POWER FACTOR AUTOMATIC COMPENSATION WITHIN 20/6kV ELECTRICAL TRANSFORMATION STATIONS

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***Abstract* – The addition of the compensation of the power factor is one technical measure to improve the functioning of the electrical installations. Because the loads of the electrical installations show fluctuations in 24 hours and during one calendar weeks the number of capacitors that must be active must be variable according to the reactive power that must be compensated. This is done by step capacitor batteries with automatic connection controlled by a dedicated electronic equipment with microprocessor. The equipment receives information on the offset between the installation current and voltage that is to be compensated according to which it connects or disconnects the necessary capacitor steps to the distribution system lines, so that the power factor to be kept around a preset value. The equipment permanently displays the instant power factor value and it is provided with an abnormal functioning state warning block. This way the paper presents ways to do automatic compensation of the power factor within electrical supply stations within a single 20/6kV transformer of 4 MVA power and also the compensation of the power factor within electrical supply lines within two 20/6 kV transformers of 2x4 MVA. The solution presented is distinguished in that it solves the problem of power factor compensation at a transformer station upgraded. Capacitor connection is made automatically by coupling or decoupling capacitors steps by comparison with the difference prescribed.**

Keywords: *power factor, electrical equipment industry, power stations, process monitoring.*

1. INTRODUCTION

In the energetic system among the active energy there is considered also the reactive energy which has two components: reactive energy consumed by the electric receivers (electric transformers, async electric motors, induction ovens, power electronic equipment) and wastes within the lines and electric transformers. The measure that defines the reactive power consumption is the power factor, cosφ which is defined, in an alternative current circuit, as the ratio between the active power P and apparent power S (φ is the lagging between voltage and current). The value of the power factor that must be done by a consumer in order not to waste reactive energy is in the [0,92…1] range. This way there is used an automation cabinet for power factor compensation that is the device that uses the capacitor batteries to keep the power factor in the [0,92…1] range which means that the reactive energy will not be counted.

The cabinet contains many capacitors (according to the value of the reactive energy) grouped on 3 and respectively 4 steps, which will be connected according to the needs requested by the dedicated equipment.

The capacitors are done in tri-phased special structure that includes own discharging resistors.

The automatic control of step switching is done with a programmable logic controller. This measures the consumption parameters (U, I, cosφ) and according to the values it controls the coupling or decoupling of the capacitor steps using the reactive energy connectors [1], [2], [3], [7],[10].

2. AUTOMATION CABINET FOR THE COMPENSATION OF THE POWER FACTOR

For compensating the power factor within the electrical supply stations within a single transform of 20/6 kV with a power of 4 MVA there was assured the mounting of a capacitors battery in 3 steps for compensation of the reactive energy with the total value of 1200 kVAR, with automatic connection of the capacitor steps according to the required reactive energy and respecting the conditions imposed by the factory regarding the interval between two successive connections of the steps, restricted by the time necessary for the capacitors discharging.

For compensating of the power factor within electrical supply stations with 2 transformers of 20/6 kV with 2x4 MVA there was assured the mounting of a capacitors battery in 4 steps for compensation of the reactive energy with the total value of 1900 kVAR, with automatic connection of the capacitor steps according to the required reactive energy and respecting the conditions imposed by the factory regarding the interval between two successive

connections of the steps, restricted by the time necessary for the capacitors discharging.
The capacitor batteries are mounted in several metallic cabinets of specified dimensions, which contain the entire force and control equipment necessary for assuring the imposed functions (Fig. 1).

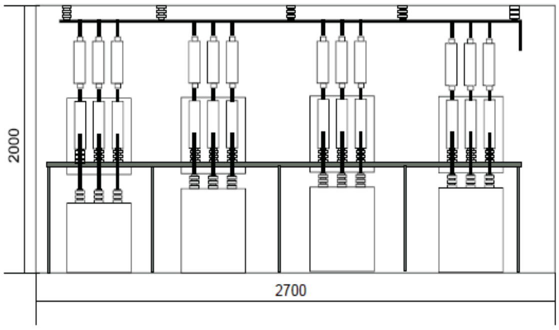

Figure 1: Block diagram of the automation cabinet which underlines the placement of the components for the 4 steps compensation battery

Each automation cabinet contains:

- a set of cooper bars mounted on isolators for the supply with the force voltage of the steps of compensation battery;
- a set of fuses, provided with fuse burning warning notification, for the supply of the contactor that connects each compensation step;
- a force contactor with void contacts with a base current of 400 Aef with allows the coupling of the capacitive loads corresponding to each compensation step;
- one or two tri-phased capacitors (according to the value of the compensation step) with base voltage of 6,6 kV;
- a compartment with the automation equipment which contains a variety of switching, command and control equipment on low voltage side, supplied with 220 V AC voltage within the distribution cabinet within the electrical station. The equipment assures the connection of each compensation step according to the received commands from the programmable logic controller within the electrical transformation station and the sending of the information related to the state of the fuses and of the contactors of compensation steps to the programmable logic controller [6], [9], [12].

The connection between the automation cabinet and the electrical transformation station of 20/6 kV is done by using 3 cables:

- one force cable needed for the 6kV voltage supply of the distribution lines within the automation cabinet;
- one cable for low voltage supply of the variety of automation equipment within the cabinet;
- one cable for the communication with the programmable logic controller mounted in the automation cabinet within the electrical station needed for taking commands for steps connection and sending to the programmable logic controller of information regarding the state of the fuses for supply of each step and of the state of the force contactors which connect the compensation steps.

3. COMPENSATION BATTERIES

There is presented the electrical schema of a capacitor battery for the compensation of the reactive energy with a total value of 1200 kVAR with 3 compensation steps (Fig. 2).

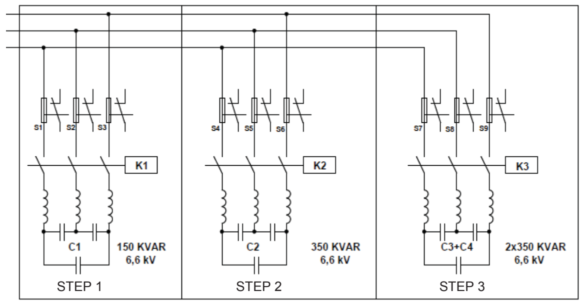

Figure 2: Electrical schema of a compensation battery of 1200 kVAR with 3 compensation steps

The value of the compensation steps is:
Step 1 – 150 kVAR
Step 2 – 350 kVAR
Step 3 – 700 kVAR(2x350)
By choosing these values there can be assured an adjustment of $2^{\text{steps number(3)}}$ of the compensation capacitive value according to a control algorithm.
The control schema for the steps of the compensation battery according to the implemented algorithm is assured by an extension of the programmable logic controller within the electrical station (Fig. 3).
The meaning of the elements within the control schema is:

- K1, K2, K3 the contactors that connect the capacitor steps;
- K01, K02, K03 intermediary contactors;
- C1, C2, C3 are mounted on the capacitors which disconnect if inside the capacitors there are created gases of if their temperature raises over a preset limit;
- S1, S2, S3 are auxiliary contacts from the protection fuses which supply with voltage each capacitor step;
- XN4DO is an extension module of the programmable logic controller with 4 outputs with relays;
- XN4DI is a digital input module with 4 digital inputs of 24 V DC galvanic isolated.

The extension is mounted in the low voltage compartment of the compensation battery and communicates with the programmable logic controller through a serial connection of CAN OPEN type (Fig. 4).

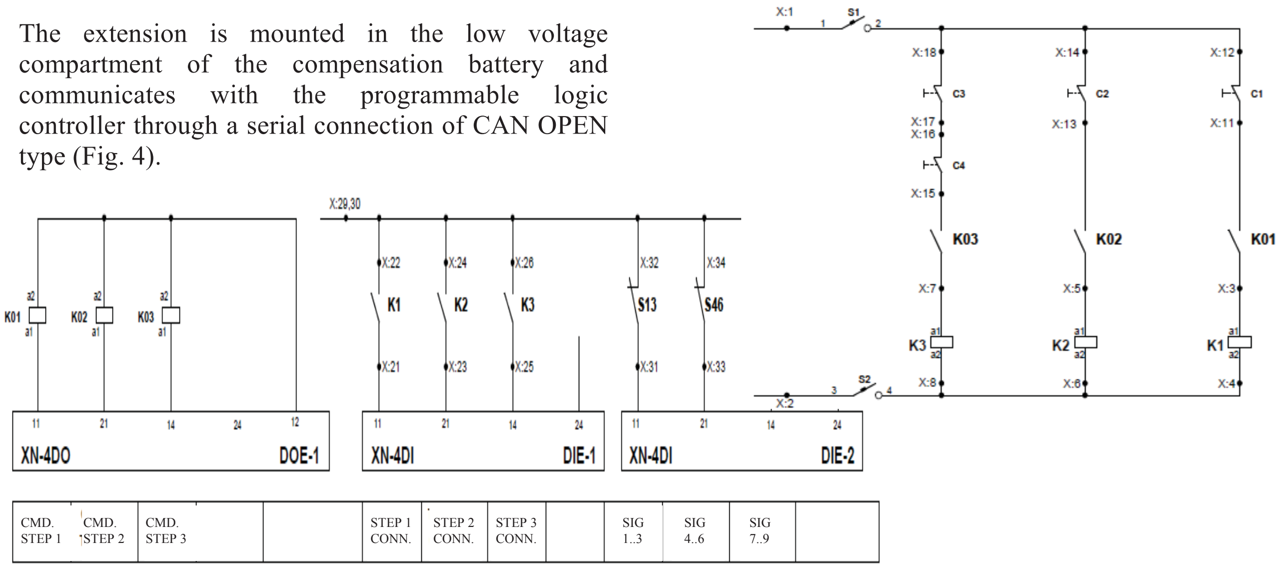

Figure 3: The control schema of a compensation battery with 3 compensation steps

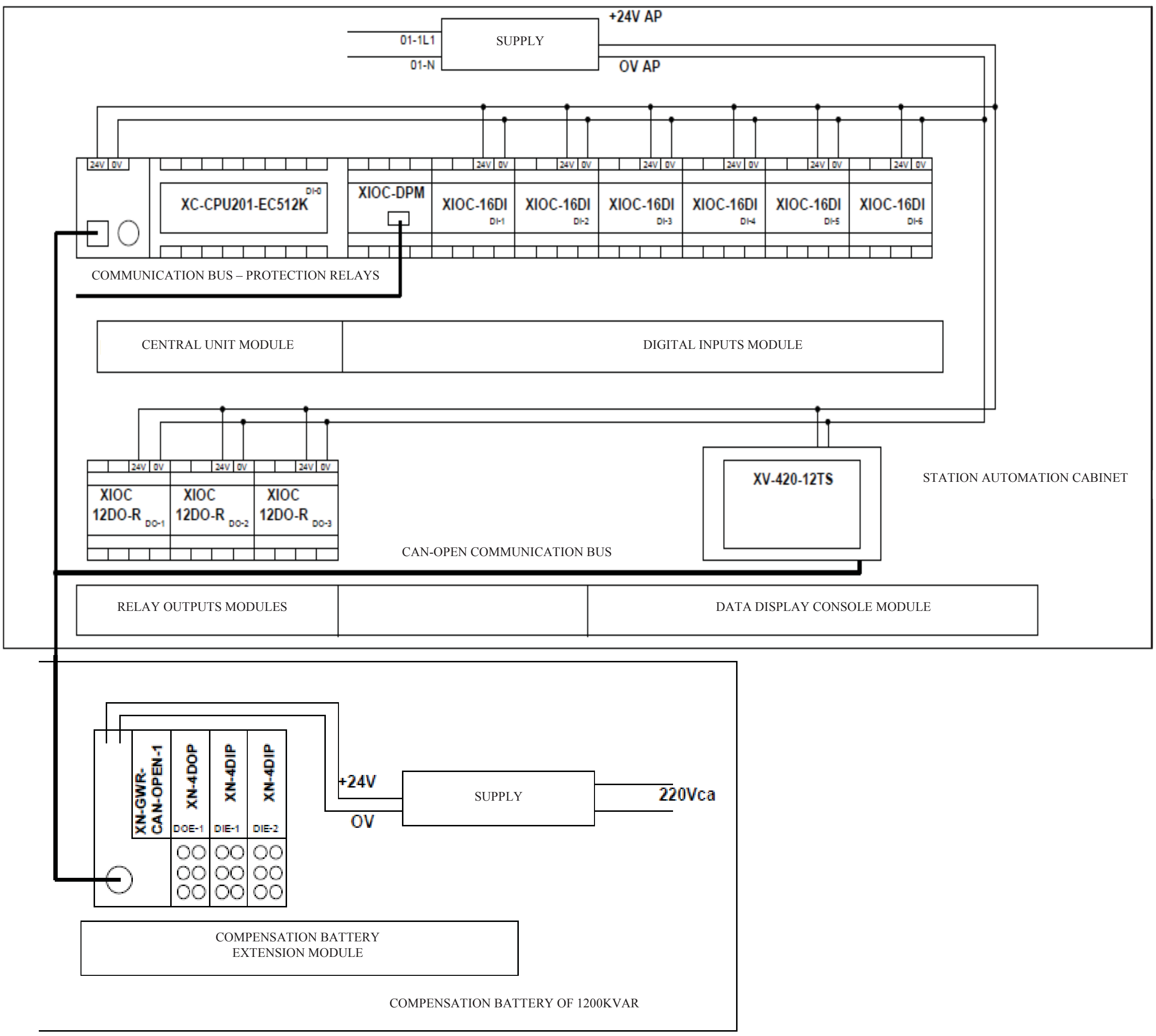

Figure 4: Configuration of the programmable logic controller for the compensation battery with 3 compensation steps

4. CONTROL AGORITHM FOR THE COMPENSATION BATTERY

By using a special subroutine implemented in the memory of the programmable logic controller, based on the data regarding the active and reactive power taken from the various acquisition, command and protection equipment (PCE-F) mounted on each consumer supply line within the electrical station (Fig.5), by using the PROFIBUS internal data communication bus, there will be automatically computed the following measures:

- $P_{CONSUMED}$ – the total consumed active power on the station output lines;
- $Q_{CONSUMED}$ – the total consumed reactive power on the station output lines;
- FP – the total power factor;
- Q_{IDEAL} – the ideal reactive power computed based on the value of $P_{CONSUMED}$ for the obtaining of a power factor of 0,92.
- Q_{NEEDED} – represents the difference Q_{IDEAL}-$Q_{CONSUMED}$, that is the compensation value.

Based on these values the programmable logic controller will compute an average value on a 10 minutes interval (the minimum interval between the successive connection of a compensation step) $Q_{NEEDEDmedium}$ and based on this value it will send a command to the automation equipment mounted in the compensation battery for capacitor steps connection so that to obtain a value as close as possible to $Q_{NEEDEDmedium}$. The communication between the programmable logic controller and the automation cabinet is done by using the CAN-OPEN communication bus with a dedicated data communication cable [4], [5], [11].

For a compensation battery with 3 steps there are possible the following situations (Table 1)

K1	K2	K3	Q(kVAR) value
disconnected	disconnected	disconnected	0
connected	disconnected	disconnected	150
disconnected	connected	disconnected	350
connected	connected	disconnected	500
disconnected	disconnected	connected	700
connected	disconnected	connected	850
disconnected	connected	connected	1050
connected	connected	connected	1200

Table 1: Possible combinations for a 3 steps compensation battery

According to the value obtained for the reactive power there is sent the command to connect the respective steps by the extension block and of the force contactors K1, K2, K3 (Fig. 6).

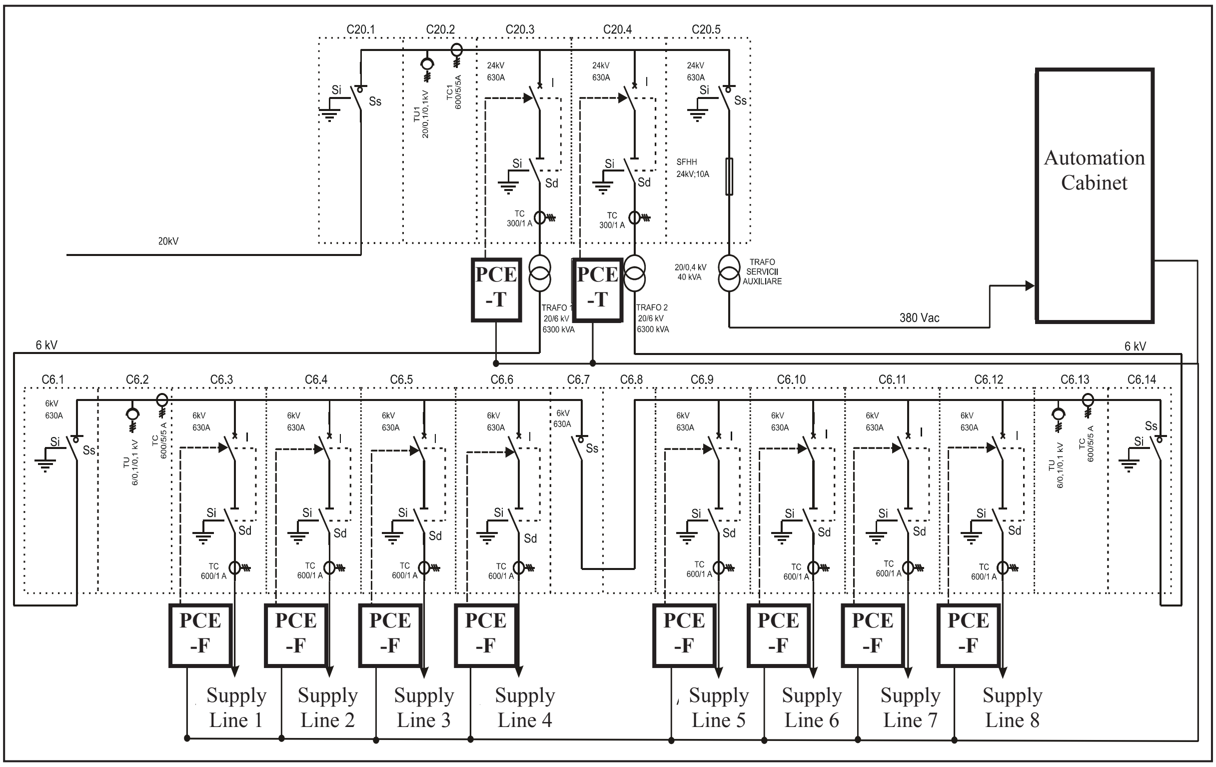

Figure 5: The schema of an electrical transformation station of 20/6 kV

Notes:

- Because of the functional constraints, a medium voltage capacitor can be reconnected to the network only after the elapse of a its minimum discharging time (500..600sec typically). Because of this the programmable logic controller must permanently store which capacitor steps are disconnected, the moment of time when a disconnect command was sent, and based on these, and based on Q_{NEEDED} value to send the connect commands for one, two or of the 3 steps taking into consideration the minimum reconnection time.
- The process is repeated each 10 minutes assuring the obtaining of a power factor in the [0,92…1] interval.
- If the technological process has great and fast variations of the power factor there are productive solutions which can assure the discharging of the capacitors in an interval less than 1 minute. So that there can be assured the power factor in the imposed limits.
- The process of power factor compensation is activated only in the case that the active consumed power on 6kV lines goes over a preset value (set by the user). Based on previous applications the value is typically set to 250 kW.

4. CONCLUSIONS

1. The introduction of the compensation of the power factor is improving the electrical stations functioning and has the following advantages:
   - lowering the price paid for the consumption of electrical energy by eliminating the consumption of the reactive energy and reducing the active energy consumption;
   - the creation backup active power by discharging the power transformers and cables.
2. The efficiency of the compensation cabinet is obvious and the revenue is got in a few months.
3. This way there is obtained a functional improvement of the electrical energy transport, transformation and distribution installations, and an improvement of the functioning safety along with a better usage of the electrical network by reducing the apparent power with which it is loaded.
4. The proposed solution is doing the power factor compensation without the need of any intervention in the electrical installation of the transformation station this way fulfilling the requirements imposed by the customer and with no perturbations over the functioning of the electrical station.

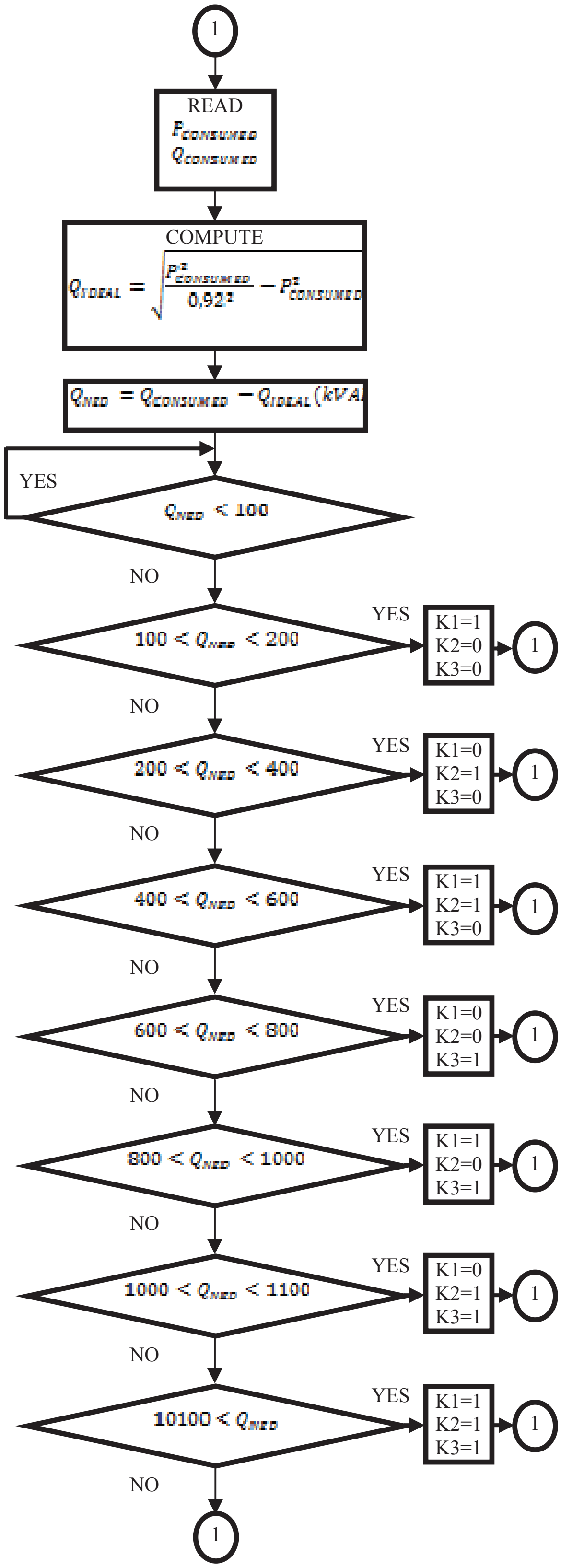

Figure 6: The logical diagram of the control of a compensation battery with 3 steps

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