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CONTROL OF INDUSTRIAL PLATE-TYPE ELECTROSTATIC PRECIPITATOR WITH THREE SECTIONS

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Abstract: Plate-type electrostatic precipitators are the largest and most used industrial dust control, most applications are in the production of electricity (thermoelectric power plants). In many industrial applications, plate-type precipitators have three sections and silicon-controlled rectifier power supplies type. Although, the collection efficiency obtained by these type of precipitators are more than 95%. To improve the old industrial plate-type precipitators, the paper presents an expert system control of industrial plate-type electrostatic precipitator with three sections. The logical diagrams of the programs are presented for the proposed solution.
Keywords: thermoelectric power plants, electrostatic precipitators, logical diagrams

1. INTRODUCTION

Classical electrostatic precipitators purge hundreds of thousands of m^3/h that exceeding 95%, and their gauge is very high. Typically, the cost of electrostatic precipitators' maintenance is equal to that of the energy consumed. An important application of electrostatic precipitators includes cleaning polluted air that is a result from the combustion of fossil fuels from electric power plants.

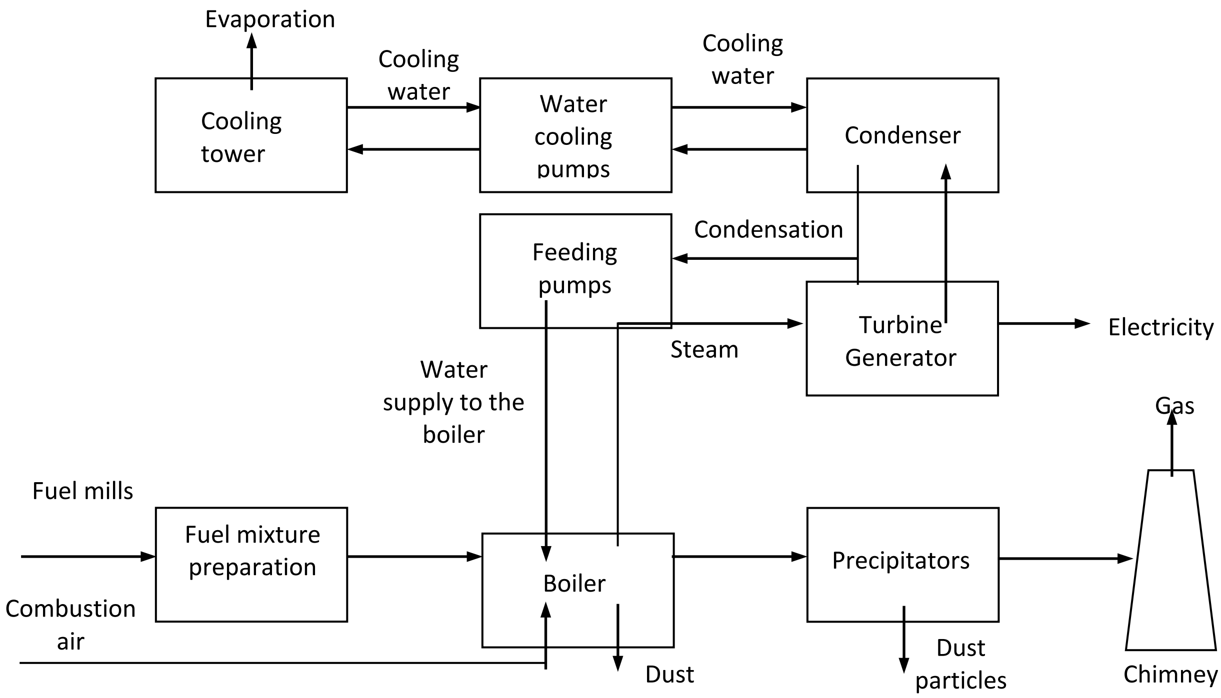

Figure 1. Principle of a thermal power station

In an electric power station, the precipitators consume about 1% of the energy produced by them [1].

Electrostatic precipitators includes integration into a power plant that in principle the scheme of Fig. 1. In this case, the electrostatic precipitators are located between the boiler fuel combustion and chimney. It is also the possibility electrostatic precipitators to be used alone without mechanical de-dusting.

2. POWER SUPPLY SOURCES

Electrical equipment of electrostatic precipitators are the most important part, which depending on the constructive achievement, functional layout and adjusting regime of voltage, determine the safety and efficacy of dust collection.

Traditional DC power was used in the last two decades and is obtained from a power source in the configuration variable alternative voltage. To be able to control the power of the Corona line low voltage is adjusted by a variable voltage (phase control with a pair of thyristors connected in anti-parallel), before being applied to high voltage transformer primary. By choosing a transformation ratio n for step-up voltage transformer, high voltage is obtained in their secondary winding; the voltage is rectified with a high rectifier voltage bridge. The secondary voltage is applied directly to a precipitator sections, without any filtering. The discharge wires are connected to minus terminal of the bridge, and surface collections are connected to the positive terminal of the bridge and, also, to the ground [1,2].

Intermittent power, is a recently introduced method in the early 1980s, in order to save electricity and to improve the efficiency of dust with high resistivity. This type of supply is also known under other names: energy control, semi-pulse, pulse changes, etc. Intermittent feeding is the cheapest alternative method that has been developed and well-marketed for high resistivity of the dust. Intermittent power supply is obtained with the same electrical equipment as the traditional DC power supply. The difference is in the automatic control of voltage, a number of pulses of current are suppress. This suppression is achieved by thyristors blocking, in the respective halves of the period, or alternatively by using a starting angle $\alpha=180^0$. The peak voltage is greater than in the case of DC power supply for the surface under the pulse current is higher. Minimum voltage is smaller than in the case of DC supply due to the high length of time between current pulses.

Intermittent power supply cause a low value of average voltage and average current from electrostatic precipitator's section. In the case of low resistivity, reducing the power of the Corona has the effect of lowering migration speed and reducing of collection efficiency. For the average resistivity of dust powder can be seen, in both cases, the same low emission of dust; but for higher concentrations of dust, intermittent supply is best for the same power density. In the case of high resistivity dust intermittent supply is better than DC power supply, the effect being low dust emission and lower power consumption.

Pulses energization for the electrostatic precipitators includes pulses was made at the end of the 1980s, being a major technique development. This method has been found to improve dust collection of high resistivity. The dust is difficult to collected, constituting one of the major drawbacks of electrostatic precipitators. Powering through pulse consists of short duration high voltage pulses (60 kV) on the base voltage (40kV); the pulse width varies between the 1μs and 100μs. The high voltage pulses are reported with a frequency of 1 to 400 Hz. Compared to other solutions for the precipitators' sections, the differences are as follows:

- ✓ high voltage pulses have higher amplitude;
- ✓ the voltage is kept close to the Corona discharge voltage;
- ✓ the peak value of section voltage is equal to the base voltage and high voltage pulse, so the total voltage is greater than in the case of traditional D.C. power supply. The high voltage pulses electric scheme differs from traditional D.C. power scheme. The new schema must contain a pulls generator circuit and a power supply base voltage. Moreover, pulses amplitude, the base voltage amplitude and frequency repetition of pulses should be amended in line with a control strategy, this function is fulfilled by a special control unit.

3. CONTROL OF ELECTROSTATIC PRECIPITATORS

Along electrostatic precipitators industrial exploitation were used several adjustment methods [3,4]:

- ✓ on the basis of current and voltage;
- ✓ based on the electric arc in electrostatic precipitator sections;
- ✓ on the basis of the number of electrical discharges in electrostatic precipitator;
- ✓ on the basis of the maximum amount of power consumed at the Corona discharge;
- ✓ on the basis of the average value of the maximum voltage.

Do not use in general only a particular adjustment process, but their combinations. By maintaining automatic voltage limits immediately close to breakdown discharge, the voltage is memory. When the discharge occurs, the voltage drops to zero or at a low voltage necessary to extinguish the arc, then the voltage increased again after an interval of 0.3-0.5 s. A disadvantage of this method is that periodic voltage decreasing, the average value applied to the section is smaller and the overall efficiency is low. This method is used in processes that do not appear too large changes of the characteristics of the gas.

Automatic voltage adjustment based on the breakdowns frequency in the electrostatic precipitator has principle production with a particular frequency of incomplete discharge in electrostatic precipitator. It found experimentally that it is obtained a maximum of de-dusting at a frequency of 40-70 discharges/minute. If the dust resistivity is high, frequency discharges dust can reach 50-120 discharges/minute [5]. The frequency of discharges is an exponential law:

$$S = e^{b \cdot (U_M - U_i)} \quad (1)$$

where U_M is the maximum value of the voltage [kV], U_i - the maximum discharge voltage for one discharge/minute, in [kV], and b is the empirical constant. This type of adjustment can be used at high resistive powders with high concentrations of dust.

Another tuning system is based on the use of the primary transformer voltage and the average high voltage on section. The average voltage on sections grows linearly with the primary voltage until it reaches a certain value to the average voltage, than occur a slow variation or a sudden drop in voltage [6]. Maximum average voltage corresponds to the optimal number of discharges in the electrostatic precipitator. Taking into account the strength and duration of the discharge, and the discharge frequency is determined based on the efficiency of the precipitator. This system is suitable for very high resistivity and high concentrations of dust.

The signals acquired from the process to be used by the control units, are not always the same. Europeans have a long tradition of using precipitators' current and voltage (so-called secondary values), while the Americans used primary values of current and voltage, but in recent years there is a tendency to adjust the process based on secondary values. Installations with opacimeter on chimneys are increasingly used in particular in new installations. The signals received by the opacimeter are used for continuous monitoring of dust emitted through the chimney. The use of the opacimeter signal in automatic control units of voltage has the following aims:

- ✓ to optimize technological process of electrostatic precipitators;
- ✓ the energy saving in terms of easy operating.

In order to achieve an efficient control of power supply and shacking of precipitator's sections, it should be kept in mind a lot of variables, which are often hard to measure. These variables are: the electrostatic charge of the particle, the particle size and distribution of dust, gas, temperature, resistivity of dust, grinding mode of fuel, the way the boiler combustion takes place, etc. [1]. Such complex systems were implemented on programmable logic controllers and with specialized software [7].

Precipitators have modification of parameters in a wide range, and sometimes without a well-defined correspondence between them, making almost impossible the math modelling. Through the use of sets of rules between the main parameters of he electrostatic precipitators, fuzzy control can be an alternative to power sources (control strategies of voltage) and sections' shacking. Research in the field have been made with good results [2,5].

Statistical control of processes is a concept that is based on statistical methods that supervise stages of an industrial process. To use this procedure, process variables have purchased and analyzed over a period of time, when the process takes place in stable conditions. It is important to know the evolution of the process variables in certain operating conditions in order to predict his future evolution. For a given set of conditions initial can predict exactly how it will change each parameter, which is the time it takes to make this change. To be able to apply statistical control is important to know causes of parameters process modification [8]. In general, there are two types of variation, determined according to the causes:

- ✓ common;
- ✓ special.

It was determined from experiments that more than 80% of the parameters' variations of the process are common causes. To be able to distinguish between the common and special causes that have determined the process variables, using generally two parameters $\bar{x}$ and R:

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n} \quad (2)$$

$$R = x_{max} - x_{min} \quad (3)$$

where $\bar{x}$ is the mean value of the measurements in a group, and R is the rank of the group, x_{max} - maximum group value, x_{min} -the minimum and the group. The rank for each group is an indicator of the instability of the process. Upper and lower limits of control represent the relationship between process variables and statistics are calculated from the rank group. Additional causes that will cause the change process will be reflected by the increase in rank R. After the causes are eliminated, R decreases. Any improvement of the process will be observed in R.

Small changes in performance equipment that controls the process may result in the modification of parameters of the process, which may lead to unstable processes. To implement in practice, such control is necessary software and electronic equipment of last generation, that is able to collect, manipulate and withhold information in with industrial process development.

Identification is an experimental technique for determination of dynamic model of the process, and includes the following steps [9]:

- ✓ the acquisition of inputs/outputs;
- ✓ choice model structure;
- ✓ estimation of parameters of the model;
- ✓ identified design validation.

One of the key elements is the parametric adaptive algorithm that adjusts the parameters of the model prediction based on the indications culled from the system every step of sample. New parameter value is equal to the previous value plus a correction term that depends on the last measurements.

An expert system (Fig. 2) is a branch of artificial intelligence and has three modules [10]:

- ✓ knowledge base which is a data structure containing all the specialized knowledge of a human expert;
- ✓ inference mechanism that retrieves data from the knowledge base; these are used for constructing reasoning;
- ✓ the fact is represented by an auxiliary memory which contains all user data.

To build an expert system are the following:

- ✓ the possible existence of applications that can be implemented with the help of an expert system;
- ✓ the existence of a specialized expert system for a certain category of applications to which is attached a specialized knowledge base.

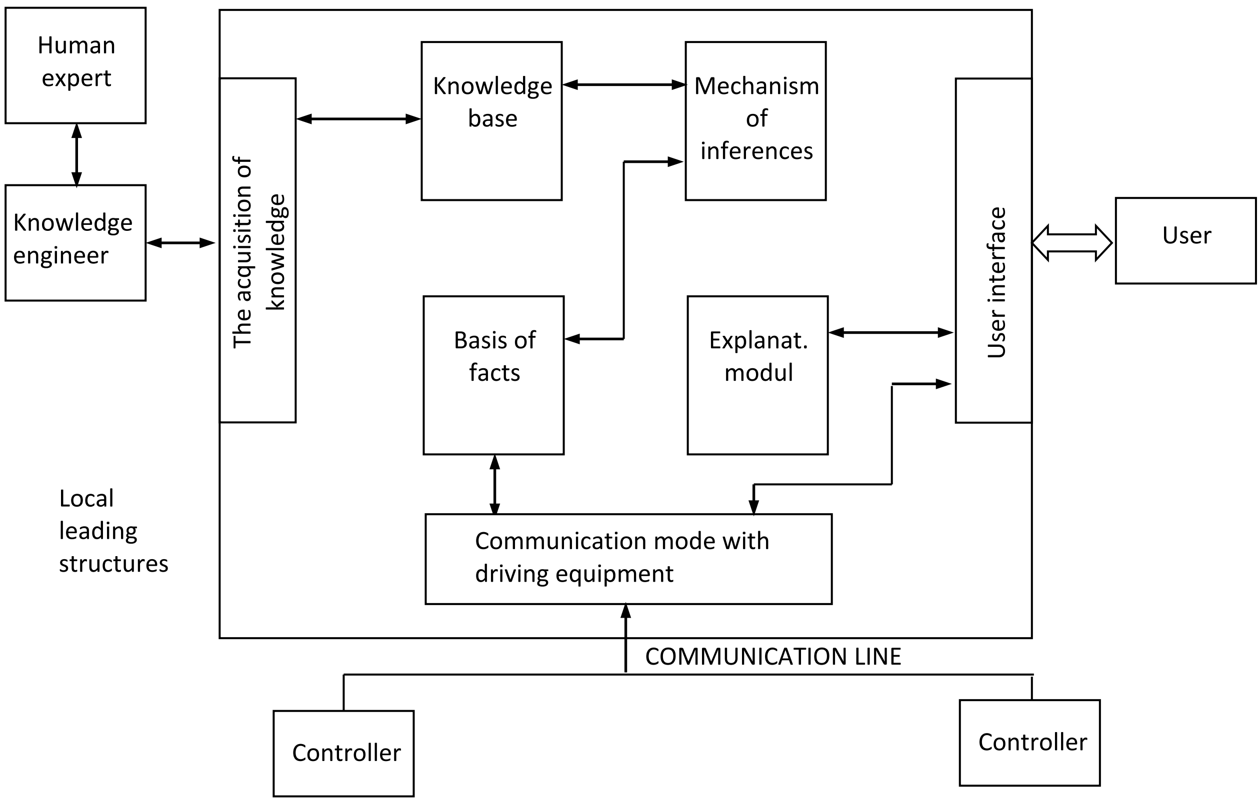

Figure 2. The structure of an expert system that communicates with the local driving equipment

4. PROPOSAL FOR CONTROL OF AN ELECTROSTATIC PRECIPITATOR WITH THREE SECTIONS

An outline of a logic diagram, designed for command of an electrostatic precipitator with three sections is presented in Fig. 3. Such an expert system can deploy on a high-performance microcontroller 16 or 32 bits. Each section has a separate power source.

The first time, place the setup performs some initialization work voltage (continuous, intermittent, etc.) to the three sections. Increase the voltage on the sections, so as not to produce discharging and shake frequency is set for each section individually. Measurement of currents, voltages and dust concentration, the input and output dust concentration (measure through opacimeters) are made permanent; searching on the basis of knowledge about similar situations. If you found such a situation the algorithm is taken for controlled voltages and frequencies the sections' shaking. If it has not encountered a similar situation, are other forms of voltage for electrostatic precipitator, than increase the voltages on the sections. If dust concentration falls below a preset limit, then change the frequency of shaking. Check at regular intervals it not to exceed the default values of the measured currents on the three sections, which causes lightning in precipitator's sections. If lightning occurs in one of the precipitator's section, then the voltage on that section goes to zero, and after a break, the voltage increases at a previous value (Fig. 4).

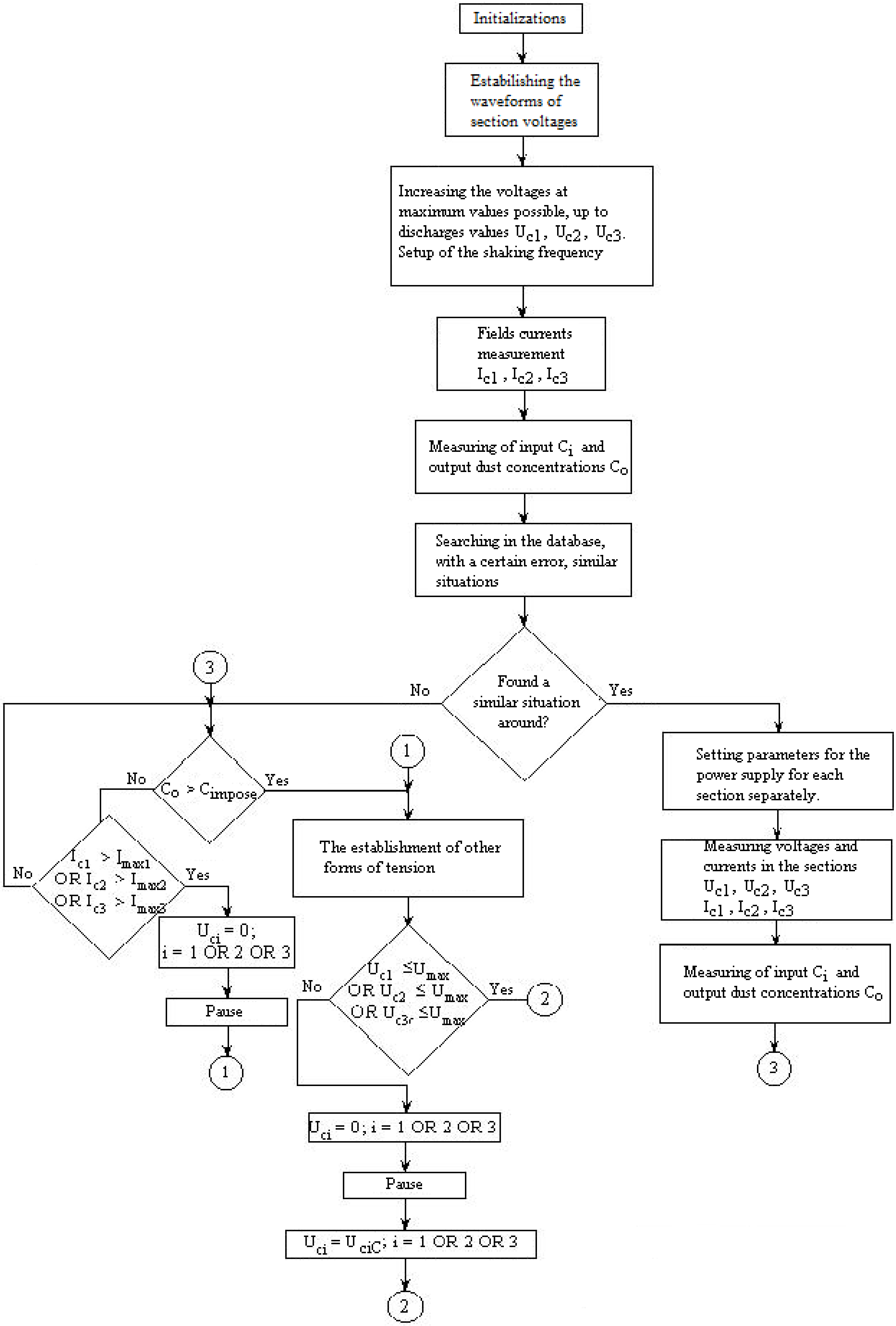

Figure 3. The logic diagram for the command of expert system of electrostatic precipitator with three sections

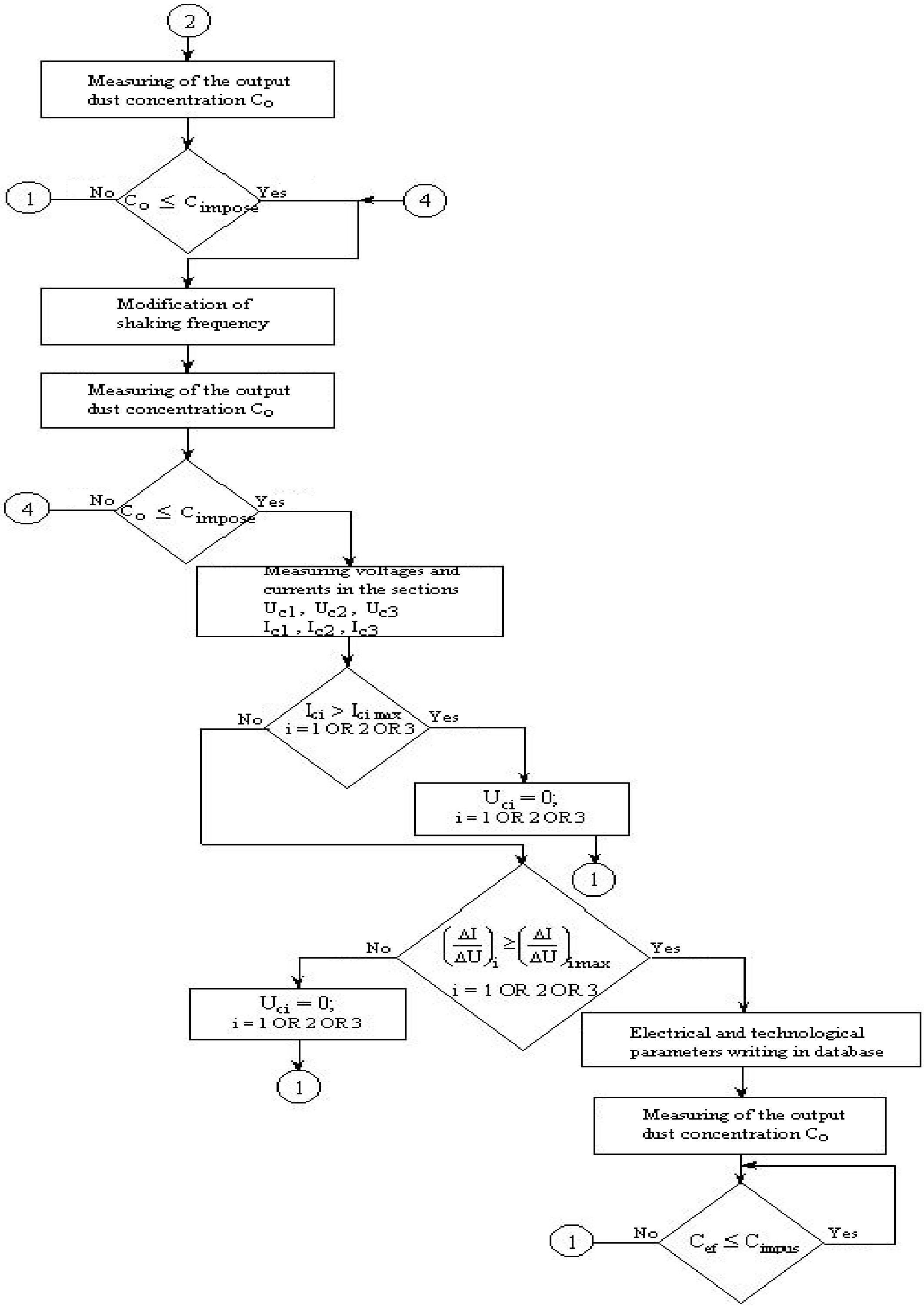

Figure 3. The logic diagram for the command of expert system of electrostatic precipitator with three sections (cont.)

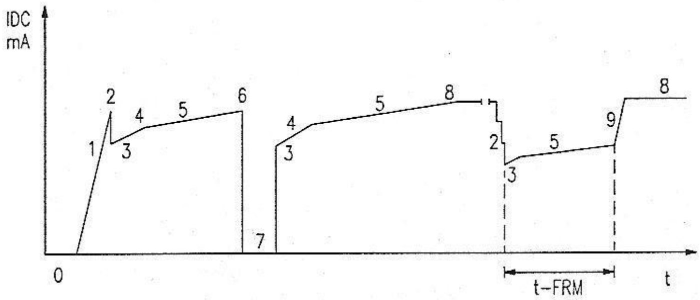

Figure 4. Flow control during typical events in section operation

In Fig. 4 have made the following marking: 1 - putting into operation; 2 - type 1 discharge; 3 - the time of restitution; 4 - return current; 5 - the normal evolution of the current; 6 - type 2 discharge; 7 - time of extinction; 8 - the upper limit of the current; 9 - the rapid growth of the current [4]. The power supply switch on when the main contactor is switch on. During the first two seconds of thyristors firing pulses are blocked; after that, the voltage is increased to a adjustable base. A direct current is increased by a rate of 200%/minutes. The start-up sequence is completed when the current limit is reached (8), (current limit is adjustable parameter) or when type 1 or type 2 discharges occur (6). A discharge causes a reduction in direct current (4) to the adjustable value. At the time of unloading (2) until the current reaches the value (4) runs a recovery time (3), the precipitator's is adjusted, in a special way, in order to avoid a new discharge. The current is increased by a rate (5) corresponding to the required discharge rate. Growth rate (5) is calculated and is based on the values set for the current and the rate of discharge.

Permanently to measure the concentration of dust from the outlet and it is compared with the value of the imposed value.

To determine the back Corona effect the ratio ($\Delta I/\Delta U$) is memory and memorize the previous values. Back Corona charging the particles cause the opposite of powder with a positive charge and then attach these particles per very small surface of discharge wires. As a result of this effect, the largest amount of dust will be evacuated on chimney. The knowledge base of the system is the most difficult to build. Its have chosen those parameters which define the behaviour of precipitator from the multitude of parameters which define the operating of an electrostatic precipitator. Storing parameters must be done after a certain algorithm so that searching for the data to be situations on the road as quickly as possible. Sample frequency of precipitators' parameters is another size which must be taken into account. A frequency too high cause the accumulation of large amounts of knowledge, making it hard to find a real operation's case, and a common sample too small can "jump" over major cases.

5. CONCLUSIONS

It has been proposed a logic diagram of an expert system for command electrostatic precipitator with three sections. The voltages and currents are permanent measure and the output dust concentrations. The output dust concentration is monitored permanently and is compared to a preset value. It is searching in a database (built on the basis of measurement of parameters in the past) a similar situation and to set the parameters of the command. The algorithm changes the amplitudes and shapes of voltages, as well as the sections of shaking. Detection back Corona effect is achieved by calculating the $\Delta I/\Delta U$ ratio at discrete moments of time. A special problem in the construction of such software is to determine the frequency of sampling to memorize the parameters to be entered in the database and the time interval after which they must be measured.

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