https://www.sworldjournal.com/index.php/swj/article/view/swj23-00-006
DOI: 10.30888/2663-5712.2024-23-00-006

УДК 004.2

IMPLEMENTATION OF THE FUNCTION OF STEPWISE CURRENT RELAY PROTECTION BASED ON A PARALLEL OPERATION PROGRAMMABLE LOGIC CONTROLLER

РЕАЛІЗАЦІЯ ФУНКЦІЇ СТУПІНЧАСТОГО СТРУМОВОГО РЕЛЕЙНОГО ЗАХИСТУ НА БАЗІ ПРОГРАМОВАНОГО ЛОГІЧНОГО КОНТРОЛЕРА ПАРАЛЕЛЬНОЇ ДІЇ

Hrytsenko S.D. / Гриценко С.Д.
assistant / асистент
State Biotechnological Universite, Kharkiv, Alchevsky, 44, 61000
Державний біотехнологічний університет, Харків, Алчевських, 44, 61000
Piskarov O.M. / Піскарьов О.М.
c.t.s., as.prof. / к.т.н., доц.
ORCID: 0000-0002-6980-984X
Kharkiv National University of Radioelectronics, Kharkiv, Nauky Avenue, 14, 61000
Харківський національний університет радіоелектроніки, Харків, проспект Науки, 14, 61000

Abstract. *The issue of increasing the reliability of relay protection devices by using programmable logic integrated circuits (PLIC) has been considered.. The algorithm of the current step protection is analyzed and implemented on PLIC using VHDL language. It is shown that the use of PLIC can significantly increase the speed, reliability and noise immunity of relay protection devices. The conclusion is made about the prospect of using PLIC to create highly reliable relay protection systems.*

Key words: *improving the reliability of relay protection devices, programmable logic integrated circuits, FPGAs, parallel-acting controller FPGAs*

Introduction. Relay protection (RP) is designed to protect power systems and its elements from dangerous consequences of damage and abnormal modes. Reliable RP operation is essential for normal and reliable functioning of modern power systems. Currently, microprocessor-based relay protection devices (MPRPD) have been developed and are widely used. However, the practice of their application shows that these devices have typical disadvantages of microprocessor equipment, namely: limited reliability parameters of both hardware and software. Therefore, improving the reliability of relay protection devices is an important and urgent task.

The use of programmable logic integrated circuit (PLIC) technology can eliminate some MPRPD disadvantages, and first of all, replace the serial principle of information processing with a parallel one, which allows to manifold increase the speed, reliability and noise immunity of RP devices and systems [1].

Conducted studies have shown that implementation of RP systems on PLIC is possible [2]. A PLIC parallel action controller was taken to practically test the RP algorithm.

Analysis of recent research and publications.

The analysis of known publications shows that PLICs are widely used to build digital devices of varying complexity and capabilities in various fields. However, no mentions of using PLICs in RP devices were found.

Main research materials.

The main algorithms for the functioning of relay protection with relative selectivity include current step protection. Current cutoff refers to overcurrent

protection that responds to an increase in current. Its main difference from maximum current protection [3] lies in the method of ensuring selectivity. Current step protection is a combination of current cutoffs and maximum current protection, which allows performing full-fledged protection with high speed. Usually, current step protection is performed in three stages:

- instantaneous cutoff - protects the initial line section;
- cutoff with time delay - used for reliable protection of the remaining line section;
- maximum current protection - performs the functions of close and remote backing.

The controlled signal from the current transformer *TA* is fed to the current relays of the first stage *KA1.1*, *KA1.2*, *KA1.3*, second stage *KA2.1*, *KA2.2*, *KA2.3* and third stage *KA3.1*, *KA3.2*, *KA3.3*. In case of short circuit, current relays are activated, which generate one at the output. The signal at the output of logical elements *DW1*, *DW2*, *DW3* becomes equal to one if at least one input signal is equal to one. Elements *DT1*, *DT2* implement a time delay necessary to meet the requirements of protection selectivity. *KL* is the output protection device, *KH1*, *KH2*, *KH3* are signaling elements (Figure. 1).

If the protection behavior is represented as a logical function T, then the tripping condition can be written as:

$$T = (KA1.1 \text{ OR } KA1.2 \text{ OR } KA1.3) \text{ OR } (KA2.1 \text{ OR } KA2.2 \text{ OR } KA2.3) \text{ AND } DT1\uparrow \text{ OR } (KA3.1 \text{ OR } KA3.2 \text{ OR } KA3.3) \text{ AND } DT2\uparrow = 1,$$

where *KA1.1*, *KA1.2*, *KA1.3*, *KA2.1*, *KA2.2*, *KA2.3*, *KA3.1*, *KA3.2*, *KA3.3* are the logical signals at the outputs of the overcurrent protection measuring elements;

DT1 ↑, *DT2* ↑ are time delay operators.

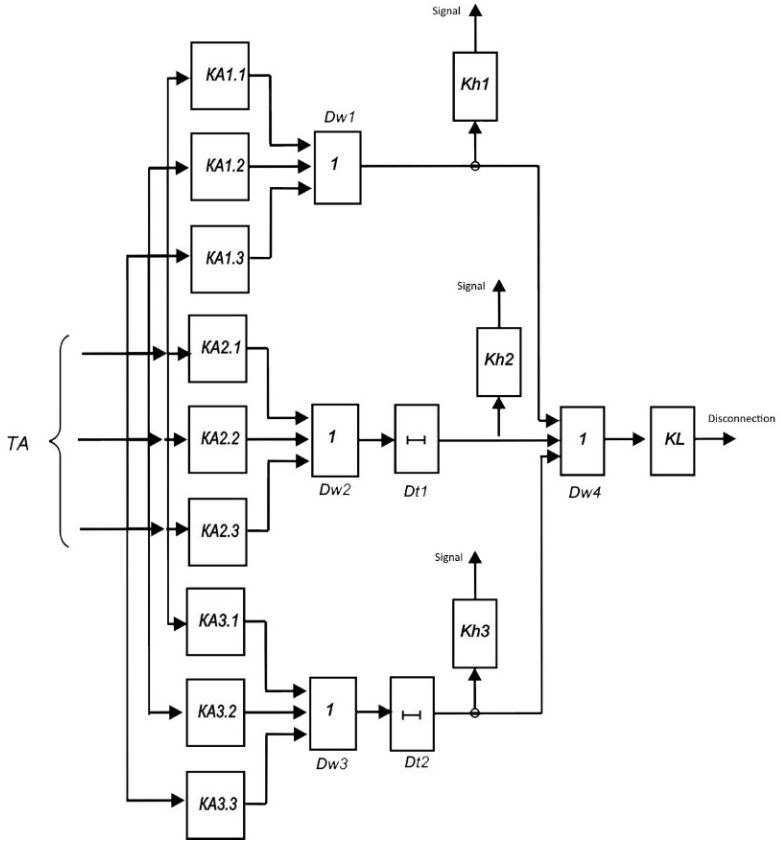

Figure 1 - Algorithm of current step protection using logic elements

In a very simplified version, the end product built using PLIC technology is a set of discrete logic implemented on a single chip. The main difference is that the "hardware" of the PLIC-based control device is determined not by the PCB routing and a fixed set of elements and connections, but is programmatically formed from a set of semiconductor switches. Thus, it is possible to implement control and processing logic in a very compact semiconductor device package due to physically implemented connections and transitions. Since PLIC technologies make it possible to implement parallel single-cycle processing of vectors of arbitrary length, a PLIC-based device operates much faster, and importantly, more reliably than any microprocessor device with a traditional sequential mode of operation.

In addition, modern PLICs have another difference: thanks to the built-in programming and configuration systems available in many PLIC types, which allow reprogramming them directly on site without external programmers, PLIC-based devices can be upgraded even while in permanent operation at the customer's facility.

To implement the RP device, a PLIC parallel action controller was used based on the EPM7128SLC84 Cyclone family crystal from Altera with flash load memory. An analog-to-digital converter (ADC) block was added to convert the input analog signals from current (TA) and voltage (TV) transformers into digital format, as well as an executive element that is used to disconnect the damaged network section from the power source (Figure. 2).

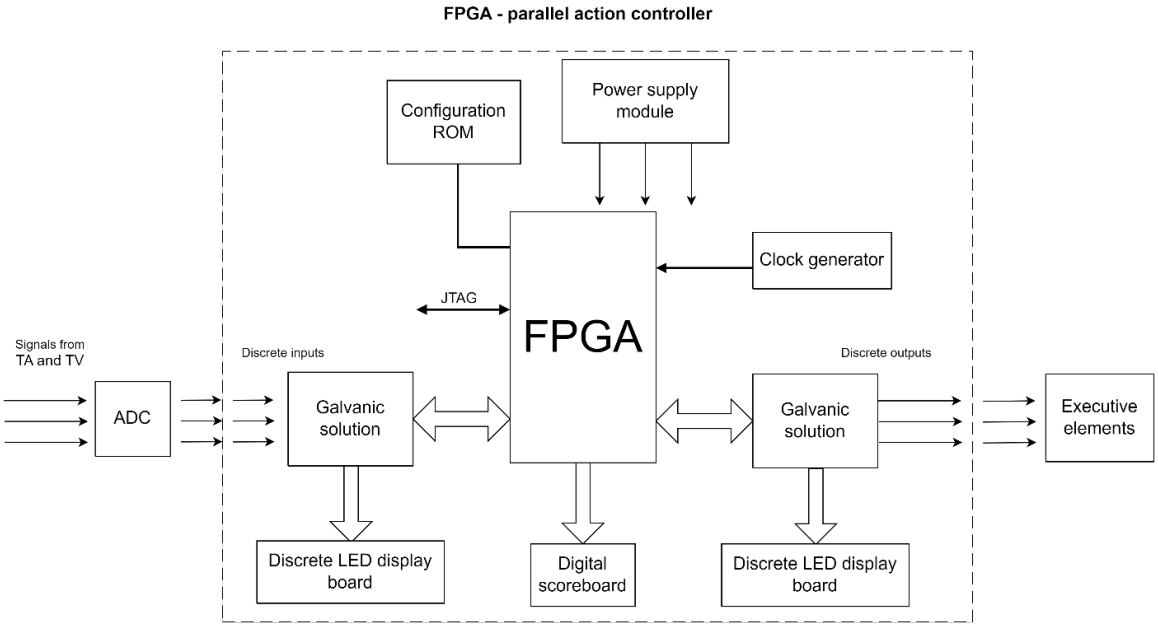

Figure 2 - Functional diagram of relay protection on a PLIC parallel action controller

The VHDL language and Intel Quartus Prime development environment were used to write the control program for this algorithm.

Principle of operation. The controlled signals from the current and voltage transformers are fed to the analog-to-digital converter. Next, the digital value of voltage and current is transmitted to the discrete inputs of the PLIC parallel action controller, via galvanic isolation to the input pins of the PLIC chip. In the PLIC, the data is processed according to a given algorithm (Figure. 1) and, depending on the result,

signals are generated at the discrete outputs of the controller. In case the algorithm is executed with critical input values, a signal is sent to the executive elements.

Conclusion. The conducted research has significantly advanced our understanding of the feasibility of integrating current step relay protection through Programmable Logic Integrated Circuits technologies. The findings underscore the potential for developing highly reliable relay protection systems by leveraging the capabilities of PLICs. The successful implementation of current step relay protection using PLIC technologies opens up promising avenues for enhancing the efficiency and dependability of protective systems in diverse applications.

Furthermore, the results of this study highlight the adaptability of PLICs in addressing the intricate requirements of relay protection, demonstrating their ability to provide intricate and responsive solutions to dynamic electrical environments.

The positive outcomes observed in this research lay a foundation for future advancements in relay protection technology, paving the way for innovative solutions that can withstand the evolving challenges in the realm of electrical protection. As technology continues to progress, incorporating PLICs into relay protection systems holds great promise for achieving unprecedented levels of reliability, efficiency, and adaptability.

In conclusion, the study strongly supports the notion that PLIC technologies represent a viable and promising avenue for the development of highly reliable relay protection systems. The ongoing exploration of PLICs in the field of electrical protection is expected to contribute significantly to the evolution of smarter, more resilient power systems, ensuring the continuous and secure operation of critical infrastructure.

References:

1 Hrytsenko S. D, Radchenko S. S., Furman I. A. Use of PLIC technologies for relay protection implementation // PROCESS AUTOMATION systems: application in the educational process and production, Kharkiv, 2011. P. 8-9.

2 Furman I. O., Radchenko S. S., Hrytsenko S. D. Study of the possibility of technical implementation of advanced relay protection systems // Problems of energy supply and energy saving in the agro-industrial complex of Ukraine: Bulletin of KhNTUSG named after Peter Vasilenko, issue 102, Kharkiv, 2010. P. 100-101.

3 Hrytsenko S. D., Radchenko S. S., Furman I. O. Implementation of relay protection functions using a PLIC parallel action controller // Problems of energy supply and energy saving in the agro-industrial complex of Ukraine: Bulletin of KhNTUSG named after Peter Vasilenko, issue 117, Kharkiv , 2011. P. 58-59.

Анотація. *Розглянуто питання підвищення надійності пристроїв релейного захисту шляхом застосування програмованих логічних інтегральних схем (ПЛІС). Проаналізовано алгоритм струмового ступеневого захисту та реалізовано його на ПЛІС з використанням мови VHDL. Показано, що застосування ПЛІС може значно підвищити швидкодію, надійність та завадостійкість пристроїв релейного захисту. Зроблено висновок про перспективність використання ПЛІС для створення високонадійних систем релейного захисту.*

Ключові слова: *підвищення надійності пристроїв релейного захисту, програмовані логічні інтегральні схеми, ПЛІС, ПЛІС контролери паралельної дії.*

Article sent: 30.12.2023