclosers within the entire applicable current range shall be coordinated in order to avoid nuisance tripping of the upstream devices
- tripping times of all reclosers within the entire applicable current range shall preserve wire from burning at the point of their installations

As a result of application of the mentioned limitations optimum time-current characteristics shall be automatically calculated.

In general case there are two possible outputs resulted from the mentioned procedure:

- solution does not exist, i.e. at least one of the mentioned limitations cannot be satisfied for any combination of reclosers settings
- solution exists, i.e. for a certain range of TCC satisfies all mentioned criteria.

In the latter case among available solutions the one having the highest pickup currents and the lowest tripping times is selected.

Software implementation

The protection settings automatic calculating algorithms are included in the new version of the Tavrida Electric user software – TELUS 3.0. User is provided with the special visual-style editor, which allows him drawing feeder schematic (Fig. 2) and specify the protection settings calculating criteria. The time-current characteristics of the slow, fast and sensitive elements of the overcurrent and the earth-fault protections are then automatically calculated almost immediately (Fig. 3 - Fig. 6).

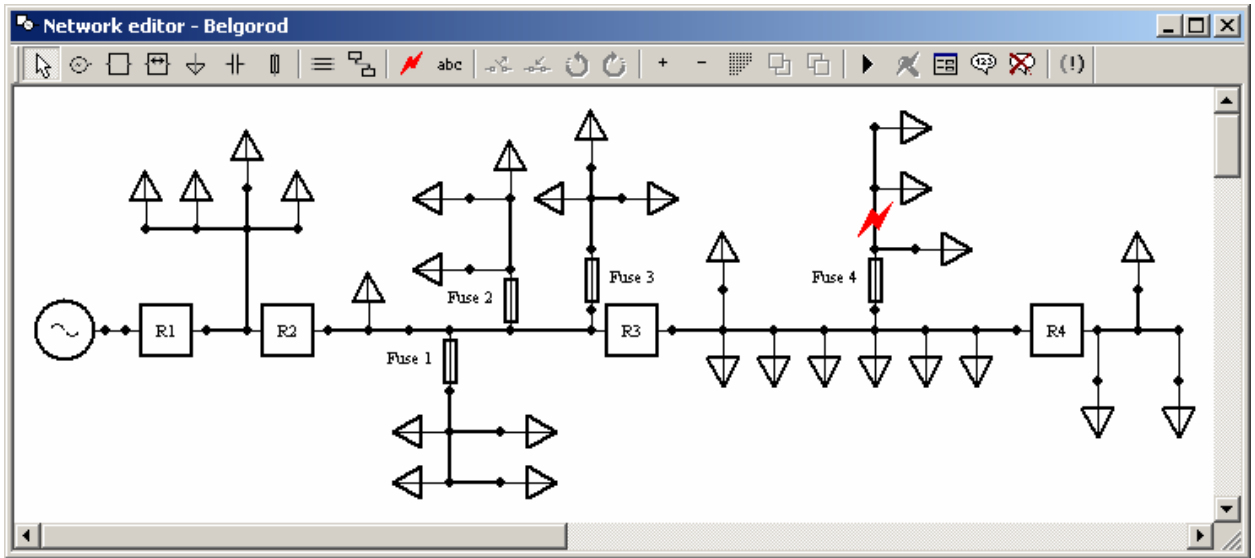


Fig. 2 - Feeder schematic visual editor.

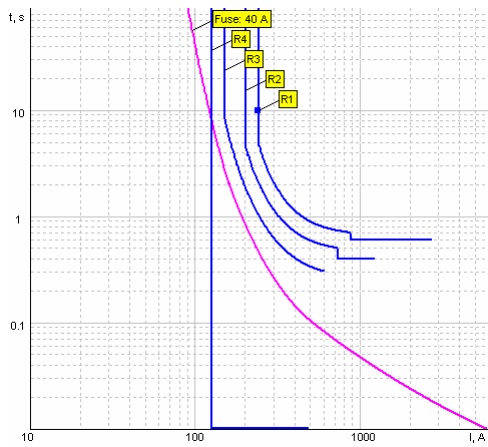


Fig. 3 - Set of slow phase current TCC's for reclosers 1-4 calculated with the aid of autocoordination algorithm for feeder pictured in Fig. 2.

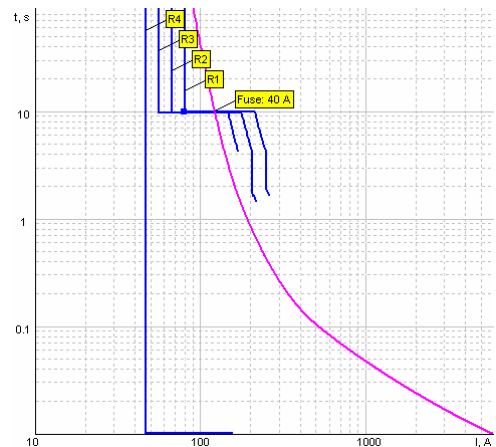


Fig. 5 – Set of slow earth fault TCC's for reclosers 1-4 calculated with the aid of autocoordination algorithm for feeder pictured in Fig. 2.

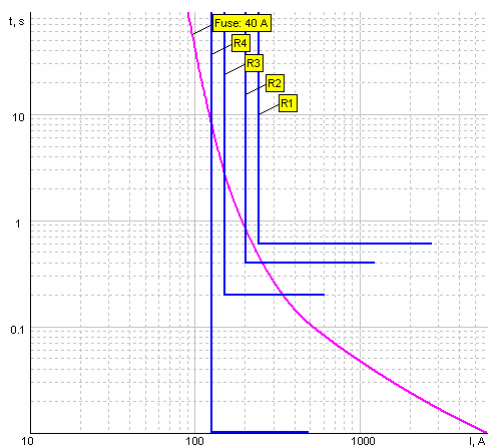


Fig. 4 - Set of fast phase currents TCC's for reclosers 1-4 calculated with the aid of autocoordination algorithm for feeder pictured in Fig. 2.

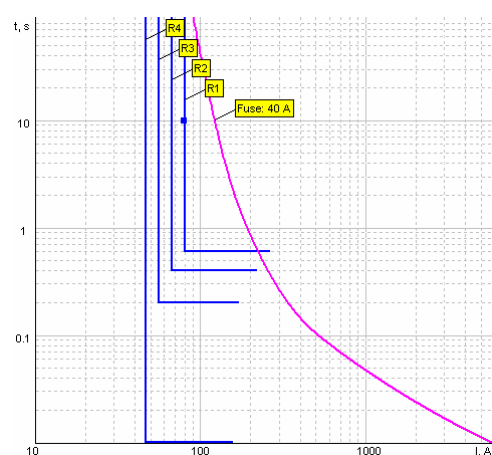


Fig. 6 – Set of fast earth fault TCC's for reclosers 1-4 calculated with the aid of autocoordination algorithm for feeder pictured in Fig. 2.

The user is allowed to correct the value of any setting of any recloser. However, the automatic checking takes place to verify that the new value still corresponds to the recloser-to-recloser coordination conditions, line wires thermal stability criteria, minimal fault current and maximum load current conditions. The correspondent neighbour reclosers' settings are automatically changed to meet the coordination criteria. All changes can be visually watched on the time-current diagram windows (Fig. 3 - Fig. 6).

Designed protection settings are downloaded into recloser simulation model, that implements then exactly the same software code as a real recloser. Afterward correctness of settings can be tested with the aid of feeder simulation model. In order to do this fault model shall be added to the system. Visually it looks as lighting sign (refer to Fig. 2). Mathematically wise it presents 6 conductivities installed between each phase and earth and between phases. Non-zero conductivities determine fault type.

After running simulation dynamic behavior of all devices (fuses and reclosers) for the particular fault is calculated. Setting different fault types at different locations one can test correctness of reclosers operation.

Fig. 7 demonstrated an example of operation of recloser R3 as a reaction to sustained earth fault located downstream with regard to this recloser. At this reclosing sequence has been set for two instantaneous and two delayed trips (IIDD). As one can see in this case R3 provided expected behavior (lockout after three unsuccessful reclosing attempts).

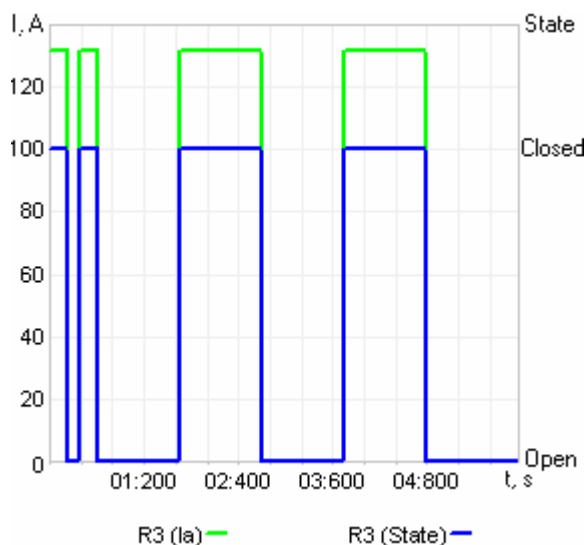


Fig. 7 – Position of main contacts and phase A current seen by R3 during clearance of sustained downstream earth fault.

Another example (Fig. 8) illustrates reaction of the same recloser for the non-sustained earth fault that has been programmed to disappear after second reclosing. As one can see dynamic behavior of R3 again met expectations (restoration of supply after second reclosure).

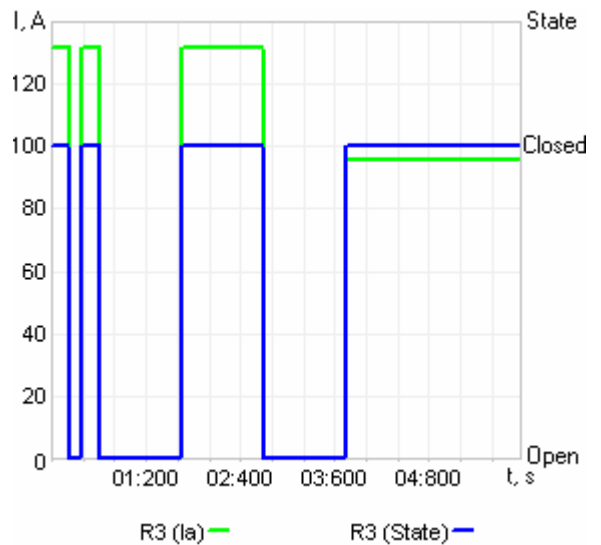


Fig. 8 – Position of main contacts and phase A current seen by R3 during clearance of non-sustained downstream earth fault.

Practical example

Applicability to the new setting design philosophy has been practically tested for the overhead line feeder located in Belgorod District (Western Russia). Topology of feeder is shown in Fig. 2. We ordered setting design work for specialized design bureau that used standard technology and did the same ourselves with the aid of new software.

Afterward we tested both set of settings with the aid of feeder model.

We could not force our set of settings to demonstrate unpredictable behavior, though for the settings designed with the aid of conventional technology few mistakes has been found. This happened despite the fact that standard design procedure has been backed up with professional protection engineers, though in case of advanced procedure virtually no qualification in protection engineering has been required.

It is also interesting to note that conventional procedure took two weeks. At this dynamic testing of settings has not been available. At the same time designing and testing of settings with the aid of new software took two hours including drawing feeder model.

Conclusions

We developed new algorithm and relevant software for automatic calculation and testing settings of series reclosers installed in overhead line.

This algorithm takes into consideration all important considerations generally regarded by protection engineers. At the same time it dramatically reduces requirements for qualification of staff involved in setting design activity. It also allows substantially reducing man-hours required for setting microprocessor relay. Further tests of the real software code (including designed settings) with the aid of feeder model allow ensuring correctness of settings.

On the basis of the above we conclude that this algorithm presents extremely useful tool

for protection engineers that may change dramatically existing setting design practice.

References

1. Oddbjorn Gjerde, Bjorn I. Langdal, Gerd Kjolle, Yngve Aabo, "Utilisation of numerical protection and control for a better handling of reliability of supply and maintenance", Proceedings of the 18th International Conference and Exhibition on Electricity Distribution – CIRED, Turin, June 2005.
2. IEEE PSRC Report "Distribution line protection practises - Industry survey results", December 2002.