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# Reliability of Microprocessor-Based Relay Protection Devices: Myths and Reality

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**Abstract:** The article examines four basic theses about the ostensibly extremely high reliability of microprocessor-based relay protection (MP) touted by supporters of MP. Through detailed analysis based on many references it is shown that the basis of these theses are widespread myths, and actually MP reliability is lower than the reliability of electromechanical and electronic protective relays on discrete components.

**Keywords:** Microprocessor-based protection devices, Relay protection, Reliability, AD converter, Central processor, Watchdog timer.

## 1 Introduction

Malfunction of relay protection is one of the main causes of the heavy failures that periodically occur in power systems all over the world. According to the North American Electric Reliability Council [1] in 74 % cases the reason of heavy failures in power systems was the incorrect actions of relay protection in trying to avoid the failure. Thus the reliability of a power system depends on the reliability of relay protection in many respects.

It is a fact that intensive research and development in the field of electromechanical protective relays (EMR) have been completely frozen for the past 30-35 years and all efforts of developers have been redirected to development of electronic, and then microprocessor-based protective devices (MPD). Meantime EMR completely provided and continue to provide until now reliable protection of all objects in electric power industry. The reason for the full disappearance of the EMR and transition to MPD is not the inability of EMR to carry out the functions, rather it is something completely other. Due to the large expenditures by leading of MPD-manufacturers in promoting the MPD, the development of new materials and technologies have not affected the EMR in any way. After tens of years in operation, today's EMP have worn out and become outdated and, consequently, are a cause of a fair amount of discontent amongst protective relays experts. On the other hand, demounting

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EMR and transition to MPD in the electric power industry is connected with the necessity for investing significant amounts of money, not only for purchasing MPDs, but also for computers and special expensive test equipment, as well as for the replacement of expensive MPD failed units, which cannot be repaired. Significant capital investments are required as well for reconstruction of grounding systems of substations, for training of the relay personnel, etc. All this essentially disrupts the process of transition to MPD. According to [2], in 2002 in Russian power systems there were in operation 98.5% EMR and only 1.5% of various electronic devices of relay protection. According to [3] MPD constitutes about 0.12% of the total quantity of relay protection devices in Russia. In the West rates of replacement of relay protection in working power objects also is not so high (excluding new erected power objects, of course) According to [4] at existing rates it is required about 70 years for replacement of all old protective relays with microprocessor-based. Such low rates for updating protective relays in working power objects all over the world causes intensive advertising activity of MPD-manufacturers and their distributors.

One of the main reasons usually presented in the vindication of MPD advantages is its considerably higher reliability, ostensibly, in comparison with electromechanical and electronic relays. This thesis is represented as being so obvious, that, usually, does not cause objections and frequently is repeated by managers and even by technical specialists of the power engineering companies. However, in a deeper analysis of a situation it appears that the basis of this thesis is made with a whole set of widespread myths about microprocessor protection [5].

## 2 Reliability Myths

### 2.1 Myth 1: MPD Reliability is higher than EMR reliability because MPD does not contain moving internal elements [6].

EMR malfunction is usually associated with ageing and damage of wiring insulation (wear, drying), corrosion of the screws and terminal clips, deterioration of the mechanical parts of the relay. However, the number of operation cycles (i.e., movement of mobile parts) over the entire EMR service life under real operating conditions in power systems does not exceed several hundreds. So to speak about mechanical deterioration of EMR mobile parts, for all practicality, it is only in the case of evident defects of the factory-manufacturer or use of improper materials for these purposes. As for corrosion of the metal elements or drying out of the insulation, this is a consequence of use poor-quality materials by the relay manufacturer. Such defects are typical for EMR of Russian manufacturer and do not come close to meeting the products of the leading Western companies which have been in operation for 30-40 years even in a tropical climate [7]. Thus, to speak of EMR as an insufficient mechanical resource*, as a kind of the relay*, is absolutely unreasonably. On the other hand, if the moving elements of the EMR are in movement *only at the moment of operation (pick ups) of the relay,* the thousands of electronic components in the MPD *constantly are in work*: signal generators, numerous transistor switches, amplifiers, comparators, timers, counters, logic elements, voltage stabilizers, constantly works; the microprocessor constantly exchanges signals with elements of memory, the analog-digital converter constantly conducts processing input signals, etc. Many elements constantly are under influence of a high working voltages (120 - 250 V) and voltage spikes which periodical arise in the input circuits and external power supply circuits; as well as constant power dissipation (that is, they are heated), etc. In especially heavy work in MPD conditions switching power supplies very frequently are the reason of MPD malfunction.

### 2. 2 Myth 2: Reliability of semi-conductor (solid state) relays on discrete components is higher than reliability of electromechanical relays [8]. Reliability of electronic protective devices based on integral microcircuits (ICs) with a high degree of integration is higher, than reliability of devices on discrete electronic components [8]. Reliability of microprocessor-based relays is higher than reliability of electronic non-microprocessor devices.

The unconditional statement about the greater reliability of semi-conductor relays over electromechanical relays is a popular mistake [9]. Semi-conductor relays possess increased reliability only at very large number of switching cycles (hundreds of thousand, millions) or at high switching frequencies. In many other cases reliability of semi-conductor relays is essentially lower than electromechanical relays [10].

Discrete electronic elements have much higher capability for withstanding voltage spikes and other adverse influences than integrated microcircuits [11]. According to [12] 75 % of all damages to microprocessor devices are the result of voltage spike impact. Voltage spikes with amplitudes from tens of volts up to several kilovolts, arising from switching transients in circuits [13] or the impact of electrostatic discharges, are "fatal" for internal microcircuits and processor microcells. According to [12] normal transistors (discrete elements) can withstand a voltage of electrostatic discharges almost 70 times higher than, for example, a microchip of memory (EPROM) in a microprocessor system. The most calamitous of temporary failures caused by electromagnetic noise that occur in the microprocessor functioning can be time [14], such as spontaneous changes of the operative memory (RAM) and registers contents, and internal damages can have the latent character [15]. These kinds of damage do not come to light in any tests and can appear during at the most unexpected moments.

In [16] it is mentioned that in connection with low stability to transients and voltage spikes the MPD demand especially rigid requirements for the protection level against electromagnetic influences. Attempts of using an MPD without strengthened electromagnetic protection frequently lead to their malfunctioning [16,17]. Electronic devices with discrete components contain fewer components than similar devices on ICs, Fig. 1. This does not seem to promote higher reliability of ICs.

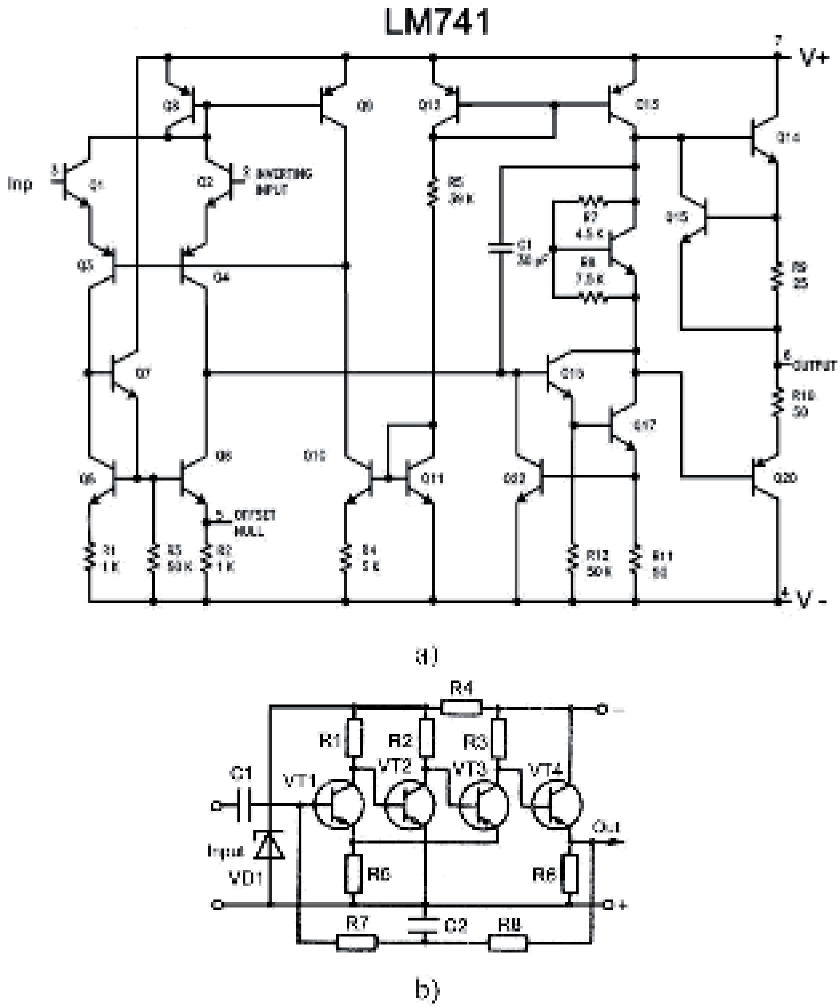


**Fig. 1** – *Circuit diagrams of two amplifiers: at the top of a widely used* IC LM741 *type containing* 20 *transistors; below - the amplifier on the discrete elements with same parameters, containing only* 4 *transistors*.

The statistics on damages of MPD elements, collected by engineers of some MPD manufacturers, Fig. 2 [18], very persuasively denies the myth about higher reliability of ICs.

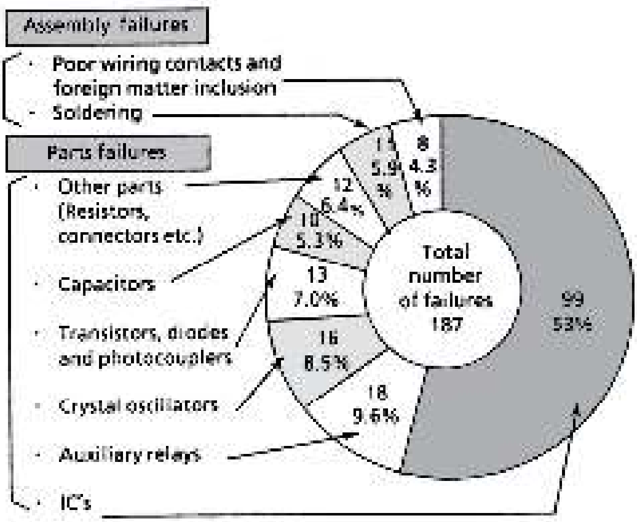


**Fig. 2 –** *The statistical data on damages* MPD *based on investigations leading Japanese companies* [18].

According to the statistics submitted in [8], it is extremely visible that the protective relays with electronic elements have three times the damageability than electromechanical relays, and microprocessor-based relays 50 times the damageability!

Reliability of the microprocessors of such manufacturers as Intel and AMD can be actually very high, and in fact the microprocessor though not big is a very important part of the MPD which contains very many ICs. In [19] it is affirmed that the main processor unit (that is the printed-circuit-board with the microprocessor, memory, the analog-to-digital converter, library of programs and all auxiliary elements) part of MPD is the most subject to malfunctioning.

Another strike against microcircuits lies not only in physical damage of the microprocessor, but also software failures - damages not known earlier for electromechanical and electronic relays. As it is pointed out in [19], program bugs are not always detected during MPD testing. An additional source of problems is the necessity for periodically upgrading the MPD program versions. Frequently during this process software-to- hardware incompatibilities [19] appear. Such problems can show up during the most unexpected moments and can lead to very heavy consequences for a power network. As is known, one of the reasons of the largest failures in a power supply system of the USA and

Canada occurred in August, 2003 and was a computer-related problem, a “lag” of a computer control system in a power company “First Energy” [20].

### 2. 3 Myth 3: Reliability of MPD is much higher than reliability of all other types of the protective relays due to presence of the built-in self-diagnostics. With the self-diagnostics in MPD 70 - 80 % of all internal MPD’s elements are covered [21, 30]

This thesis is very widespread and is met with in practically all publications devoted to MPD advantages. We shall consider features of this self-diagnostics more in detail.

***Analog-digital converter* (ADC)**

This device transforms an input analog signal from CTs and VTs in binary code transmitted through special filters to processing in the microprocessor. All ADC work by sample of input values through the fixed intervals of time and thus will transform a sine wave signal to a set of the fixed amplitudes. As can be seen from Fig. 3, this is a rather complex device carrying out a complex algorithm and containing a sizable set of internal units.

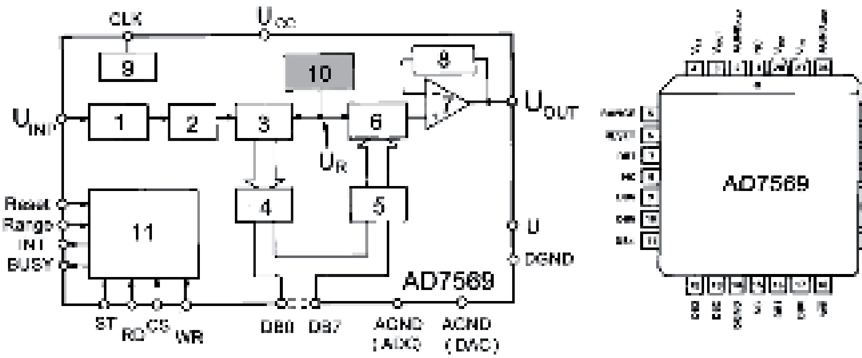


**Fig. 3 –** *Structure of the analog digital converte*r AD7569 *type*.
1 – *range network*; 2 - *unit of tracking/holding*; 3 – *analog digital converter* (ADC);
4 – ADC *latch*; 5 – DAC *register*; 6 – *digital analog converter* (DAC);
7 - *the amplifier*; 8 – *range network*; 9 – *synchronizing clock*;
10 – *reference power supply*.

Some modern ADCs are so complex that they include even a small microprocessor to manage their work. The ADC is actually the principal unit of the measuring device, and, as in any complex measuring device, there are various errors in the transformation of input values present in the ADC. These are errors in quantization, additive and multiplicative errors, differential and integrated nonlinearity of the transfer characteristic, an aperture error, aliasing, etc. How it is possible to supervise the proper functioning of such complex devices during the continuously change of input values when there is only a single element storing a constant level of a signal during ADC functioning as the reference voltage source 10 (see Fig. 3). The so-called "self-diagnostics" ADC is based on this reference voltage monitoring [21]. The efficiency and usefulness of such “self-diagnostics” the reader can estimate himself.

***Memory***

MPD employs two kinds of memory: *ROM* (Read Only Memory) intended for storing the managing program and setting, and *RAM* (Random Access Memory) intended for temporary storage of the results of input values measurement and intermediate calculations. The managing algorithm is a set of certain numerical codes. A certain control sum, which is remembered in a separate cell of memory, is made of these codes. During MPD functioning, the pre-recorded control sum is periodically compared with the actual sum. A mismatch of these sums should specify malfunction of a ROM [21]. Clearly, that process of calculation of the actual control sum and its comparison with pre-recorded sum is a discrete process, performed within certain intervals. And what happens if a malfunction occurs at a time between the intervals of comparison of the control sums? Won’t there be a false operation of the protective relay and switching-off of a power network? The question is not completely hypothetical: such real cases which not were detected by of self-diagnostics algorithm are described in [19].

The situation with the self-testing of the RAM is much more difficult as the contents of the RAM constantly change at a high frequency in the random mode during MPD operation. It is difficult to understand how, in a general, it is possible to test the memory cells which constantly re-record at the high frequency during operation, that is, to diagnose so-called «dynamic failures». MPD manufacturers have decided not to trouble themselves with the solving this problem and to test the RAM in an automatic mode by periodic recording the certain constant number in especially reserved memory cells and periodically reading this number with the subsequent comparison of these two numbers. If these numbers match, according to the manufacturers, this ostensibly confirm serviceability of the RAM [21], though it is absolutely not clear how it is possible to estimate serviceability of all RAM in the proper storing of the information in several cells of memory only. Besides it is well-known that absence of the static errors in memory does not guarantee occurrence of dynamic errors [22, 23], that is, the errors arising directly during record and reading process.

The problem with reliability of the MPD memory elements is actually much more complex. It appears that memory elements are subject to random unpredictable failures which have been not connected to physical damage of memory cells. Such random, temporary malfunctions caused by spontaneous changes of the contents in memory cells are referred to as “soft-failures” or “soft errors” (not to be confused with program failures - “software programming errors”). Such errors were not known earlier for the electronic devices based on discrete semiconductor elements or on usual microcircuits. Progress in the last years in the area of nanotechnology has led to a dramatic reduction in the sizes of semiconductor elements (along the order of microns and even parts of a micron), reduction of thickness of layers in semiconductor and insulation materials, reduction of working voltage, increase in the working speed (working frequency), reduction of electric capacity of separate memory cells, increase in density of placement of elementary logic cells in single chip. All this taken together has led to a sharp increase in the sensitivity of memory to ionizing radiation [24, 25]. This sensitivity became so high that usually (that is, completely normal) the radiating background at sea level became dangerous to memory cells. Streams of the high-energy elementary particles coming from space are especially dangerous. Even one such particle that hits a memory cell gives rise to secondary streams of electrons and ions causing spontaneous switching of the elementary transistor or discharging the capacity in charge storage memory elements.

The problem is aggravated in modern microprocessor-based devices with the tendency toward the ever expanding use memory elements [25]. Many modern integrated microcircuits with high integration levels, included in the microprocessor-based device, contain the complex structures with embedded memory of such volume that serviceability, in general, is not supervised in any way. As shown in [26, 27], the problem of the sharp increase in sensitivity to ionizing radiations is actual not only for memory, but also for high-speed logic elements, comparators, etc., that is, practically, for all modern microelectronics.

***CPU* (*Central Processor Unit*)**

As against the complexities described above with the monitoring of memory serviceability, the self-diagnostics of the CPU looks simple enough, Fig. 4.

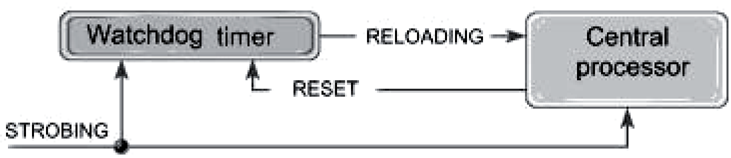


**Fig. 4 –** *A principle of the monitoring of serviceability of the microprocessor with the help of the watchdog timer.*

It simply sends control cycling pulses with a period set to the so-called «watchdog timer» - the watchdog timer is reset to an initial condition with arrival of each new control pulse, and then begins a new cycle of time reckoning. If at a certain moment the next control pulse from the CPU has not arrived, the timer starts the CPU reloads. A serious malfunction of the microprocessor and its "lag" during reloading process which is found out by the timer as the repeated absence of a control signal causes the locking of the CPU and transmitting a signal about CPU malfunction.

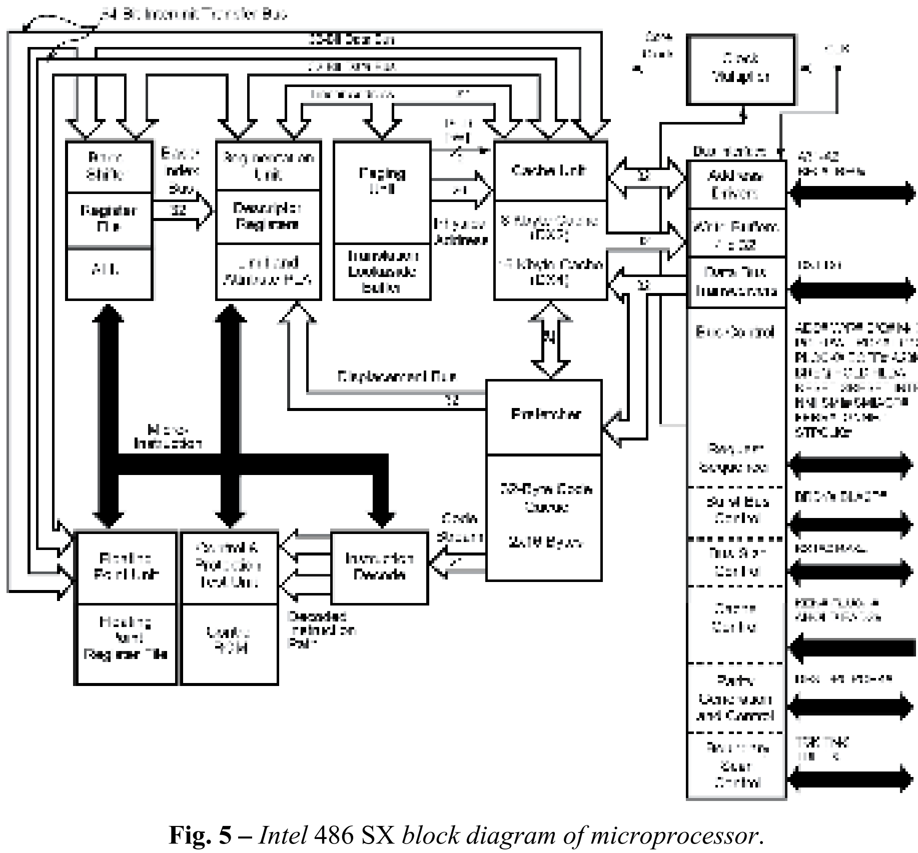


**Fig. 5 –** *Intel* 486 SX *block diagram of microprocessor.*

Process on tracking control pulses by the watchdog timer is synchronized with the help of external clock pulses (so-called “strobing”). Sometimes the watchdog timer is built directly in the microprocessor, and sometimes (which is more preferable) it is an external specialized integrated microcircuits (IC). As an example of such devices the IC series ADM690 – ADM695, manufactured by Analog Devices can serve. This small chip contains not only the watchdog timer, but also the monitor of a voltage level of a CPU feeding. The pause between control pulses of the watchdog timer of this series can be 0.1 or 1.6s.

It is abundantly clear that to check the serviceability of hundreds of thousands of transistor nanostructures of which any microprocessor consists is absolutely impossible. At best all that can be said is that it monitors only the general working ability of the CPU, in other words, checking if it is alive or dead. Given the very complex internal structure of the CPU, Fig. 5, containing many, many units (microcells; registers for temporal storage of the commands, the data and addresses; the arithmetic logic device; system management and synchronization, etc.), the control signals from the CPU can continue to act on the watchdog timer even if part of the internal structure of the CPU is damaged.

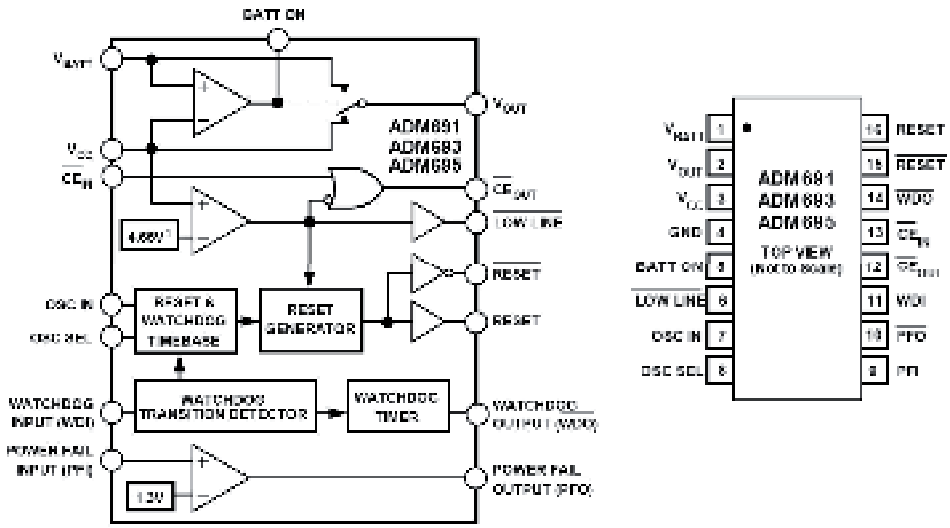


**Fig. 6 –** *Series* ADM691 - ADM695 *watchdog timer, manufactured by Analog Devices Co.*

It is obvious that damages of certain regions of the internal CPU structure (or parts of internal managing program) can be detected only in an operating mode (upon activization of these regions). If these regions of the CPU become active only at the input signals corresponding to emergency mode in an electric network, it means that the watchdog timer is a cold comfort.

In itself, the watchdog timer is the device made with the same technology as all other microelectronics devices, Fig. 6, and is subject to malfunctioning and failures just as all other microelectronic devices. Owing to it working algorithm the watchdog malfunctioning during normal MPD operation can result in the locking of the CPU (i.e., locking of the whole MPD), or it will not notice “lag” of the CPU, in either case the relay protection will not work properly at emergency mode. Thus, the operational ability of the whole MPD appears to have a very strong dependence on the serviceability of one small chip named "watchdog".

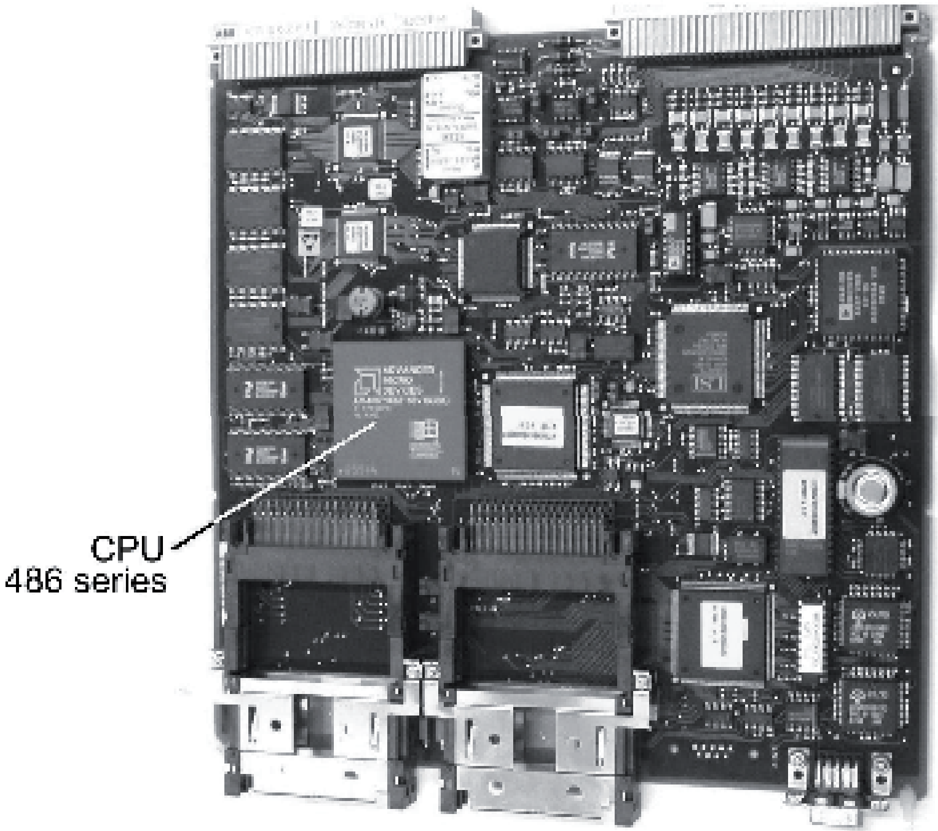


**Fig. 7 –** CPU *of the of central processor unit of the* MPD *series* RE *_316, *manufactured by* ABB.

One more important consideration is that the CPU is not the an isolated element upon which correct functioning in MPD structure depends, it also depends on the serviceability of tens of other complex integrated microcircuits to which CPU is connected, but for which self-diagnostics is not stipulated. It's enough to look at the printed-circuit-board (PCB) of the central processor unit, Fig. 7, to understand that serviceability of the CPU alone does not speak about serviceability of whole this PCB. Damage of any of numerous microelectronic (and not only!) components of this multilayered PCB will inevitably lead to infringement of correct MPD functioning and any watchdog here will not help, as proves to be true judging from the data results in [19].

***Power supply***

MPD of all types are supplied with what is called switching power supplies in which the input voltage (AC or DC) acts on the rectifier and the filter then interrupts with the high frequency (tens-hundred kilohertz) with the help of a powerful switching transistor, that turns in high-frequency AC. This high-frequency voltage is transformed by the high-frequency transformer to a low voltage (more often, 12 V), which is rectified, filtered and stabilized. Further lower voltages are formed from this DC voltage (5 V, for example), necessary for MPD functioning. Microprocessors, usually, are rather sensitive to a level of a feed voltage and can perform unpredictable operations at the voltage reduction below a certain value. In this connection, in MPD a constant monitoring of the level of a feed voltage of the CPU is carried out. As it was mentioned above, IC of family ADM 691-695 can be used for the continuous monitoring of the power supply voltage level. As well as in a case with the watchdog timer, the ADM 691-695 chip generates a signal for locking the CPU at an inadmissible voltage supply reductions. The locking signal remains until the voltage level is restored. Is it really possible to count such voltage level monitoring as self-diagnostics of the power supply, raising it functioning reliability? Hardly, therefore it is the internal technological locking which only prevents failures in the CPU. Such monitoring has no relation to the reliability of the power supply.

And meanwhile, power supplies are the most unreliable unit of the MPD. First, elements of the power supply work in a high load mode; they are constantly subjected to the influence of high values of a voltage and a current, voltage spikes, dissipated rather high power on the elements. Secondly, they contain a lot of aluminum electrolytic capacitors that rather badly carry the influence of high frequency currents on which switching power supplies work, and frequently are the reason of full breakdown of the power supply (and, consequently, of the whole MPD). We ask can monitoring of an output voltage level in this case help? Can it signal beforehand about the deterioration of a capacitor and thereby prevent the sudden MPD failure?

***Output electromagnetic relays***

As shown in previous researches [28,29] that the author conducted, contacts of the miniature electromechanical relays (usually used in all types modern MPDs as output elements) directly control the trip coils of high-voltage circuit breakers or the coils of auxiliary relays with a significant overload. Therefore reliability of these relays is essentially reduced to the comparison with the value which was normalized by the relays manufacturer. On the other hand, in promotional brochures of various manufacturers about MPD advantages it is usually emphasized that serviceability of such important elements as output relays is continuously supervised by means of a self-diagnostics system of the MPD. At first sight, it is rather difficult to represent that it is possible to check the serviceability of the electromechanical relay in working MPD if the contacts are inserted directly in circuit of the trip coil of the high-voltage circuit breaker.

It is impossible to check the serviceability of contacts of the output relays in this case, so what check is possible? The coil only. This is what the MPD manufacturers have implemented: the supervision of the continuity of the coil of the relays. This is done by passing a constant weak current through the coil. But what if the most intense and unreliable part of the electromechanical relay is not the coil at all, but the contacts?! This is true, but it is not so important for the advertising campaign. It was necessary to declare loudly only to the MPD consumer about of self-diagnostics of output relays, but that these self-diagnostics are completely inefficient, as a rule, almost nobody knows.

***Units of digital and analog inputs***

The digital inputs unit is a set of powerful resistors, opto-couplers, electronic filters, multiplexers, etc., mounted, usually, on a common PCB together with the output relays, Fig. 8. The analog inputs unit is a set of voltage and current transformers mounted on a separate PCB, Fig. 9. In [30] is noted that these units are only partly covered by self-diagnostics, without any explanation of how it is performed, but in [31] it is stated that they are not covered at all by self-diagnostics. PCBs of analog and digital inputs in the MPD have, as a usual, various configurations, Fig. 8. The given type of the PCB established in given MPD should be necessarily entered into its memory.

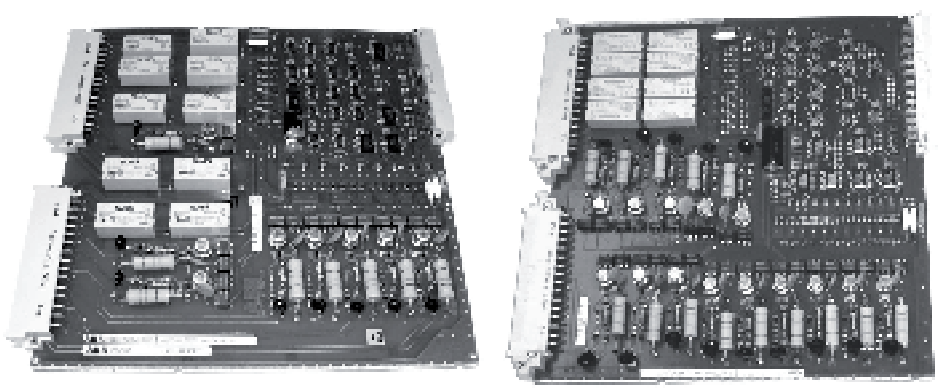

**Fig. 8 –** *Units of digital inputs of various configurations from MPD series* REL316.

To clear up the situation and to place points above *i*, we have replaced one such PCB (in MPD REL316 type) the type of which is stored in the MPD's memory, with a PCB of another type (Fig. 8) without changing the data in the MPD memory. Apparently the MPD loaded into a normal operating mode without noticing the substitution of the PCB. It is clear that it will not correctly function. What can be said about self-diagnostics of serviceability of internal components of these units in such situation? As they say, further comment is superfluous.

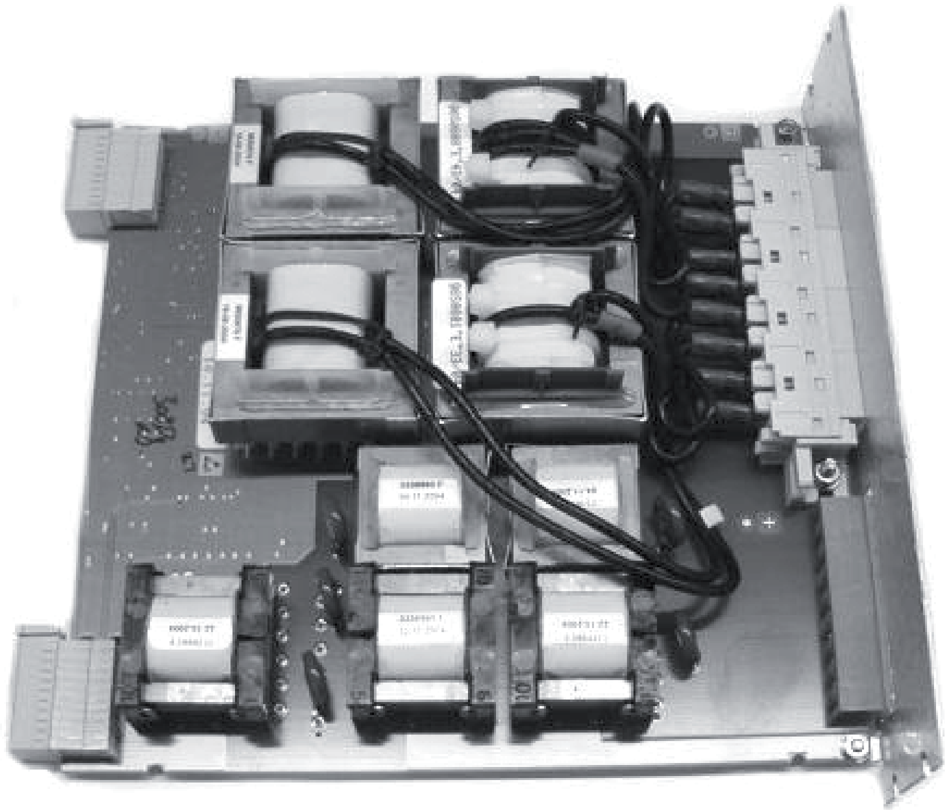

**Fig. 9 –** *Units of analog inputs* MPD *containing voltage and current transformers*.

In conclusion of this section it is necessary to note that, contrary to a popular belief, internal self-diagnostics actually is not the means intended for decreasing MPD failure rate, i.e., for increasing its reliability. The purpose of self-diagnostics is the locking of the MPD and delivering an alarm signal before the occurrence of emergency mode in a power network, instead of during a MPD failure.

## 2. 4 Myth 4: MPD are essentially more reliable in comparison with relay protection devices of the previous generation as it contains considerably fewer number of components and these components are much less subject to physical ageing. MPD also contains smaller number of internal connections [32]

As for the claim that MPD contain a fewer number of components than relay protection devices of the previous generation, it turns out that actually the number of components making up some MPDs is more than the number of components of protective relays of previous generations. As for the claim of more intensive physical ageing of elements of the protective relays of the previous generation, this thesis also does not bear up. The author of this thesis compares the modern elements and technologies used in MPD with materials (impregnation and cover varnishes, plastics, insulation materials, contact and anticorrosion materials) that were in use in the USSR 50 years ago and employed in the protective relays for over several decades. As we already remarked above, old electromechanical relays of the western manufacture (BBC, Westinghouse, General Electric, etc.) in which high-quality materials and coverings were applied still work successfully and show no signs of ageing.

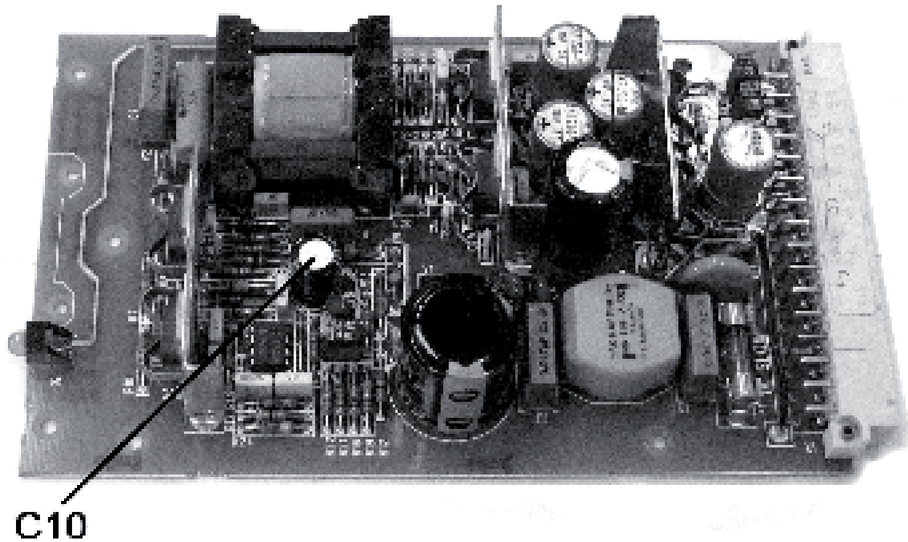


**Fig. 10 –** *Switching power supply* SPGU240A1 *type used in* MPDs *various types.* C10 - *the capacitor, where a change of parameters results to full loss of working ability of the power supply.*

Besides, the progress in the field of materials over the last decade has not been less than the progress in the field of microelectronics. On the other hand, not all is so bright with the ageing of the electronic components widely used in

MPD. Even high-quality electrolytic capacitors of Japanese manufacture start to change the parameters after 7 - 10 years of operation under high-frequency used in MPD's switching power supplies. As a result a change of parameter of one such capacitor only, Fig. 10, completely stops power supplies functioning. For example, of power supplies such as SPGU240A1, used in MPD types SPAC, SPAD, SPAU, SPAJ have been shown to cause this.

In other cases destruction not only of the electronic components takes place, but even dissolution copper streaks on PCB under action of the electrolyte which has leaked out from capacitors, Fig. 11.

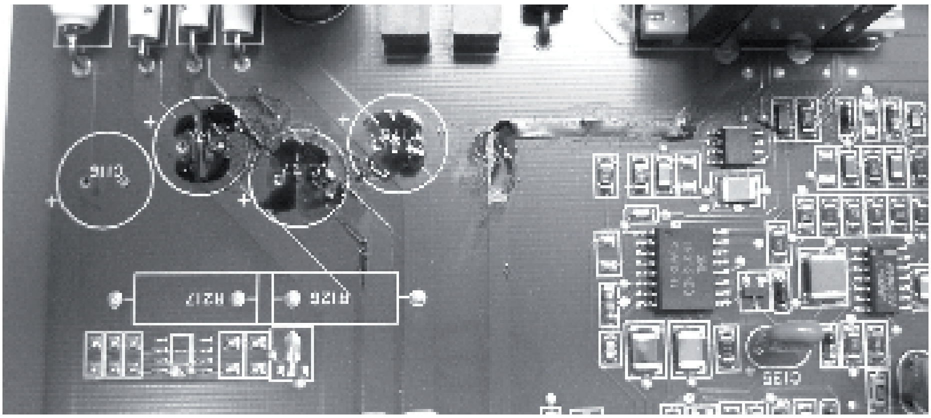

**Fig. 11 –** *Destruction of copper streaks on the printed-circuit-board which is taking place under capacitors because electrolyte leakage.*

One more problem is the aspiration of manufacturers for MPD miniaturization at any cost. This has led to using electronic elements in MPD working with an overload and dissipated increased value of heat that does not promote an increase in MPD reliability and reduction of elements ageing. This problem for circuits of digital inputs on which the voltage up to 250 V is applied [33] is especially prevalent.

Multilayered PCB MPD involves a huge number of contact transitions (crosspieces) between layers. From the author's personal experience there have been cases of faulty MPD actions due to the increase of transitive resistance of these transitions.

The design of many types of MPDs come with a motherboard with multicontact sockets and functional boards with the reciprocal sockets connected with a motherboard. Instead of a motherboard the flexible multicore trunks with the numerous contact sockets connecting among themselves, separate PCBs are sometimes used. These contact connections do not always provide a reliable transfer of low-voltage/low-current signals between boards. In any case, contrary to the widespread myth, MPD contains many more interconnections than the relay of the all previous generations.

## 3 One More Class of Problems Which MPD Manufacturers Prefer not to Mention

In view of the increased sensitivity of modern microelectronics to electromagnetic radiations, there is a problem for MPDs in connection with electromagnetic compatibilities (EMC). Many experts have noted the often incompatibility between real parameters of grounding systems in substations and the requirements showed by MPDs [34, 35] and, as result of it, on MPD failures. But little is known by the experts in the field of relay protection about a problem of "electromagnetic terrorism", the powerful electromagnetic radiations [36] that intentionally impacts on electronic devices, and also about a problem of hacker attacks (cyber security problem) [37]. These problems were unknown earlier in relay protection and became a reality only in connection with MPD applications, as their sensitivity to electromagnetic noises is 10,000 times higher than in electromechanical relays [34]. The built-in MPD software is also subject to external influences. And if, in addition to all the aforesaid, one takes into account that one MPD carries out the functions of 3 - 5 EMRs, the situation with MPD reliability is aggravated even more, as damage of one of the common MPD elements is equivalent, in consequence, to the simultaneous damaging of several kinds of protection at once. In this connection in [38] transition of microprocessor protection is offered to provide additional independent, simple, inexpensive, *not microprocessor* reserve protection for a cases of extreme situations.

## 4 Conclusion

1. Reliability MPD is lower than reliability of electromechanical relays and electronic relays on discrete elements.
2. Built-in self-diagnostics MPD is ineffective and is not a means at all for increasing of MPD reliability.
3. Nanotechnologies, used at manufacture of MPD's elements, leads to the occurrence of problems not known earlier for relay protection. Ignoring these problems can lead to catastrophic consequences. The managers making of the decision in the field of relay protection and the personnel of the power companies should be informed about these MPD features.
4. The recording function of emergency modes in power network and data transmission function on modern connection channels are not direct functions of relay protection and for their realization there are separate

microprocessor devices which carry out these functions much better than MPDs. As against relay protection, failure of these devices does not lead to heavy failures in power systems. Therefore for relay protection devices the focus should be on other demands on reliability and, accordingly, to use other approaches at the designing, directed on increasing of reliability and decreasing in vulnerability.

5. The persons responsible for making the decisions on reconstruction of relay protection and ways of further developments should understand, precisely, the properties and features of the MPD, to take into account not only widely promoted MPD advantages, but also the serious lacks, one of which is lowered reliability.

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