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STUDYING MAIN CHARACTERISTICS AND APPLICATION POSSIBILITIES OF A DIGITAL PROTECTION RELAY

Radoslav Yordanov – Student
Department of Electrical Power Engineering,
University of Ruse "Angel Kanchev"
Phone: +359 892 955 704
E-mail: s203121@stud.uni-ruse.bg

Assoc. Prof. Ognyan Dinolov, PhD
Department of Electrical Power Engineering,
University of Ruse "Angel Kanchev"
Phone: +359 82 888 330
E-mail: odinolov@uni-ruse.bg

Abstract: *This article explores the digital relay protection Argus 7SR10 of a widely adopted manufacturer in the field of electrical power systems, focusing on its application in renewable energy sources, particularly photovoltaic electrical plants. The analysis includes an examination of applicable software and key parameters, along with experimental tests yielding new data. Results demonstrate the protection's stable performance, high accuracy of the time-delay mechanism, and an overall unacceptable error rate of 5.61% for current setting non-compliance. The conducted experimental studies substantiate the functionality and applicability of the protection in specific domains. Significantly divergent error levels in time and current aspects of the protection suggest opportunities for effective training activities, enabling learners to observe potential practical situations and draw varied conclusions.*

Keywords: *Digital Protective Relaying, Argus 7SR10, Experimental Tests, Education*

INTRODUCTION

Digital relay protections are an essential part of modern electrical power systems, providing fast and effective protection against various electrical faults. With their ability to monitor and respond to events in real-time, these protections play a key role in ensuring the quality and reliability of power supply.

In an educational context, studying digital relay protections offers students the opportunity to grasp the principles of relay protection, the functions of relay systems, and the technological innovations associated with them. Training using digital relay protections not only provides technical knowledge but also develops analytical thinking and problem-solving skills within the context of complex modern electrical power systems. This is crucial given the continuous evolution of the energy sector and the increasing need for qualified specialists in the field of electrical engineering.

In the field of education related to digital relay protection and automation, some research and developments are found in the literature. A scientific report (Januszewski, M., Kowalik, R., Kurek, K., Rasolomampionona, D., Klos, M., 2022) describes the establishment of laboratory stands and a training method for the configuration of digital relay protections with an emphasis on digital data exchange, such as GOOSE datagrams. The stands have been implemented in the digital relay protection laboratory at the Warsaw University of Technology. New laboratory exercises have been introduced as part of a structured course. Each stand includes two relay protections.

Another report (Kudryavtsev, A., Zatsepina, V., 2022) explores the possibility of creating an intelligent digital laboratory for relay protection and automation. Descriptive characteristics of the microprocessor units used are presented, and the functional capabilities of each individual unit, as well as the interrelationships between them, are analyzed.

In (Gabriel, L., Fujita, G., 2018), an algorithm for control was designed in the LabVIEW programming environment. It is used for practical experimental studies of transformer differential digital protection in a teaching laboratory. The mathematical models used were verified through simulations in SIMULINK, and a software environment with an intuitive user interface was designed. In (Wang, Q., Tang, Z., Knezevic, I., Yu, J., Karady, G., 2016), a laboratory system for training in digital protections was presented. The platform aims to provide learners with practical experience in working with these protections. The laboratory equipment is installed on an experimental bench, which consists of four main parts: an equivalent three-phase power distribution network; a fault generation module; monitoring systems; and digital relay protection systems. In (Sachdev, M., Nagpal, M., Adu, T., 1990), interactive software was developed to evaluate the algorithms used in the design of digital protections. The software includes modules for signal processing and tools for generating test data for the performance evaluation of digital relay systems.

The aim of this research is to study and verify the operation of the Argus 7SR10 digital relay protection with a justification of its potential applications in the development of didactic materials and the provision of educational environments and processes.

PRESENTATION

Research object

The Siemens Reyrolle Argus 7SR10 digital relay protection was chosen as the subject of study. The overall appearance of the protection is shown in Figure 1, and the main technical data are summarized in Table 1. Figure 2 presents the Reydisp Evolution software product for the parameterization and configuration of the protection.

Fig. 1. General view of the Argus 7SR10 digital protection relay

Table 1. Data on the main parameters of a digital protection relay

Type	Reyrolle Argus 7SR10
Manufacturer	Siemens
Rated current, A	1-5
Rated voltage, V	40-160
Rated frequency, Hz	50-60
Operating voltage, V	60-240
Operating power, W	8
Serial number	GF2303517183

Reyrolle Argus 7SR10 is a digital relay protection system designed to provide reliable protection and management of electrical power systems. Developed and manufactured by Siemens, these types of relay protections are intended for application in various types of medium and high voltage electrical networks, ensuring fast and effective detection of fault conditions and protection of elements within the power system from damage.

The technical capabilities of the Argus 7SR10 include advanced algorithms for detecting various types of faults, as well as built-in communication mechanisms that facilitate integration with other energy management systems. The relay protection is equipped with an intuitive user

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interface, simplifying device configuration and monitoring. Designed to meet high standards of reliability and efficiency, the protection system encompasses functions such as overload and short-circuit protection, distance protection, voltage monitoring and control in the power grid, synchronization, and restoration of power supply after faults, data exchange with other devices in the power system, event and data recording for system analysis and issue resolution, among others.

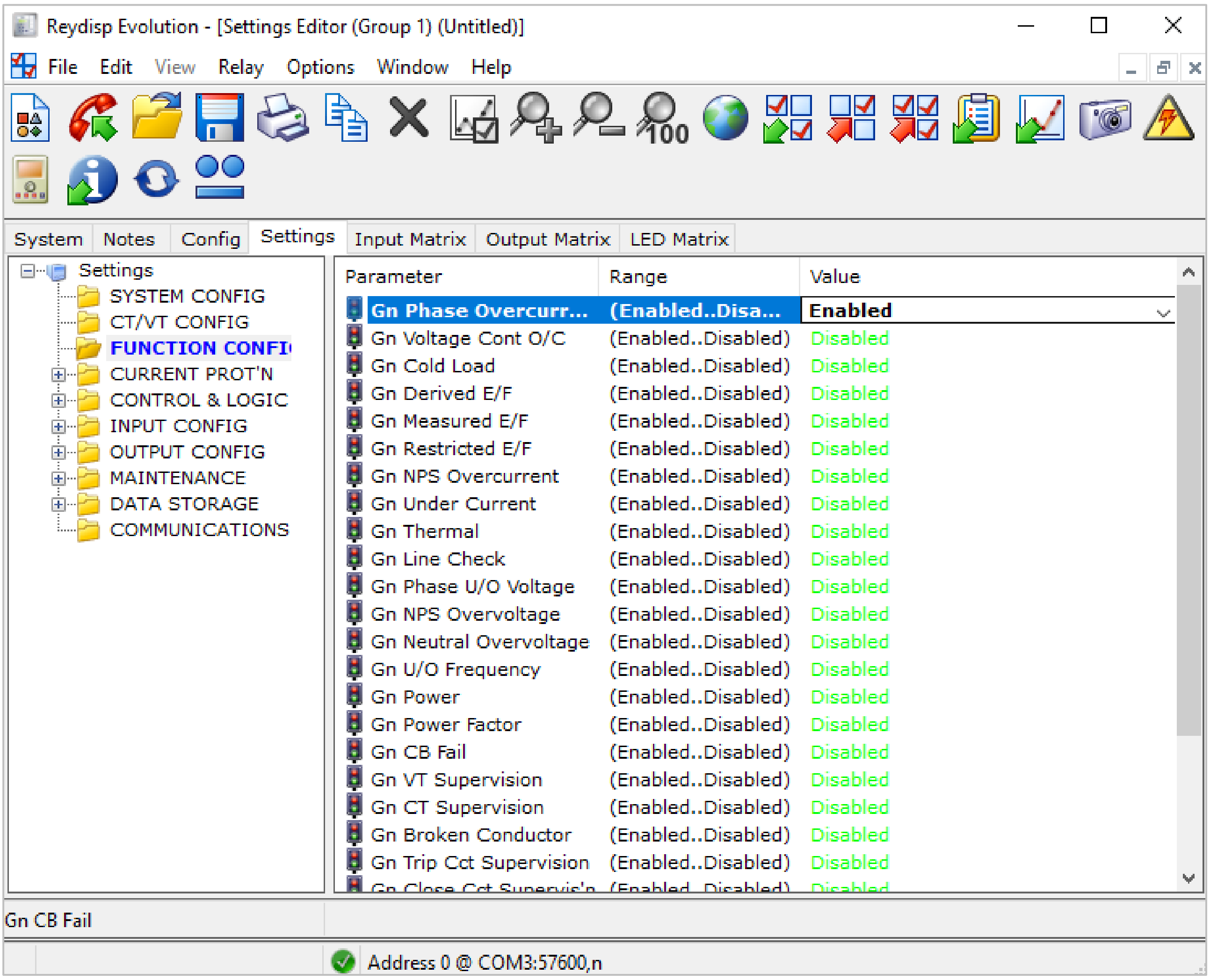

Fig. 2. Fragment of the graphical interface of the software product for configuration and adjustment of the Argus 7SR10 digital relay protection

Research methodology

The experimental setup for conducting the research studies is presented in Figure 3.

The experimental setup involves investigating the pickup current and pickup time of the maximum current protection. The characteristics of the tripping are determined.

In the first experiment, the pickup current of the protection is examined. A specialized device for testing relay protections, the Sverker 760, is used to supply current to the protection. The operating voltage of the protection is provided by the grid. Data from the experiments are recorded from the display of the device. The ON+TIME function is used to measure the exact time delay at which the protection operates.

The investigated protection is configured in real-time using a personal computer with Reydisp Evolution software installed. Through the software, the protection is set to operate as maximum current protection. The pickup current multiplier for each experiment is set. The rated current of the protection, equal to 5 A, is configured based on which the currents on the scale are calculated.

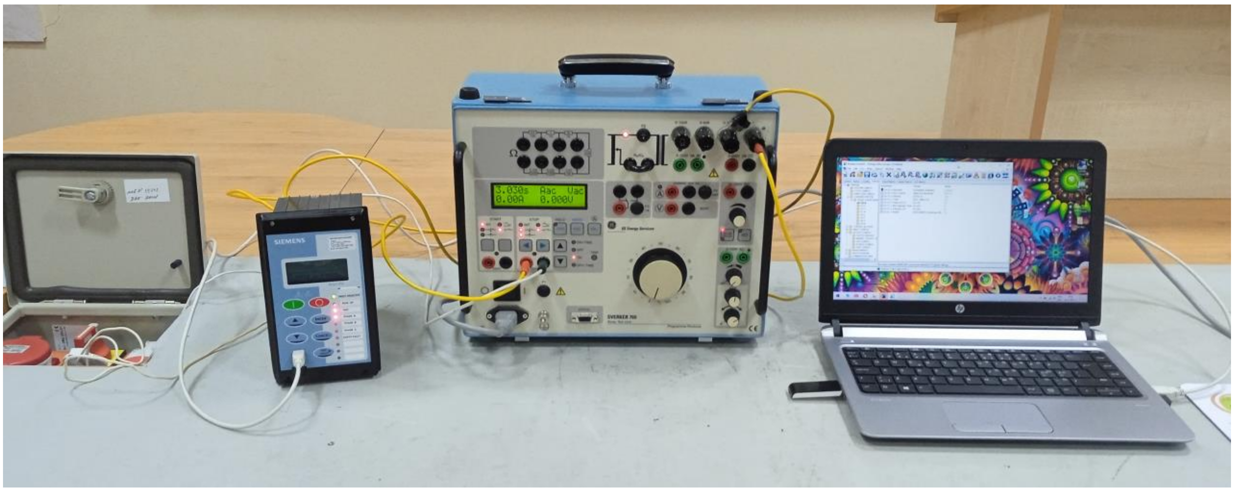

Fig. 3. Experimental setup for research and testing of the Argus 7SR10 protection relay

The experiments are conducted as follows. Initially, the protection is configured. After adjustment, the supplied current is gradually increased with the smallest possible step until the protection operates. The pickup current, operating voltage, and reset current of the protection are recorded from the experiments. The power consumed by the protection, the reset ratio, and the mismatch error of the setting current are calculated.

In the second experiment, the operating time is investigated. For this purpose, using the protection software, the protection is configured again to act as maximum current protection with an intentionally delayed action. The same device is used to supply current to the protection. After configuration, the pickup current is adjusted, and then the current is gradually increased from the power supply until the protection operates. The desired intentional delay time is set using the software. When all operating conditions are met and the delay time is set, current is supplied to the protection using the ON+TIME function, causing it to operate. After the delay expires, the protection contact switches. The operating time is recorded from the display of the Sverker 760. The arithmetic mean value is calculated for each group of experiments, and the tripping characteristics of the operating time are determined.

Results

The results of the studies are presented in Tables 2, 3, and 4, and in Fig. 4.

The following symbolic notations have been used: k – pickup current ratio of the protection; $I_{ск}$ – configured pickup current of the protection; I_{33} – measured pickup current; U_3 – pickup voltage; $I_{в3}$ – reset current; S_{33} – apparent consumed power of the protection; $k_в$ – reset coefficient; ΔI – error of setting current discrepancy; $t_{ск}$ – configured operating time of the protection; t_{33} – measured operating time; $\bar{t}_{33}$ – mean value of the measured operating time; Δt - error of set operating time discrepancy; R[t_{33}] – range of t_{33}; V[t_{33}] – coefficient of variation of t_{33}.

The reset coefficient of the electronic relay varies from 0.83 in experiment 11 to 0.96 in the second experiment. The average value of this coefficient is 0.92. The error of the setting current discrepancy ranges from 4.62% at a setting current of 11.25 A to precisely 8% at the lowest investigated setting current of 1.25 A. In twelve of the experiments, this error exceeds 5%, with an average value of 5.61%.

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Table 2. Data from the study on the pickup current of the digital protection relay

№	**k**	**$I_{ск}$**	**I_{33}**	**U_3**	**$I_{в3}$**	**S_{33}**	**$k_в$**	**ΔI**
-	-	A	A	V	A	VA	-	%
1	0.25	1.25	1.35	0.043	1.24	0.058	0.92	8.00
2	0.50	2.50	2.63	0.087	2.52	0.229	0.96	5.20
3	0.75	3.75	3.97	0.136	3.65	0.540	0.92	5.87
4	1.00	5.00	5.24	0.184	4.91	0.964	0.94	4.80
5	1.25	6.25	6.58	0.232	5.70	1.527	0.87	5.28
6	1.50	7.50	7.89	0.278	7.38	2.193	0.94	5.20
7	1.75	8.75	9.31	0.327	8.75	3.044	0.94	6.40
8	2.00	10.00	10.56	0.37	9.98	3.907	0.95	5.60
9	2.25	11.25	11.77	0.423	10.55	4.979	0.90	4.62
10	2.50	12.50	13.21	0.460	11.9	6.077	0.90	5.68
11	2.75	13.75	14.67	0.506	12.2	7.423	0.83	6.69
12	3.00	15.00	15.82	0.542	14.46	8.574	0.91	5.47
13	3.25	16.25	17.06	0.567	15.36	9.673	0.90	4.98
14	3.50	17.50	18.45	0.614	17.32	11.328	0.94	5.43
15	3.75	18.75	19.63	0.652	18.66	12.799	0.95	4.69
16	4.00	20.00	21.16	0.700	19.44	14.812	0.92	5.80

Table 3. Data from the study on the operating time of the digital relay protection (part 1)

$t_{ск}$	s	2	4	6	8	10	12	14	16	18	20
t_{33}	s	2.02	4.024	6.021	8.022	10.02	12.02	14.02	16.02	18.02	20.02
		2.026	4.026	6.026	8.025	10.01	12.02	14.02	16.01	18.02	20.02
		2.018	4.02	6.021	8.026	10.01	12.02	14.02	16.02	18.01	20.01
$\bar{t}_{33}$	s	2.021	4.023	6.023	8.024	10.013	12.020	14.020	16.017	18.017	20.017
Δt	%	1.067	0.583	0.378	0.304	0.133	0.167	0.143	0.104	0.093	0.083

Table 4. Data from the study on the operating time of the digital relay protection (part 2)

$t_{ск}$ = 3 s $R[t_{33}]$ = 0.007 s $S_{кор}[t_{33}]$ = 0.0025 s $V[t_{33}]$ = 0.083 %													
t_{33}	s	3.025	3.024	3.018	3.023	3.021	3.021	3.023	3.025	3.018	3.021	3.024	3.025

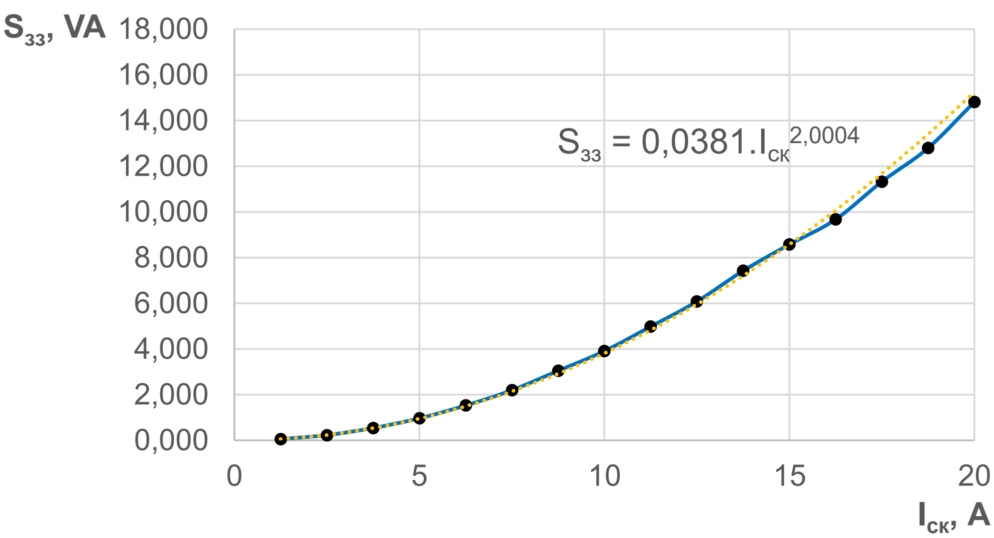

Fig. 4. Graph showing the dependence of the pickup power of the digital relay protection on the configured pickup current of the protection

The error of the set operating time discrepancy within the protection range is lower. Depending on the experiment, it varies from 0.083% to 1.067%, with an average level of around 0.3%. The characteristics of the tripping time dispersion at the same protection setting take on low values. The standard deviation is less than 0.003 s with a range of 0.007 seconds. The coefficient of variation around the mean, expressed in percentages, is 0.083%.

The voltage drop across the protection increases from 0.043 V in the first experiment to 0.7 V in the last, 16th experiment. As the configured pickup current increases, the total power consumed by the protection increases nonlinearly in a quadratic dependency.

CONCLUSIONS

1. The object of the study was selected as a digital protection system from one of the most commonly encountered and adopted manufacturers of products in the field of power engineering. Due to its suitable functional capabilities, the protection system is widely used in one of the most current directions in this field, namely renewable energy sources, particularly photovoltaic power plants.
2. An analysis of the applicable software and the key parameters has been conducted, experiments have been carried out, and new experimental data have been obtained for the selected object. The results demonstrate stable operation of the protection system, very high accuracy of the time-delay mechanism, and an overall unacceptable discrepancy error of the setting current with an average error value of 5.61%. The experimental studies conducted justify the functionality and applicability of the protection system in specific domains.
3. The significant difference in error levels between the time and current settings of the protection system provides grounds for organizing effective training activities, where trainees have the opportunity to observe potential practical situations and draw conclusions of various kinds.

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