A&QT-R 2002 (THETA 13)
2002 IEEE-TTTC International Conference on Automation, Quality and Testing, Robotics
May 23 - 25, 2002, Cluj-Napoca, Romania

ADVANCED CONTROL AND PROTECTION SYSTEM IN ELECTRIC RAILWAY TRANSPORT

Nicolae Rusu, Stela Anghel, Ladislav Lako

The "Politehnica" University Timisoara, The Faculty of Engineering of Hunedoara, 5 Revolutiei Str., 2750 Huneodara, Romania, tel. 054-712538, fax. 054-207000, e-mail decan@fih.utt.ro

ABSTRACT:

Electric railway transport represent a specific consumer and at present the protection of the contact line is based on the existence of a deforming status. In the future, this status has to be diminished and a new conception is to be brought forward with respect to the protection system. The paper introduces such an original system, based on the fuzzy logic. Its laboratory testing confirmed its multiple advantages.

KEY WORDS: protection, control, fuzzy, electric railway transport

1. INTRODUCTION

Due to the large distance between two railway transport sub-stations (50-60 Km), the high impedance of the contact line and the problems connected with the safety of the traffic, the protection of the electric equipment is different from the usual one (the one used in electro-energetics) particularly as regards the contact line. At present, this is based on the analysis of the wave shape of the current (the di/dt relay), which under normal work conditions is deforming and on short circuit becomes sinusoidal. Because in the near future steps will have to be taken in order to diminish the deforming status, this principle can no longer be used.

The paper introduces a complex protection device against all the abnormal work conditions of the contact line, based on the fuzzy logic. It analyses three magnitudes: the voltage V(U), current V(I) and phase V(φ), on the basis of a set of rules established by human experts. The device contains the necessary circuits meant to generate the signals, and a dedicated micro-controller with all the necessary peripherals (memories, converters, A/N and N/A, etc.). After de-fuzzing, the output signal is processed by a circuit of programmable time delay, so that the triggering of the high-voltage interrupter take place at the time imposed by the rules.

The suggested structure, which has been built and tested, shows a series of advantages as to the classical protection systems: the functional characteristics are determined by the software, therefore very flexible (the set of rules can be modified at any moment); it is not sensitive to the wave shape of the magnitudes under consideration; it has a large application area and a low cost.

2. THE FUNCTIONAL DIAGRAM OF THE PROTECTION SYSTEM

This Diagram contains an electronic system for the determination of magnitudes V(I), V(U), V(Q), a fuzzy controller and a timing block triggering the interrupter of the force circuit (Fig.1).

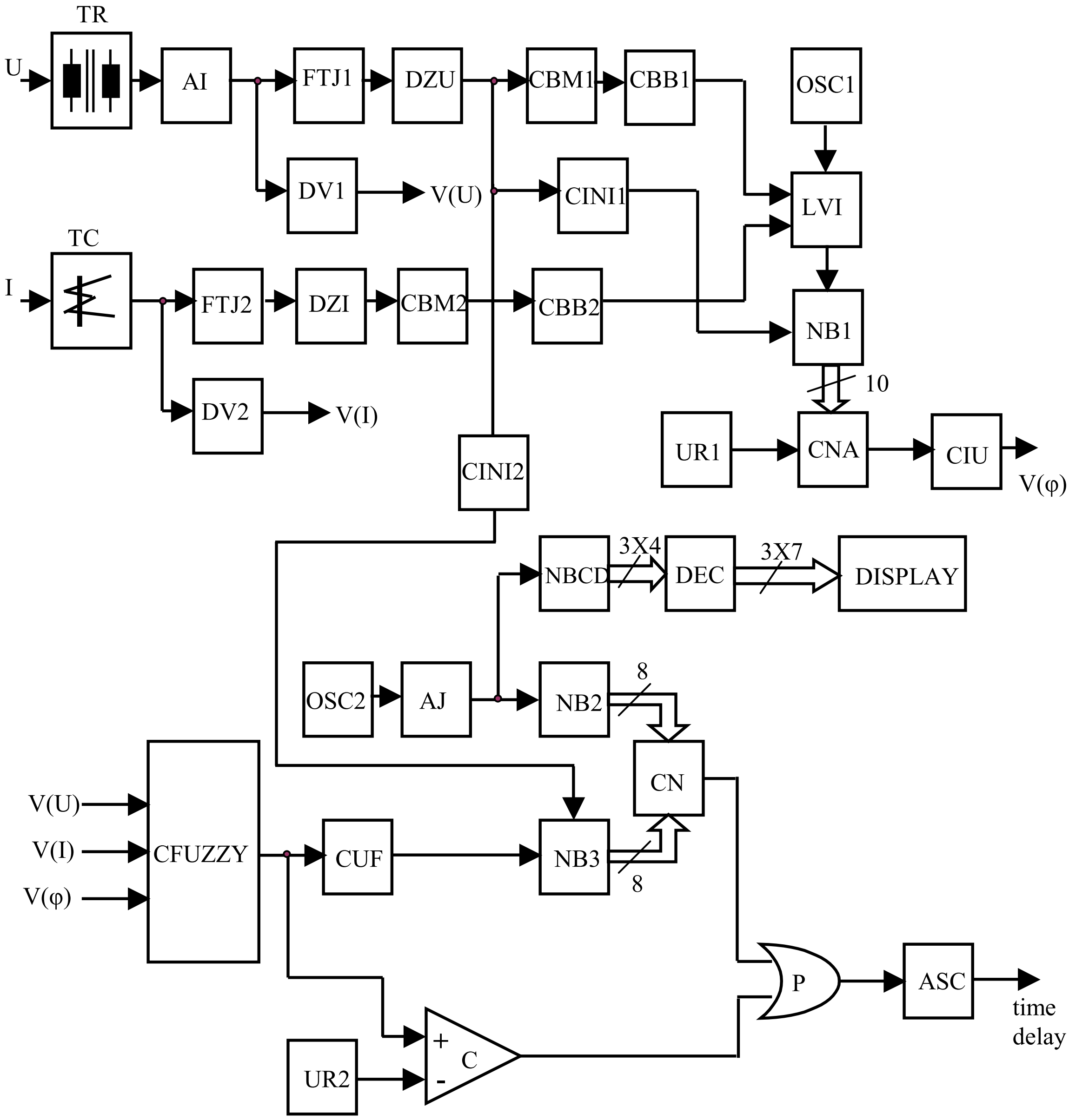


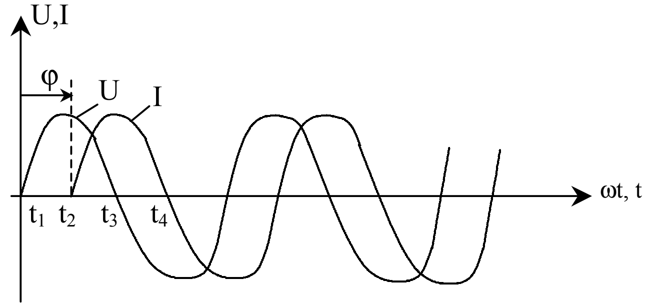
Fig.1 The Functional Diagram of the Protection System

Taking into account the elements in fig. 2, we give further the functioning of the diagram.

At time moment t_1 the voltage wave passes through point zero towards positive values. At this moment the current has a certain negative value. The passing through point zero of the voltage wave is noticed by the zero detector DZU, which generates an impulse which triggers the monostable CBM1; its output gives a square impulse, applied to the bistable CBB1. Its output will switch into a high logical state which, by means of the validation/inhibition logic LVI will allow the access of the timing impulses generated by oscillator OSC1 to the binary counter NB1. This state is maintained all along the time span between moments t_1 and t_2.

At time moment t_2 the current wave also passes through point zero towards positive values. At time moment t_2 the zero detector DZI generates an impulse, which

Fig.2. The wave shapes of voltage U, respectively current I pointing out to the phase shift φ between them



triggers the monostable CBM2; its output gives a square impulse, applied to the bistable CBB2. Its output will switch to 1 logic, which will prevent the access of timing impulses towards the binary counter NB1 by the validation / inhibition logic. As a result, the value given by binary counter NB1 at time moment t_2 expresses the phase shift between the voltage and the current in the power grid.

The binary counter NB1 is structured for 10 binary ranks. Its binary outputs are applied to a numeric-analogical converter, labeled CNA; at its output we have a current signal whose value depends on the binary value marked by counter NB1, so the phase shift between the voltage and the current. Because the input of the fuzzy micro-controller accepts only two voltage signals, it is necessary to place in between a converter current-voltage, CIU. As a result, the voltage signal V(φ) at the output of the current-voltage converter expresses the phase shift φ .

In order to allow a new determination of the phase shift for the next half-cycle, it is necessary to initialize counter NB1 prior to a new passing of the voltage wave through the zero point (moment t_3). In order to achieve this we introduced an initializing circuit, CNIN1. As a result, at time moment t_3 all the bites in counter NB3 have the valued 0 logic.

At time moment t_3 the voltage wave passes through zero towards negative values, but the current preserves a positive value. The passing of the voltage wave through zero is noticed by zero detector DZU, which generates a new impulse, triggering the monostable CBM1; its output gives a square impulse applied to the bistable CBB1. Its output will become 0 logic, state which, through the validation / inhibition logic LVI will allow again the access of the timing impulses generated by oscillator OSC1 to binary counter NB1. This state is maintained all along the time interval between moment t_3 and t_4.

At time moment t_4, the current wave passes through zero towards negative values, which is noticed by the zero detector of the current wave DZI, which generates an impulse triggering the monostable CBM2, which will switch the output of the bistable CBB2. It will become 0 logic, applied to the validation / inhibition logic LVI, which will inhibit the access of the timing impulses towards binary counter NB1. Thus, binary counter NB1 will memorize at moment t_4 a value which depends on the duration of time interval t_3 – t_4, i.e. the phase shift between the voltage and the current corresponding to the second half-cycle. As a result, for each voltage period of the power grid we carried out two measurements of the phase shift, corresponding to the positive, respectively negative half-cycle.

As it has been shown, at the input of the fuzzy controller we applied three analogical signals V(U), V(I) and V(φ) with values ranging within (0…5) V, whose values depend on the respective voltage, current and phase shift in the grid. Starting from the value of the three signals and according to the processing program implemented on the fuzzy controller as processing rules, we obtain at its analogical output a DC voltage also ranging within (0…5) V. The higher this value the closer the work conditions are to a fail condition, or in case of a failure, the more serious it is.

One problem to solve is to disconnect the contact line in a time interval, which is shorter as the failure is worse. At the same time, the feeding of the contact line is to be maintained in case of short failing work conditions (due, for instance, to atmospheric overcharges).

These requirements can be met by using a programmable timing circuit. This is made of a voltage – frequency converter plugged at the output of the fuzzy controller, thereby obtaining a square signal whose frequency is higher as the voltage given by the fuzzy micro-controller is higher. These square impulses are applied to a binary counter NB3, which, during one counting period, will display a value that is directly proportional to the voltage of the fuzzy micro-controller output. Counter NB3 has 8 binary ranks. The outputs of this counter are applied to one of the inputs of a numerical counter, CN. At the other inputs of the numerical counter we applied the outputs of another binary counter NB2, whose role is to memorize a value, pre-determined by the user. This value is input to the counter by means of an adjusting block, AJ, respectively by means of the timing oscillator OSC2. The impulses applied to binary counter NB2 are applied simultaneously to a decimal code counter NBCD, whose outputs are applied to a decoding system DEC and then to a 7-segment display labeled DISPLAY. Thus, the user has a permanent control over the value given by binary counter NB2. This value represents the very threshold value meant to trigger the main feeding interrupter of the contact line. The numeric comparator CN notices the situation when the numeric value of counter NB3 becomes equal to the threshold value in the NB2 counter.

It is obvious that the triggering of the main interrupter of the contact line will be done in a time interval that is directly proportional to the threshold value of binary counter NB2, respectively inversely proportional to the voltage at the analogical output of the fuzzy controller.

The triggering of the main interrupter can also be done instantaneously in case the voltage at the output of the fuzzy controller is 5 V, which corresponds to fatal failures. This value is noticed by comparator C, which permanently compares the value at the output of the fuzzy controller to a reference voltage of 5V, given by the reference source UR2.

For a correct functioning it is necessary to periodically reset the binary counter NB3 so that its value does not reach the threshold value memorized by binary counter NB2, even for normal work conditions. This condition is met along each cycle of the power in the grid by the initializing circuit CNI2. This circuit uses as time reference the same impulse of passing through zero of the power grid voltage.

3.CONCLUSIONS

The diagram we gave has been built and tested in laboratory conditions. In case of fatal failures the respond time was under 5[ms] and it can be reduced by using a more advanced controller. Thanks to the principle we have used the device for the protection and control of the contact line work condition, can also be applied to other users, being flexible, solid, precise and reliable. Its conception is original. The base of rules used in the fuzzy analysis of the signals is the object of another paper.

BIBLIOGRAPHY

1. Mc. Lauren, P.G., 1995, A New Directional Element for Numerical Distance Relay, *IEEE Trans. On Power Delivery*, vol.10, no.2, 1995;
2. Pal, C. ş.a, 1996, Protectia sistemelor electromagnetice, Editura "C. Gâldău", Iaşi, pag. 130-145;
3. Sângiorzan D., 1990, Echipamente de reglare numerică, Ed. Militară, Bucureşti, pag.157-173.