

New Concept of Microprocessor Protective Devices Design

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Abstract: Transition from electromechanical to digital protective relays is accompanied with serious technical problems. The author offers a new approach in designing the digital relays capable of solving these problems. It is proposed to construct digital relays in the form of standard modules from which it would be possible to assemble the digital relay in the same way as now a personal computer.

Keywords: Microprocessor protective device, Relay protection, Protection functions, Relay protection reliability, Human factor.

1 Introduction

Microprocessor protective devices (MPDs) are extensively replacing all other types of relay protection devices on the market since all the world leaders in this area have almost completely ceased production of all other types of protection relays for the electric power industry. Since their first introduction into the electric power industry more than 20 years ago, these devices have caused considerable enthusiasm among specialists. There have been quite a number of articles in technical literature praising the benefits and advantages of MPDs in all aspects.

However, as any sensible professional should know, an ideal technical device does not exist and even the MPD has many technical problems and shortcomings that have already led to a significant reduction in the hardware reliability of relay protection [1-4] and increased its cost. Since there is no alternative to MPD today, we face a challenge to counterbalance the negative impact that MPDs introduced into relay protection. In this article, the author offers a new concept of MPD design capable in his view, to solve many actual problems of MPD.

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2 Actual Situation and Problems in Transition from Electromechanical to Digital Protective Relays

Today, there are hundreds of MPD models from dozens of manufacturers in the market. Each type of MPD is built in a separate body, which may be totally different from that of any other type of MPD (even of the same brand), Fig. 1.

Usually separate MPDs are installed in relay cabinets: 3 – 5 units in each cabinet, Fig. 2.



Fig. 1 – Configuration of Modern MPDs of Different Brands.



Fig. 2 – Method of MPD Installation into Cabinets in Use Today.

Historically, [5] there are a large number of non-interchangeable and incompatible MPD designs. This means that if a certain module of any MPD installed in the particular substation or power station fails, it can be replaced only by the same component, produced by the same manufacturer. Thus, after spending a small fortune purchasing an MPD from a specific manufacturer, one falls into economic dependence on this manufacturer for the next 10–15 years, since after having chosen one manufacturer it no longer makes any difference if there are other manufacturers in the market, as one cannot use their products. And the only way to get out of this is to pay a small fortune one more time for the MPD from another manufacturer (and, thus, switching from one bondage to another). And what does the manufacturer do with an absolute monopoly? Right: the manufacturer increases the price! The price of one spare MPD module can reach almost one-third or even a half of that of the entire MPD! As

there is no other choice, one is forced to pay that price. And what happens after 8 – 10 years of the MPDs operation? Here's what: the manufacturer has already developed several new designs during that time and it is unprofitable for the manufacturer to maintain the facilities producing spare modules for old relays, so production is stopped. What should a consumer do in this situation? Answer: throw the old MPD into garbage, even if there is only one faulty module (printed circuit boards of modern MPDs are developed in such a way that they cannot be repaired), and fork up another sum of money for purchasing a new unit. Therefore, insufficient hardware reliability of MPD [1-4] results in a serious economic problem since built-in self-diagnostic features, so much advertised by manufacturers, do not help to reduce failures and breakdowns.

The popular way of increasing the hardware's reliability as backup is also problematic due to the high cost of MPDs and shortage of resources to re-equip the basic set of protections, apart from the backup set.

Another way of increasing the reliability of electronic equipment related to preventive replacement of limited life units, (for example power supply units with electrolytic capacitors) is hardly ever used in practice, for the same reasons..

Full incompatibility of MPD software, sometimes even between different versions of the same program not to mention the software from different manufacturers, results in another problem hampering the use of MPD. The same energy company may use 4 – 5 types of MPDs and service staffs are required to learn all these essentially different programs resulting in serious problems due to the so called human factor. And this happens in the background of ubiquitous sophistication of MPDs and their software. Below is the opinion of a leading Russian protection engineer concerning the relay protection devices from one of the leading world manufacturers of MPDs [6]:

“Terminal Siprotec 7SJ642 (Siemens) has unreasonable technical and informational redundancy. User manual (C53000G1140C1476, 2005) declares “simple operation through integrated control board or PC with a systems program DIGSI”, which is totally untrue. For example, you should enter nearly 500 parameters (settings), despite of inevitable changes to signal matrix, while each signal has its “properties” influencing the operation of the unit (printed-out DIGSI signals matrix takes about 100 pages of text in English). Since there is a need to compile terminal adjustment tasks, where all set-up protocols should be considered, the amount of documentation becomes huge. Big volumes of data need to be entered making the setup process very difficult. Informational redundancy increases the probability of so called human factor errors. Technical redundancy requires only high-level specialists to be involved in work with the terminal. Available technical documentation includes thousands of pages, which often do not provide necessary data while containing errors”.

The Siemens product mentioned above is not the only device with these kinds of problems. The above is also true for any other brand. Unfortunately, this is a common trend today. The lack of simple and basic design and software standards significantly complicates acceptance and periodic testing of MPD [7].

The latest trend of increasing the number of protection functions in one module, “charging” excessive additional non-protection functions and implementation of so called nondeterministic (not defined) logic additionally affect the reliability of relay protection and increase the unpredictability of MPD behavior under emergency conditions [8, 9].

3 Is There Any Way to Solve These Problems?

The concept of MPD design we propose is based on the following basic principles:

1. The operating assemblies of the MPD should be distinctively well-separated, thus the chaotic layout of the assemblies on the printed boards [10] should be replaced with an ordered, standardized arrangement. For example: operating assemblies such as power source unit, input current and voltage transformers with signal preprocessing units, digital input module, output relay modules, central processor module, etc. should be arranged on separate printed boards of a standard size with universal connectors.
2. Separate relay protection devices for power plants and substations should be designed and sold as separate universal printed boards (modules), rather than as a number of devices in enclosures of different sizes and shapes, to be used by a customer to configure required MPD. These boards (modules) should allow simple installation (by guide rails to connect to cross-board connector) in metal cabinets with separate sections and separate doors. Metal cabinets should be constructed with technology aimed to protect the contents from external electromagnetic disturbances.
3. The MPD should perform only relay protection functions. The number of functions integrated in one module should be optimized according to cost, reliability and limited by standard.
4. The MPDs software should include a standard basic framework and set of different applications and libraries compatible with a common basic framework.
5. All modules in the cabinet must be connected to two heavy-duty power sources, connected together as main and stand-by.
6. All these principles must be described in the new standard with a conventional name, such as, “Principles of MPD Design: Basic Requirements”.

4 Realization of the Proposed Concept

But is it possible to realize the proposed concept from a technical point of view? As we mentioned above, the majority of MPDs available in today's market do not include a set of modules strictly separated by functions and design and they remain a hodgepodge, such as a CPU and switched power supply located on the same printed board [10-14]. We have analyzed many different types of the most up-to-date MPDs of the world leading brands and finally found devices, which ideally correspond to the above design requirements. These are MPDs series 900 of the well-known Chinese company Nari-Relays with universal modules used in protection devices of different types, Fig. 3.

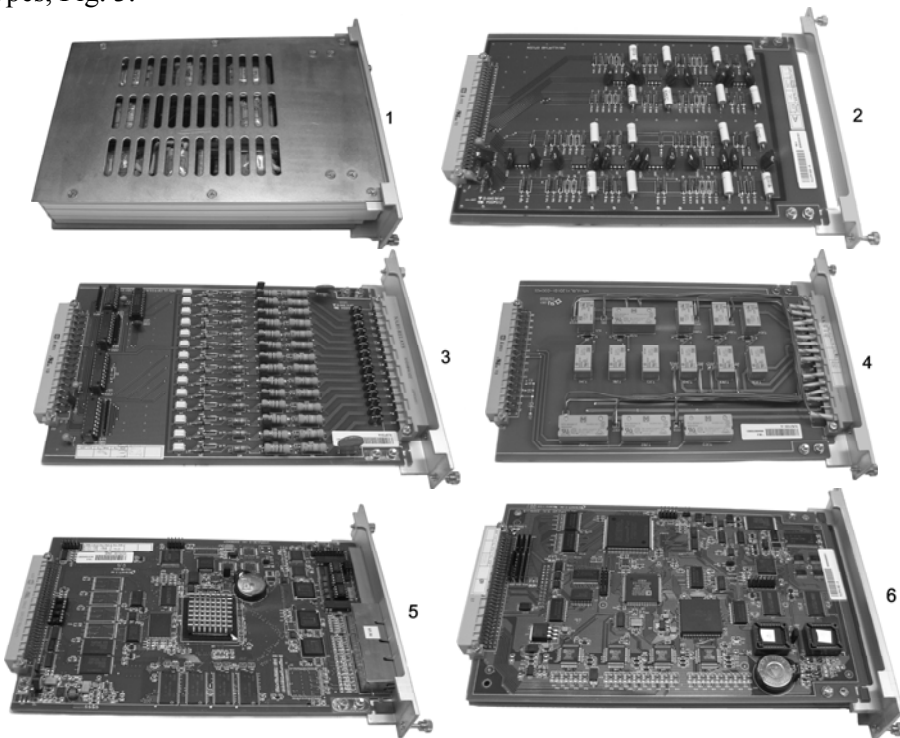


Fig. 3 – Set of universal functional units (220×145 mm) arranged on separate printed boards, which different Nari-Relays MPDs consist of: PCS-931 (differential line protection), PSC-902 (distance protection), etc.

- 1 – input current and voltage transformers module;
- 2 – low-pass filter (anti-aliasing filter);
- 3 – digital input module;
- 4 – output relay module;
- 5 – optical communication module;
- 6 – CPU module.

These turnkey modules do not require any preliminary preparation except for logic and setting configuration. Moreover, once assembled the MPD does not require any adjustments. In order to assemble the MPD one needs to install printed boards as shown in Fig. 3 (the actual set includes power source board, which is not shown in the picture since it is not required as part of the set in our concept) into labeled rails of the enclosure (in our case it is the section of the cabinet). Assembly of such complex protection as distance consisting of 7 separate modules supplied in cartons, and all assembling process doesn't take more than 10-15 minutes, after which one can begin entering the set points. It is a fair assumption that a semi-experienced protection technician who does not have expertise in microprocessor technology won't have any problem with on-site assembling of protection relay consisting of such universal units.

Basically, nothing today prevents early implementation of the proposed concept in a given country. Even a small company can enter the MPD market offering consumers a new concept of cheap and reliable relay protection, equipped with backup block-modules. The venture should start by purchasing sets of universal Nari-Relays modules (with different algorithms written in EEPROM and different sets of input transformers) and also mastering the production of cabinets.

5 What are the advantages of the proposed MPD development?

For a consumer:

- Significant reduction in MPD cost value;
- MPDs may be composed of individual modules of different brands that best meet the needs of the operating organization in terms of optimal balance between quality and cost;
- Optimal SPTA set of MPD modules;
- Reducing the urgency of the problem of low reliability MPDs through quick and easy on-site replacement of failed low-cost modules with stand-by modules operated automatically, if the basic units are damaged, no need to repair faulty modules;
- Anti-monopoly measures since one won't depend upon the manufacturer of MPD;
- Enforcing competition between producers thanks to new market players – small and medium-size companies specializing in production of only certain types of modules rather than complete MPDs;
- Simplifying the testing of the MPD and reducing the influence of “human factor” failures;

- More user-friendly software, which allows the selection of the most suitable and convenient application (interface) and the painless replacement of MPD applications (interfaces);
- Acceleration of technological progress in the field of MPD without complicating the operation and without the adding of additional problems during upgrading devices to the next generation;
- Reduced cost of updating the MPD, as the whole MPD will not have to be updated every 10-15 years as is the case today. One will only need to update some individual modules. Moreover, one will be able to update the CPU board more frequently than presently, thus speeding up the technological progress in this area.

For a manufacturer:

- No need to produce outdated modules to old MPD installations.
- No lifetime free repairs.
- Significant increase in sales of individual modules.
- New emerging markets for basic framework and sets of different applications and libraries compatible with a common basic framework.
- Specialization in the production of individual and the most profitable types of modules.
- Small and medium-size companies that do not have sufficient resources for the development and manufacture of complete MPDs may become the serious competitors.
- Competitive advantage for domestic manufacturers, with reference to who will be the first to start production of the MPDs as modules in a specific country, compared with foreigner manufacturers.

The proposed direction of development could open the MPD market to new players: some of them would produce analog input modules equipped with current and voltage transformers, the others – CPU modules, or software. The consumer could assemble the MPD from separate modules of different manufacturers, just as it is the case with PCs today, based on the cost and quality of these modules, as well as use the same software for all its MPDs. It would solve many of the issues raised above, and significantly reduce the cost of relay protection. This could also permit the installation of two sets of identical protection types instead of one in order to improve reliability, while the other set would be used as backup, starting automatically upon receipt of the "watchdog" signal coming from the damaged core MPD. In addition it would eliminate the necessity to use individual power sources for each MPD; rather it would enable the use one double high-capacity power source set of improved reliability for the entire cabinet. And finally, it would allow an end-user to

install many service modules, capable of improving the MPDs reliability, in the same cabinet.

Thus, the relay protection maintenance would be simplified as the service staff would not need to read enormous folios concerning different MPDs installed in the same facility and study specific characteristics of the software of each MPD type. In addition to easier maintenance and time savings for installation and learning new types of protection, it would significantly reduce the percentage of “human factor” errors. Such designs would solve the problems of testing complex MPD functions.

6 Is the Proposed Concept Economically Attractive?

According to the report of Newton-Evans Research Co. in 2006 a group of leading world companies, such as ABB, Areva, SEL, Siemens, NARI earned about \$950 million selling protection relays, while the second group, which included Basler, General Electric, Schneider earned another \$500 million. Besides the companies mentioned in the report, large companies such as Beckwith, Cooper Power, Orion Italia, VAMP, Woodward and others are also actively participating in the MPD market.

According to the report, it is expected that Western companies would generate as much as 2 billion dollars in 2009 selling MPDs alone.

The Russian market and other FSU countries are represented by both large Western and local manufacturers: Bresler, Ekra, RELSiS, Kievpribor, Meandr, Inc., Mechanotronica, Radius Automatika, Energomashvin, ChEAZ, and VNIIR. Since the share of MPDs in relay protection in Russia is as low as 10%, there is still a large sector of the market open to development of this concept in the near future.

Of course, the share of MPDs in the market is significantly smaller than that of PCs with their \$52-billion in sales; yet it is still large enough for successful implementation of the proposed concept.

How should one start to implement this concept? We believe that the starting point should be the development of the above mentioned national standard by a wide range of professionals including protection engineers, relay operators, scientists, design engineers, and industry representatives, as well as the signing of a contract with the Nari-Relays, as a first step towards the realization of concept.

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