

TESTING SOLUTIONS OF THE PROTECTION SYSTEMS PROVIDED WITH DELAY MAXIMUM CURRENT RELAYS

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Keywords: power system protection, current relays

Abstract: Relay protection is one of the main forms of automation control of electro energy systems, having as primary aims fault detection and disconnection of the faulty element in order to avoid the extent of damages and the as fast as possible recovery to the normal operation regime for the rest of the system. Faults that occur in the electro energy system can be classified considering on one hand their causes and on the other their types, but in the vast majority of cases the causes of the faults are combined. Further, considering their nature, faults are classified in faults due to the insulation's damage, in faults due to the destruction of the integrity of the circuits and faults determined by interruptions. With respect to their nature, faults are short circuits, earthing faults and phases interruptions. At the same time, considering their type, faults are divided in transversal and longitudinal ones. The paper presents a testing solution of the delayed maximal current relays using a T3000 ISA Test measuring equipment.

1. INTRODUCTION

A very important issue of the a. c. power grids consists in defining the command, control and protection strategy, meant to assure the normal, safe and stabile operation of the system.

There are several elements which must be considered in the choice of the protection system. The design and the choice of a protection system implies the knowledge of the faults that may appear in electric grids. From the point of view of the effects, immediate or delayed in time, these faults may be of a greater or lesser intensity. Current relays represent the primary protection in the distribution systems. The development of electronic devices, replaced the old electromechanical technology, used in the first generations of protective relays, with the static

technology. However, static relays present several drawbacks, since analog circuits are very sensitive to electromagnetic interference. On the other hand, the magnitudes of the voltage and the currents are limited in analog circuits, affecting the relay sensitivity.

Embedding a microprocessor in the architecture of a relay, which emulate the function and the logic of a relay dates from the early eighties.

Digital relays represent sophisticated equipment, having multiple uses and having the possibility of recording signals during the fault, monitoring and communicating with other relays in the grid. Digital relays use dedicated microprocessors for processing digital signals, being therefore more rapid, and efficient, but maintaining in the same time their economic advantage.

Most of situations, it is impossible to investigate the above mentioned features in a real case of a system, due to different economic, functional or security impediments. Therefore, several approaches and equipment have been developed, in order to overcome these deficiencies: e.g. real time digital simulators (RTDS), reversible real time digital simulators and software packages for modeling protective relays [1].

Digital models of the protective relays offer an economic and reliable alternative in the analysis of relays performance and of the protection systems. At the same time, they permit a detailed analysis of the performance at the level of each internal module. Implementation of new algorithms is improved using modeling, which offers the possibility of settings and corrections, before testing the prototypes and launching the production process. For more specific problems, the use of the models offers the possibility of novel solutions, if the usual configurations are not satisfactory.

2. CURRENT PROTECTION

The principle, consisting in the protection of the overcome of the limit values of the current, was the basis of the early protection systems. Starting from this basic principle, step maximum current protection systems have been developed. For an accurate operation of these relays, one must know the fault currents in each element of the grid [2, 3, 4].

The compulsory data for the relay settings are:

- ✓ the wiring diagram of the protected system, consisting in the protection relays and the associated current transformers;
- ✓ the impedances of the elements of the system (generators, transformers, transmission lines);
- ✓ minimum and maximum values of the short circuit currents in each protection location;
- ✓ starting currents of electric motors;
- ✓ maximum load current in each protection location;

- ✓ the decay curves of the fault current supplied by the generators;
- ✓ current transformers characteristics.

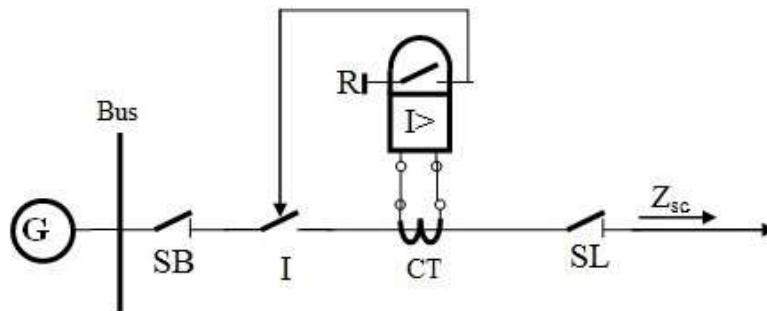


Fig. 1. Maximum current protection schematics.

The current relay settings must be checked in the first instance for the maximum value of the short circuit current. The reaction time must be minimum. Afterwards, the operation of the relay for minimum short circuit current must be checked. The reaction time must be satisfactory.

The wiring diagram of a maximum current protection for a radial network power system is depicted in *fig. 2*, where the bus insulator is denoted by SB, the line insulator, by SL, the breaker by I, the current transformer by TC and finally by $I >$ the maximum current relay.

The main devices composing this protection system are the maximum current relays and the current transformers.

The tripping condition of the relay is:

$$I_c \geq I_p \tag{1}$$

where I_c represents the current in the surveyed circuit and I_p the tripping value of the relay, with respect to the primary winding of the current transformer. Note that this protection acts in a short circuit situation (instantaneous tripping with breaking) and doesn't fit for protection against overloads. The overload protection is also a current protection, but a delayed one. The delay is needed for discriminating between transient and permanent overloads, the overloads effects on the elements of the system being delayed in time.

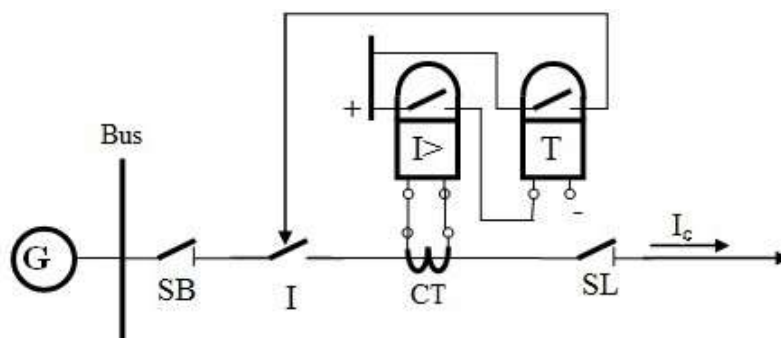


Fig. 2. Overload protection relay schematics.

Note that the contacts of the both relays, the maximum current relay $I >$ and the time relay, perform a logic AND function. Consequently, the tripping of the breaker appears only if the current in the circuit overcomes the set value I_p and the duration t_c exceeds the delay time t_p :

$$(I_c > I_p) \text{ and } (t_c > t_p) \quad (2)$$

Maximum current relays may present an independent characteristic curve, when the tripping time does not depend on the magnitude of the fault current, or a dependent one, when the tripping time depends on the magnitude of the surveyed circuit (which is a multiple of the set current). Consequently, this type of protection is characterized by the following features:

- ✓ the maximum current protection is the simplest and the cheapest protection (minimum number of components);
- ✓ the settings are pretentious and difficult to achieve in applications;
- ✓ readjustments and even relocating are needed in case of system modifications.

Protection must be selective in order to isolate the faulty area, leaving unaffected the rest of the system. In this respect, the protection device located nearest the faulty location must trip (i.e. the nearest fuse or breaker).

The correct coordination and the selectivity of the current protection may be achieved using several methods. The main possibilities in achieving selectivity are based on the following discrimination methods:

- ✓ discrimination by time;
- ✓ discrimination by current;
- ✓ discrimination fault direction;
- ✓ discrimination by both time and direction;
- ✓ discrimination by both time and current.

3. SECONDARY CURRENTS INJECTION DEVICE T 3000

A short circuit in the energy system imposes the isolation of the fault location with respect to the source, using commutation equipment. The electric arc occurring between the contacts, following the deionizing processes, determines a quick wearing of these equipment. If the short circuit duration is reduced, the protection system doesn't determine the disconnection, through the maximal delayed current relays.

The operation norms of the maximal delayed current relays impose that at several time intervals, the protection characteristics should be tested and set at the imposed values.

Checking the protective relays is made in laboratory, using secondary injection equipment (the authors of this paper have used the T/3000 [7, 8, 9] equipment, a complex verifying kit, *fig. 3*, permitting tests on all types of relays which can be tested on monophasic

faults, respectively all other possible tests on voltage and current transformers, on energy meters and on transducers as well.

The basic function of the equipment T/3000 is to generate currents and voltages, depending on the type of test, which is set on the LCD display.

The test results are stored in the internal memory of the equipment. These results can be subsequently transferred to a PC.

The equipment is provided with three generators:

- ✓ the main generator, having six outputs: high value alternating current, low value alternating current, low value direct current, current impulses, high alternating voltage source and low alternating voltage source;
- ✓ an auxiliary alternating voltage generator, generating an independent voltage phase adjustable;
- ✓ an auxiliary direct current generator used to feed relays under test.

All outputs are adjustable and metered on the large graphic LCD display. With the multi-purpose control knob and the graphic LCD display it is possible to enter the MENU mode that allows to control all functions and makes T3000 the most powerful testing device, with manual and automatic capabilities and with the possibility to transfer test results to a PC via the RS232 interface.

Other key features of the equipment are:

- ✓ oscilloscope function, permitting to display the measured current and voltage waveforms;
- ✓ other two independent measurement inputs for current and voltage, both with High and Low inputs, permitting the measurement of the output of current and voltage transformers and of any other sources;
- ✓ a print option of the saturation curve of the current transformer and other test results;
- ✓ an auxiliary output contact that follows Start and Stop inputs, allows simulating the circuit breaker.



Fig. 3. Secondary currents injection kit T 3000.

All the outputs of the T3000 kit are measured continuously. The waveform display function is useful in the case of distorted current or voltage.

In order to test the relays, it is important to use the set function of the injected power, due to the fact that the power of the nowadays relays is reduced. Because the current output is a voltage generator with low impedance, the adjustment of the low currents or of the injected currents on reduced loads is difficult because the operation in the initial area of the adjustment device is needed. The solution consists in reducing the available power in order to achieve a desired precision. Consequently the maximum voltage is reduced with a suitable factor.

The operator has different possibilities that permit to perform tests according to the characteristics of the relays. Some parameters, unused for a certain test are however visualized and saved. For instance, the auxiliary alternating voltage is also saved when a maximum current relay is saved, even though this function is not used.

For testing the transformers, there is a window for each type of test and the testing parameters are visualized and saved.

Each setting can be saved in the memory having the possibility to be reused afterwards. A fix number of tests can be saved and reused, the initial setting being that corresponding to the fault. The settings are continuously saved in the memory of the equipment, new settings being stored at the same address after the confirming requirement. In normal use, only the access to the standard settings is possible.

During the test, in the internal memory of the equipment can be saved up to 500 different tests. When a test is finalized, the settings along with the corresponding results can be stored in a personal computer where the X.PRO-3000 software is installed, which permits the revisualization of the results. When a PC is connected to the T3000 kit during the tests, the settings are available on the X.PRO-3000 interface.

Together with X.PRO-3000, the TDMS software is a powerful software package providing data management for acceptance and maintenance testing activities. Electrical apparatus data and test results are saved in the TDMS database for historical results analysis. TDMS software organize test data and results for the majority of electrical apparatus tested with ISA test sets and related software. TDMS software controls and provide data acquisition from all ISA Test.

TDMS has a built-in report editor that allows to generate professional test report for a single test object, for a group of tested devices or for an entire substation. It can create customized report or use standard forms. TDMS tests report can be exported in MS Office (Word and Excel), PDF or RTF formats.

TDMS is the control platform to run all ISA test software. Test programs, calibration, firmware, software upgrade and languages are all managed from TDMS.

The TDMS software platform allows the user to select easily and quickly the most appropriate software package for the required application. TDMS test software uses an open architecture easily expandable with additional software modules at any time.

TDMS package can be used to test any protective relays in: power generation plants, distribution and transmission networks and industry.

Manual control module has the following main characteristics:

- ✓ Intuitive graphic interface;
- ✓ Virtual front panel control;
- ✓ Graphical vector control;
- ✓ Ramp test: sequence of tests with ability to ramp any parameter up or down at the same time;
- ✓ Threshold test: automatic determination of threshold (current, voltage, frequency, phase angle);
- ✓ Rate of change (gradient) tests of frequency, voltage, current, phase angle and Vdc (Dx/Dt);
- ✓ Sequence editor;
- ✓ Test of distance relays with direct import of relay characteristics with RIO Format.
- ✓ Test of distance relays with simulation of all types of faults: single phase, two phase, two phase to ground, three phase;
- ✓ Report manager allows test report customization to user requirements;

Comrade Module permits:

- ✓ Playing back transient signals and waveform generation;
- ✓ Playing back transient signals from digital fault recorders and numerical relays;
- ✓ Analysis of relay operating time;
- ✓ Graphical view and replay of analog and binary signals;
- ✓ Impedance locus display;
- ✓ Scaling, cut, copy and paste of the analog signals.

The program Control Tab has a new layout, namely the relays Test Plan and Editor, which gives the user the possibility to create and run different test plan for different applications. The Plan Editor is available to create a test plan using predefined macro functions available for any type of relays. This new feature is particularly useful for testing multifunction relays.

The Test Plan can be associated to any relay in TDMS network structure and prior execution define relay setting and characteristic.

The Test Plan can be run on a specified relay: the entire test plan can be executed and/or the user can select the macros to execute on that relay according to its needs.

Finally, the Test Plan can be printed and saved automatically into the TDMS database.

4. EXPERIMENTAL RESULTS

Using the T3000 testing equipment the authors of the paper performed tests on several relays and current transformers.

The results of the tests, are displayed in the most simple cases using the internal memory using the section Results or using the software TDMS, *fig. 4-7*.

The Sequencer module is a software for determining the relays operating time and the logical sequence of the event.

- ✓ Overcurrent module for automatic testing of overcurrent relays, including all the standard curves IEEE and IEC [5, 6];
- ✓ Differential relays module, for automatic testing of differential relays (transformers, generators and bus bars);
- ✓ Line differential module, for automatic testing of line differential relays;
- ✓ Directional module, for testing of earth directional relays;
- ✓ Synchronizing module, for automatic testing of synchronizing devices with three or six voltages control;
- ✓ Swing Pro module, for testing power swing blocking and out of step function;
- ✓ Multifunction relays, which can be tested easily creating customized test plans;
- ✓ Harmonic generator module, allowing the creation of arbitrary harmonic waveform.

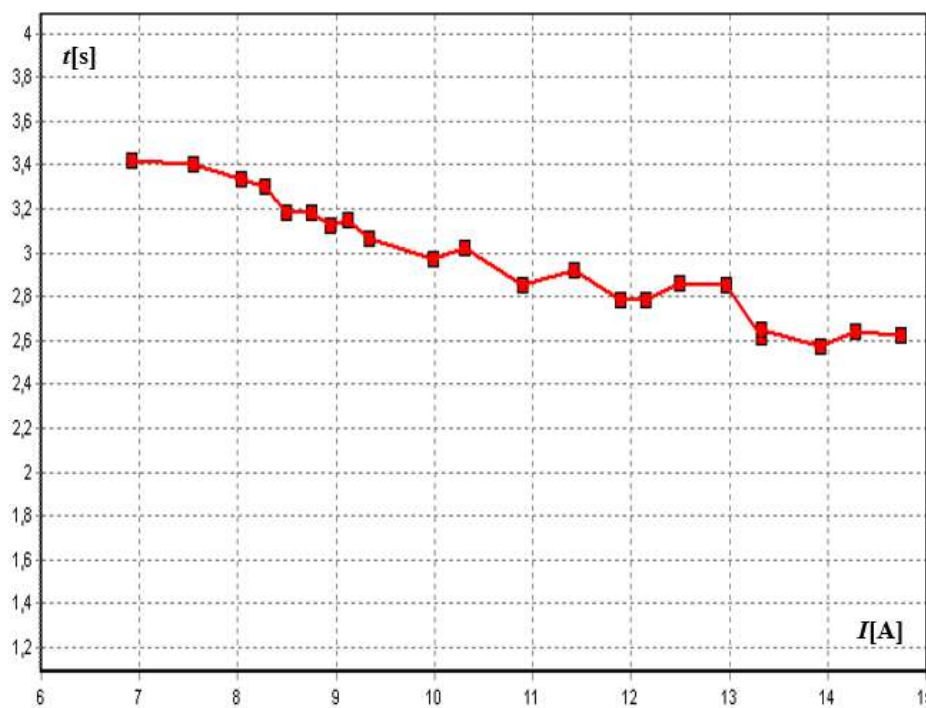


Fig. 4. Maximal current time relay RTpC-1; Set to 2 s and 6 A.

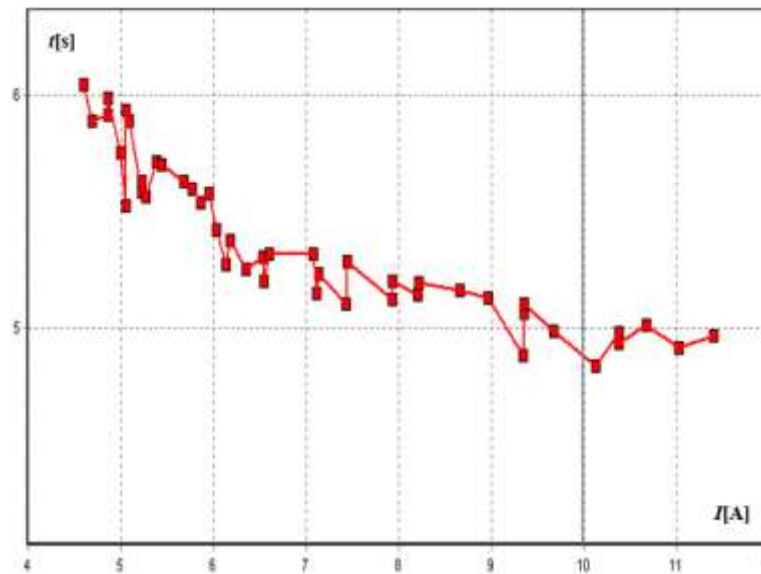


Fig. 5. Maximal current time relay RTpC-1; Set to 4 s and 4 A.

Taking into account the fact that the maximal time current relays permit a continuous setting of the timing, it is important that using the measuring kit to obtain an interdependent characteristic, as that presented in fig. 8 for the RTpC-1 relay.

The maximal induction time relay are nowadays quite rarely used in protection systems, due to the interdependent time-current characteristics. A better performances version is represented by the protection scheme presented in fig. 2. The scheme is composed by a current relay along with a time relay, presenting an independent characteristics time-current.

The test equipment T 3000 permits the separate check of the two components of the protection system, the RC2 current relay and the RTPa-5 time relay, and in the same time determines the error of the measured value related to the setted value.

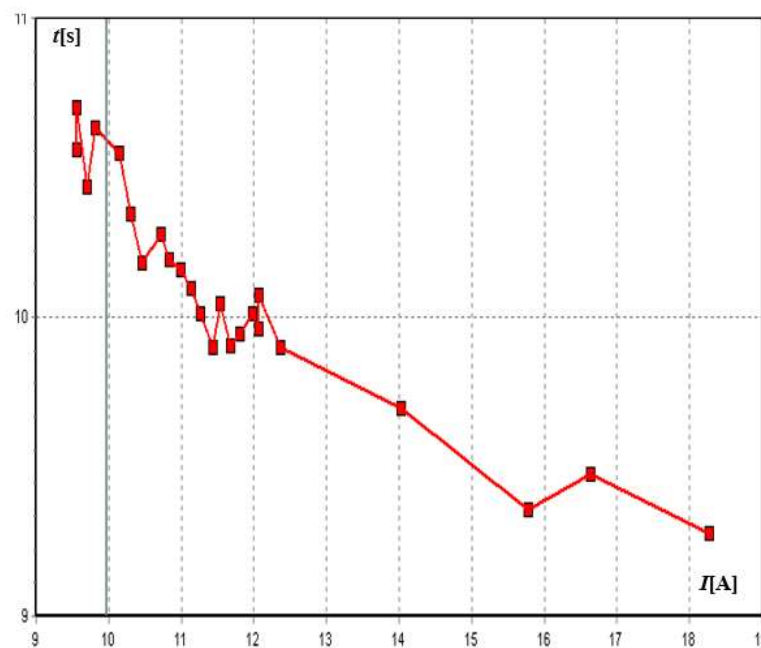


Fig. 6. Maximal current time relay RTpC-1; Set to 8s and 8 A.

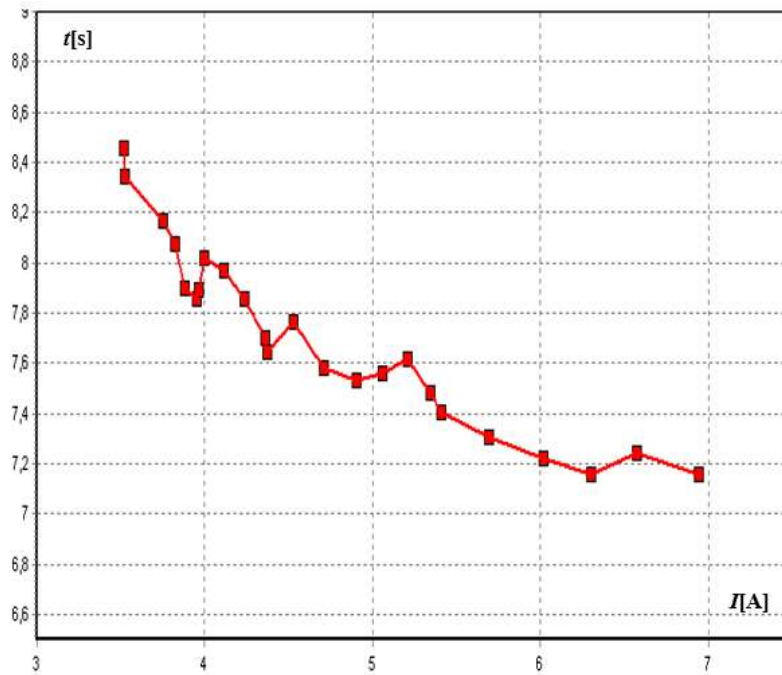


Fig. 7. Maximal current time relay RTpC-1; Set to 6s and 3 A.

5. CONCLUSIONS

Continuity in electric energy supply and the most rapid alleviation of the electric systems faults, in order to recover to a normal operating regime of these systems, means mostly a safe and a correct operation of the protective relays.

A key role in assuring these conditions have got the test equipment, used at the commissioning and the maintenance of the protection devices from the transformer stations and substations.

The choice of the appropriate measurement kit for verifying, testing, commissioning and maintenance is essential and must be considered in its technic and economic aspects.

In the choice of the T 3000 ISA TEST, the pros of this equipment have been considered, i.e. the checking possibility of all types of relays, of energy meters, of different transformers, along with the measurements of the earth resistivity, several ohmic tests, etc.

Using an equipment T 3000, equipped with a TDMS CT-VT-PT module in the measurements performed on a RTpC-1 induction relay, which have in their component a transformer with eight outputs, is very suitable because this module permits recalling previous measurements saved in the internal memory of the equipment, displaying in real time the measured values and the relay characteristics, *fig. 8*, and in the same time processing the results of the measurements.

In the case of a maximal time – protection system having in its component the a current relay RC2 and the time relay RTPa-5, the software package TDMS permits the automated computation of the errors and their storage in a graphic or a tabular form.

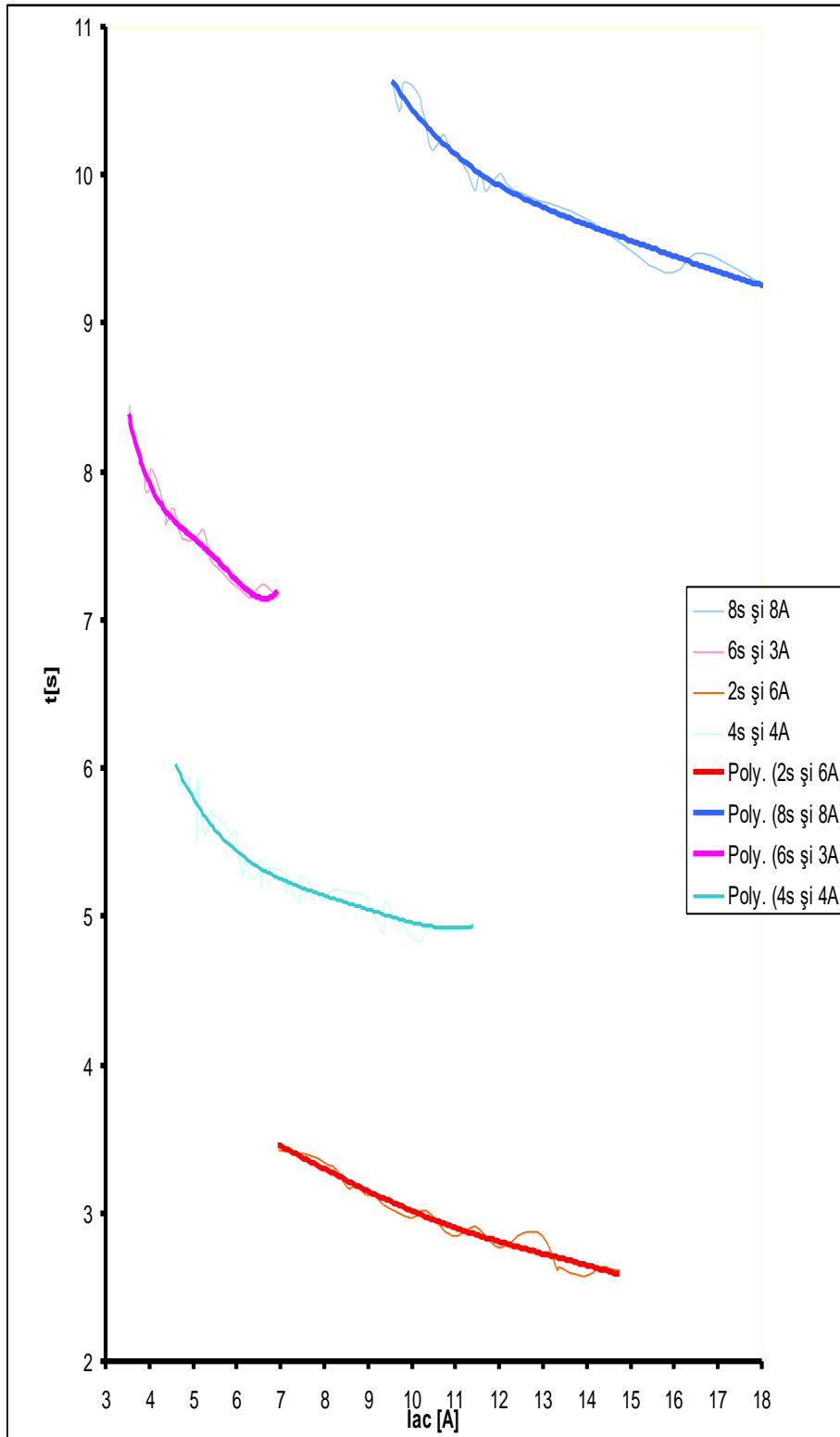


Fig. 8. Maximal current time relay RTpC-1, $i(t)$ dependent.

It is however true that the tests for the mono phase faults are not sufficiently accurate. For these type of faults a more suitable test equipment should be used (for instance a secondary currents injection kit, like Mentor 3V3I [10]). This last kit can successfully replace the equipment presented previously.

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