MICROPROCESSOR-BASED PROTECTION RELAYS

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Abstract: Relay protection saves lives and equipment. Its cost can be up to 40% of the protected object value. The world trend in protective relays are microprocessor based applications. Their advantages are the integration of measurement and protective functions, mutifunctionality and flexible operation. This paper presents a microprocessor-based relay protection for middle voltage (MV) range. Some of the values are measured, and some are software calculated. The time-current curves are implemented in software, which determines the different functionality for electricity distribution stations and for electromotor drive systems. The microcontroller based system architecture consists of several electronic cards, such as the power line interface card, system interconnection card and operator interface card.

Keywords: relay protection, microprocessor, electric distribution station, transformer, electromotor

1. Introduction

The availability of cheap and powerfull VLSI devices (microprocessors and peripherals) enables the design of a large number of versatile intelligent industrial applications. This new technology trend is characterised by computer aided and effective design, modification and implementation stages. At the same time, intelligent devices are flexible, easy to operate and easy to integrate into a networked supervisory system.

Relay protection is very important for safety of working personel, damage avoidance and plant availability improvement [1],[2]. Its cost can be up to 40% of the protected object value. The world trend in protective relays are microprocessor based applications [3]. Their advantages are the integration of measurement and protective functions, flexible selection of function parameters, easy integration into a networked supervisory system, adaptable and more precise technical characteristics, as well as with decreasing costs.

A microprocessor-based relay protection for middle voltage (MV) range is beeing developped as a joint effort of the Electrotechnical Faculty in Skopje and EMO Automatics and Electronics Devision [6]. The relay protection should satisfy the current regulations IEC 68, 251, 255, 529, and 801, integrating the functions of measurement, protection (voltage and current), automatic control and data communications.

2. Measurement and protection

The major feature of microprocessor based relay protection is the integration of measurement and protective functions. The components of a general microprocessor system for protective relaying are outlined in Fig.1.

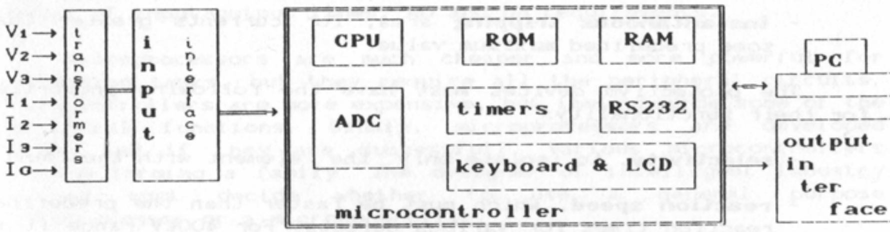

Figure 1. General microprocessor system for protective relaying

The measurement covers four currents and three voltages, as well as the frequency. The cos(φ), W, Wh, VAR, VARh and maximal power level are software calculated. Input currents and voltages are scaled by the transformers to the levels appropriate for A/D conversion. The multiplexed input signals are sampled passing through programmabe gain amplifiers (to cover wider signal ranges and improve precision) and then digitised. The basic sampling frequency is twice the cycle frequency. For higher harmonics, higher sampling rates are required. The resolution of the device is determined by the size of the ADC. Finer resolution is obtained with 12-bit converters (4096 discrete levels).

The protection functions are: overloading, instantaneous tripping, overcurrent, grounding faults, overvoltages and undervoltages. The device needs digital inputs and outputs, as well as an appropriate number of analog inputs. The time-current curves are impleented in software, which becomes important part of the device. The software determines the different functionality for electricity distribution stations and for electromotor drive systems.

3. Relay protection

Relay protection represents a set of automatic devices for the protection of power system elements [1]. These devices (tripping switchgear) provide safe, normal and reliable operation of power system components. The executive elements of relay protection are the circuit breakers. Their response time is over 0.2 seconds, so that special insulators must be used for fast (microsecond range) atmospheric overvoltages.

The most frequent faults are overcurrents (single phase, two-phase, with ground connection). The overcurrents cause high temperatures that can damage equipment. One of the most reliable and economic methods for protection is the so called time/current scheme. Normaly, the electrical equipment operate at nominal current (designed for infinite operation time). One can consider two areas above the nominal current:

- **inversely proportional** area, where the protection reaction time is inversely proportional to the overcurrent (this is some form of exponential time/current curve, usualy given in tabelar form), and

- **instantaneous tripping** area, for currents greater than some predefined maximum value.

The protective devices must have the following properties for their functionality:

- **selectivity**, to isolate only the element with the fault,

- **reaction speed**, which must be faster than the predefined reaction times for various defects. For 400KV range it is 0.1 to 0.12 seconds, for 110KV range it is 0.15 to 0.3 seconds, for 35KV range it is 1.5 to 3 seconds. The reaction time is $T_r = T_b + T_d$, where T_b is the time for the breaker to switch and T_d is the time for fault detection.

- **sensitivity**, ability to react for all thedefects in the defined protection range

- **reliability**, to react after long periods of still operation,

- **full back up**, if the main protection fails there must be an independent secondary protection to isolatethe defect.

The transformers represent the largest number of devices in power systems (especiallyin the middle voltagerange), and the electromotors represent the largest number of industrial machinery. Their protection functions have many similarities andsome are very specific. These properties and similar modes of operation enable the design of devices that can fulfill the protection tasks for both the transformers and motor drives. With traditional electromechanic and static devices one needs several different elements for various functions.

4. Microprocessors and microcontrollers

Microprocessors are powerfull devices that enable designs of intelligent systems. For industry applications, several memory and peripheral functions are integrated on the same microprocessor chip, thus forming the so called microcontroller. The microcontroller implements both processing and control functions. It usualy contains a central processing unit (CPU), program memory (ROM), some data memory (RAM), timers, counters, digital ports and serial communication link (RS232, or some advanced protocol implementation). In application development one must consider the processor speed, word size (8-bit, 16-bit), number of input/output lines, AD and DA requirements.

Microprocessors are much cheaper and more powerful for processing tasks, but they require all the peripheral circuits. Microcontrollers are more expensive, but they provide some of the peripheral functions. Usualy, microprocessors are developed first, and if they are successfull, various microcontrollers develop forming a family. The designer of intelligent industry devices must decide whether to use a general purpose microprocessor or a microcontroller.

The Siemens 80C537 microcontroller is the most advanced derivative of the 8051 microcontroller family, designed in ACMOS technology, with high speed and component density combined with low dissipation [5]. Beside its two RS232 communication ports, it is upgraded with high speed built-in A/D converter (12 multiplexed inputs), extra watchdog timers, as well as with multiply/devide arithmetic unit and BCD arithmetic instructions. Its block diagram is outlined in Fig.2. The program memory block

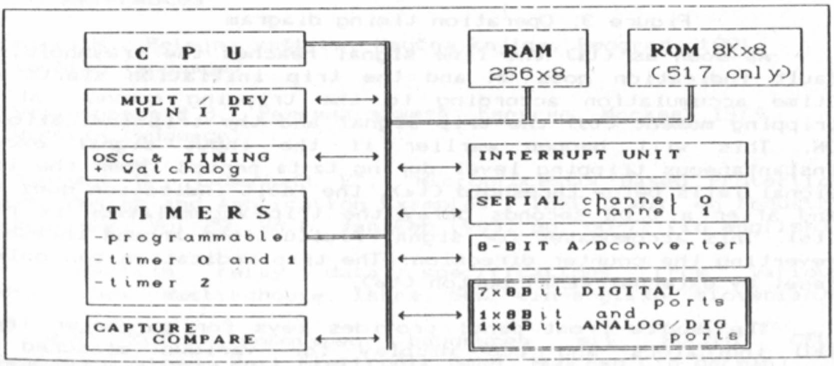

Figure 2. Block diagram of the 80C537/517 microcontrollers

is only present in the 80C517 microcontroller version. It enables small embeded single chip applications.

The 80C537 is aimed for the system development stage, usualy with a single board development system. The programming environment is organized around a PC platform, with A51 cross-assembler and C51 cross-compiler. The object code is linked with a rich module library, converted to Intel HEX format and then transfered to the development board. This is supported by two programs: MONTERM for PC terminal emulation and MONITOR operating system on the development board. The later provides all the load, debug and trace functions.

5. Design considerations

Operational characteristics can be explained using the timing diagram on Fig. 3.

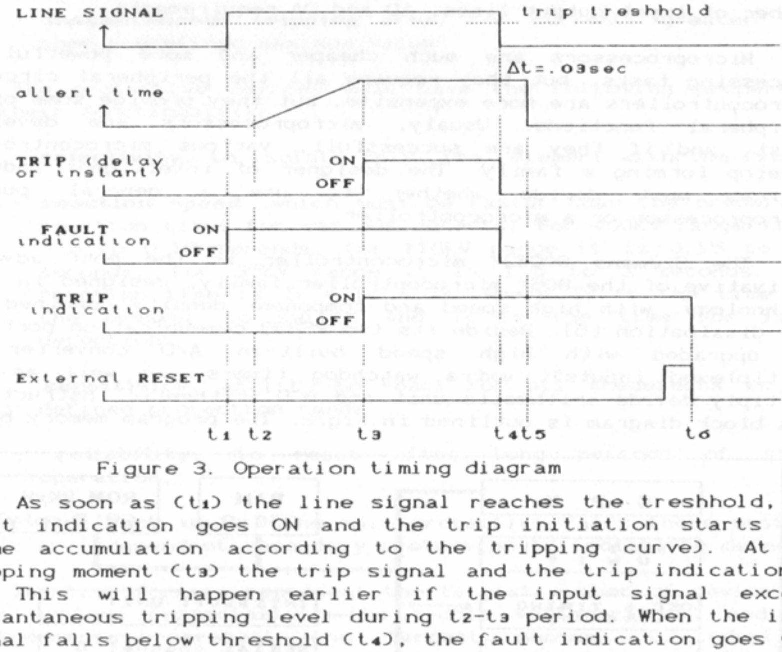

Figure 3. Operation timing diagram

As soon as (t_1) the line signal reaches the treshhold, the fault indication goes ON and the trip initiation starts (t_2) (time accumulation according to the tripping curve). At the tripping moment (t_3) the trip signal and the trip indication go ON. This will happen earlier if the input signal exceeds instantaneous tripping level during t_2-t_3 period. When the input signal falls below threshold (t_4), the fault indication goes OFF, and after a 0.03 seconds delay the trip accumulation is reset (t_5). This accomodates for signal fluctuations around threshold, reverting the counter direction. The trip indication can only be reset by external RESET button (t_6).

The device front panel provides keys for parameter input, LED indicators and LCD display for various measured and calculated values. The curve selection is from two predefined sets of curves: inverse time curves and fixed time trip curves.

There is a serial communication link that enables the intelligent device interconnection in a networked supervisory system. The device has several built-in-test procedures for: power supply test, requested test, start-up test, periodic test.

The system architecture is based on several electronic cards, such as the power line interface card, system interconnection card and operator interface card. The device has to be effectively shielded against possible radiated and electromagnetic noise, which is part of the intensive test approval by the manufacturer. For harsh industrial environments a fiberoptics communication is recomended to prevent lectromagnetic noise.

6. Conclusion

The paper presented a microcontroller-based relay protection for middle voltage (MV) range. Its advantages are the integration of measurement and protective functions, mutifunctionality and flexible operation. Some of the values are measured, and some are software calculated. The time-current curves are implemented in software, which determines the different functionality for electricity distribution stations and for electromotor drive systems. The microcontroller based system architecture consists of several electronic cards, such as the power line interface card, system interconnection card and operator interface card.

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