DEVELOPMENT OF OVERCURRENT PROTECTION RELAY MODEL USING IEC 61850-9-2 SAMPLED VALUES

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Abstract: This document deals with the overcurrent protection relay model using sampled values according to IEC 61850-9-2. In general this is only an abstract concept of relay model, which will be improved in next years. Developing overcurrent protection relay model using Sampled Values is part of TACR project called Medium voltage network protection system using current and voltage sensors with standardized digital interface based on IEC 61850-9-2. Very simple comparison with the classic overcurrent protection relay ABB REJ 525 is shown in document. New proposals were recognized after this testing. Document focuses also on new proposals which will be implemented into the relay for the best function.

Keywords: LabVIEW, overcurrent, protection, relay, model, sampled values,

1. INTRODUCTION

Implementation of process bus is very actual theme, because it helps with utilization of the switchgear and allows producers using current and voltage sensors for metering in switchgears. Medium voltage sensors use non-conventional principles such as Rogowski coil for current sensors and voltage dividers for voltages sensors. Using current and voltage sensors will significantly change design of the substation and systems of the substation such as protection, monitoring and control by replacing hardwired interfaces with communication links. The main benefits of the implementation IEC 61850-9-2 Process bus are reduction in the cost of the system and practical elimination of the current transformer saturation and also the flexibility of the whole system is improved. Current and voltage sensors are connected to the merging units, which are converting analog measured values to the digitalized sampled values. Sampled values are transferred via Ethernet to the IEDs where are evaluating. [4]

One of the most extensively used type of protection is overcurrent protection relay. If settings of parameters are set wrong in overcurrent protection; it can lead to big disaster. Algorithm of the overcurrent protection must be designed for protecting against dynamic and thermal effects of the overcurrent. [3]

Overcurrent protection relay model has been programmed in LabVIEW development environment. This environment has been chosen because it has multiple functions and programmed blocks, which should help for the best design of the algorithm. Verification of sampled values is done by Sampled Values Analyzer. It can also visualizes sampled values. After verification the data are sent to LabVIEW directly by DataSocket Server.

For the evaluation of designed algorithm, there has to be comparison with one of the existing protection relays. For the comparison has been chosen relay from ABB - ABB REJ 525. Comparison with the existing relay helps to find weak points of the algorithm and brings new ideas to the next development.

2. OVERCURRENT PROTECTION RELAY

This type of protection is used to protect against over currents. Basic algorithm of overcurrent protection compares the measured value of current with preset value as it is shown in Figure 1. If the input current exceeds preset value, protection algorithm evaluates that overcurrent occurred and sends trip signal to the circuit breaker. Circuit breaker opens its contact to disconnect protected equipment and avoid damage.

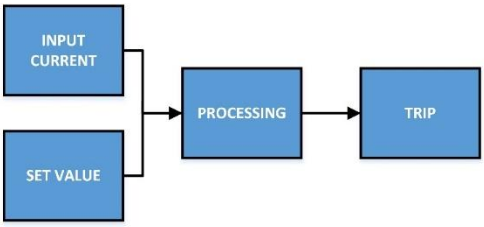

Figure 1: Basic diagram of overcurrent protection

If the trip signal is sent immediately after detection of overcurrent, it is instantaneous overcurrent relay, but if the trip signal is sent after a specific time then it is time-overcurrent relay. This time delay is called operation time of relay and it is computed by the relay on the basis of protection algorithm.

2.1. CLASSIFICATION OF OVERCURRENT RELAYS

Overcurrent relays are classified according to the operation time, into the three categories:

Instantaneous overcurrent relay:

Trip signal is send immediately to the circuit breaker as soon as the overcurrent has occurred. There is no time delay. Instantaneous overcurrent relays are used close to the source where the fault current level is very high and a small delay in sending trip signal can cause big damage to the protected equipment. Instantaneous characteristic curve is shown in the Figure 2. [3]

Definite time overcurrent relay:

Trip signal is sent after a specific time to the circuit breaker. This type of overcurrent relay is usually implemented for backup protection. If the main relay does not operated and send a trip signal then backup overcurrent relay must operate and send trip command to the breaker. Overcurrent relay is time delayed by a specific time which must be greater than the normal operating time of the main relay plus the breaker operation time. Definite time characteristic curve is shown in the Figure 2. [3]

Inverse definite minimum time overcurrent relay:

This type of overcurrent relay has operation time inversely proportional to the fault current. The characteristics of inverse time overcurrent relay depend on the type of standard selected for the relay operation. These standards can be ANSI, IEEE, IEC, or user defined. Any of these standards can be used to implement a characteristic curve for an overcurrent relay. Operation time is calculated by the relay which uses the characteristic curves and their corresponding parameters. Constants for relay characteristic types are in the Table 1. Inverse definite minimum time characteristic curve is shown in the Figure 2. [3]

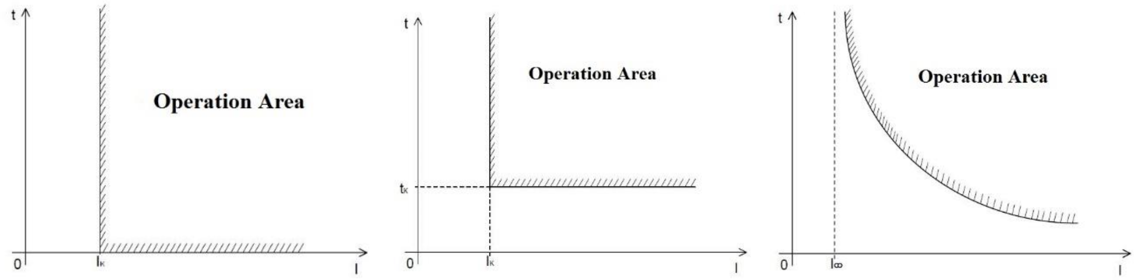

Figure 2: Instantaneous, Definite time and Inverse definite minimum time characteristic curve

IEC 60255 – 151 [2] defines equation for characteristics of IDMT relays:

$$\boldsymbol{T} = \frac{\boldsymbol{\beta}}{\left(\frac{\boldsymbol{I}}{\boldsymbol{I_n}}\right)^{\boldsymbol{\alpha}} - \mathbf{1}} \cdot \boldsymbol{TMS} \qquad (3)$$

Where

T – relay operation time,
β – constant for relay characteristic,
I_n – current set point,
I – current input to the relay,
α – constant representing inverse time type ($\alpha > 0$),
TMS – Time multiplier setting controls the relay tripping time.

Relay characteristic type	α	β
Standard Inverse	0,02	0,14
Very Inverse	1	13,5
Extremely Inverse	2	80
Long Inverse	1	120

Table 1: Types of Inverse characteristic curves

3. OVERCURRENT PROTECTION RELAY IN LABVIEW

The main task of this paper is to show how could be sampled values evaluated in LabVIEW for protection functions and also testing of the developed algorithm. Developed and tested algorithm is Definite Time Overcurrent protection algorithm. Simple functional block diagram of programmed relay is shown in Figure 3.

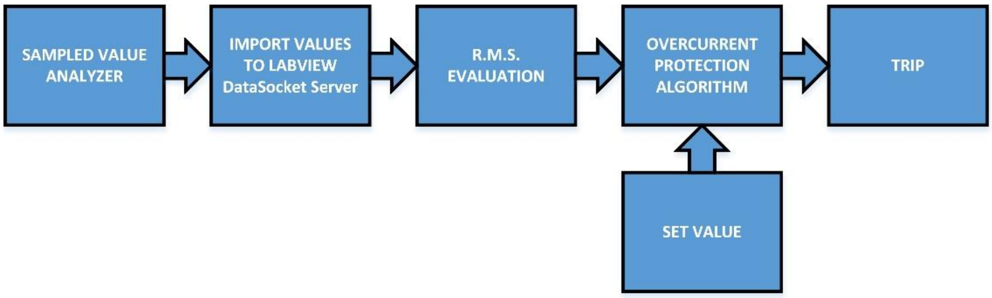

Figure 3: Block diagram of protection relay model

3.1. IMPORT SAMPLED VALUES

In the first step Sampled Values are verified by Sampled Value Analyzer. This tool verifies if data transmitted over the Ethernet meet the requirements of the IEC 61850-9-2. Export to the LabVIEW is realized by activation of DataSocket Server. Then all measurements are available on unique address and they can be read in LabVIEW. Values are saved in two dimensional array. One dimension of this array corresponds to each measurement, the second dimension represents a certain number of measurement samples.

3.2. R.M.S. EVALUATION

One of the main parts of the overcurrent protection relay is evaluation of current value which comes to protection algorithm. At first zero crossing of the current waveform is evaluated. After that the R.M.S. is computed every cycle. For both function are used functional blocks from LabVIEW Electrical Power Suite.

3.3. COMPARISON WITH SET VALUE

After the R.M.S. is obtained, this value is fed into the protection algorithm. Protection algorithm compares R.M.S. value with preset value. If the input current exceeds the preset value, the relay starts counting the preset value of time. When the operation time is elapsed the trip signal will be sent to the circuit breaker.

Graphical user interface of overcurrent protection allows to set the current value and operation time. There are also charts showing current and voltage in real time.

4. TESTING

Designed algorithm was tested with relay test set OMICRON CMC 353. Block diagram of test set is shown in Figure 4. OMICRON CMC 353 was connected to the computer via Ethernet. Parameters of the testing signal were set in QuickCMC application. Testing signal was sine wave AC current - magnitude 2 A and phase 0°. Set current was 1 A in the algorithm and time was set according to the Table 2.

Testing signal was sent to the LabVIEW Overcurrent Protection Relay Model via Ethernet according to IEC 61850-9-2 Sampled Values. Same signal was sent via classic hardwired way to the protection relay ABB REJ 525, it is combined overcurrent and earth-fault relay. Main task of the test was comparison of the operating times between developed LabVIEW Overcurrent Protection Relay Model and classic overcurrent protection relay ABB REJ 525. Results of the test are shown in the Table 2.

After testing it could be seen that there is problem in designed algorithm in evaluation the trip when the time is not set to the 1 second and it multiples.

SET TIME [ms]	ABB REJ 525 [ms]	LabVIEW Overcurrent Protection Relay Model [ms]	$\delta_{ABB\ REJ\ 525}$ [%]	$\delta_{LabVIEW\ Model}$ [%]
200	207,7	1003,0	3,71	80,06
700	705,3	987,0	0,75	29,08
1000	1000,0	1004,0	0,00	0,40
1500	1510,0	2030,0	0,66	26,11
2000	2002,0	2019,0	0,10	0,94

Table 2: Trip times of the ABB REJ 525 and developed algorithm

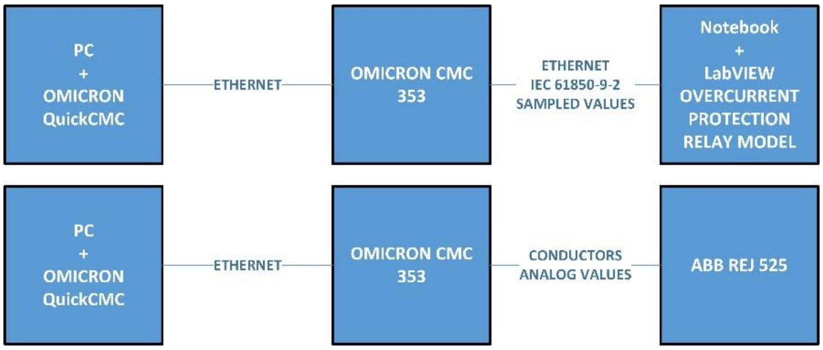

Figure 4: Test set of developed overcurrent protection relay model

5. CONCLUSION

In the first step of development a simple overcurrent protection relay model was programmed. Function of programmed algorithm was tested with OMICRON CMC 353 and in comparison with the combined overcurrent and earth-fault relay ABB REJ 525. The test was not successful because the operating time was in some cases too long.

Main problem is in speed of algorithm. Values from Sampled Value Analyzer are sent in one second block, each block consists of four thousands of values. Developed algorithm is not fast enough to compute R.M.S from this amount of values and compare computed R.M.S. with preset value.

Some improvements were proposed for the algorithm which shall be considered in the next development. The algorithm shall be reprogrammed using producer/consumer pattern which will help in speed of evaluation and efficiency of the algorithm and also buffer will be implemented.

After development there will be functional model of the directional overcurrent protection relay model programmed in LabVIEW, which could be used for protecting the real machine against overcurrent.

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