APPLICATION OF PLC PROGRAMMING IN COST EFFICIENT INDUSTRIAL PROCESS

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Abstract: Paper presents application of programmable logic controller (PLC) in consecutive putting into operation of three groups of motors. PLC programming is done on the base of prescribed technological parameters. Putting into operation of each group of motors consisted of two motors is done with programmed time delay necessary for starting current of the motors to decrease up to the rated value and consequently allowed maximal current which is not penalized by the electrical utility to be observed. Offered solution enables saving of electricity, cutting off costs related to maxi graph and economical operation of electrical drive.

Key words: PLC programming, starting current, electrical drive

1. INTRODUCTION

Reduced and reasonable usage of electricity is one of the main tasks of large electricity consumers such as factories. Development of the production and implementation of modern technologies has led to the increased electricity consumption from one hand and from the other the quality of the supplied electricity is lowered due to the usage of electronic devices i.e. power converters which often generate high order harmonics responsible for decreased power factor at electricity network. Electrical utilities have undertaken several measures in order to improve quality of the power supply and in the same time to reduce electricity consumption or to control the electricity consumption. Related to this issue are increased bills for consumers of reactive energy, increased bills for peak loads and increased bills for injection of high order harmonics. Decreased costs can be achieved in case of peak energy consummation by consecutive putting into operation of large electricity consumers, which must be in coordination with the needs of the consumers itself and the technological process. In this context, it is very important electrical data of the devices, which must be put into operation to be known. In case of electrical motors it is the starting current usually multiple value of the rated current. In case of several motors put into operation

simultaneously, the total engaged starting current should not exceed the allowed maximal current that is not additionally billed. This imposed the need of equipment, which enables systematical putting into operation of these large electricity consumers. Paper proposes solution of consecutive putting into operation of three groups of motors by the aid of PLC type EASY 719-AC-RC programmed for delayed putting into operation of each group of motors [1]-[2]. The process of programming is explained as well as electrical connections of the PLC with electrical loads. Final tests and verification of the program are performed before loading the program into the PLC.

2. PROJECT DEFINITION AND DESIGN

Main task of this project is to decrease the costs of electricity consummation due to extra charges, billed in case when maximal current is exceed i.e. cost for maxi graph. Two types of consumers exist at the production facility. First ones are common consumers such as lights, servers, personal computers, surveillance system etc. Their electricity consumption is considered as continuous and it should not be influenced on any way. Second ones are the consumers, which will be integrated in the procedure of consecutive putting into operation. They are three-phase induction motors from the producer Siemens with high efficiency class IE2. Their rated data are type 1LE1 01-1CC3, rated power 5.5 kW, rated current 12 A, in total one piece. Ten pieces of motors are from type 1LE1 01-1DC2, rated power 7.5 kW, rated current 16 A. Motors with rated power 7.5 kW are divided in three groups with two motors per group that must be put into operation simultaneously. Other motors can be put into operation independently. These are the requirements imposed by technological process.
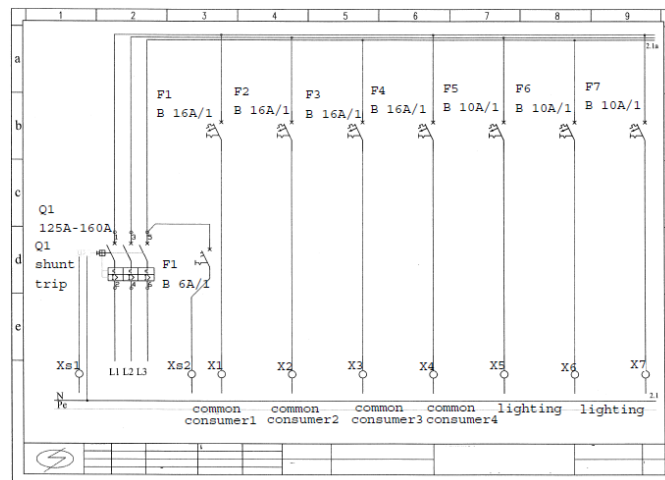

Fig. 1. Main power supply of electrical drive and common consumers

This means that group of motors, which have double starting current will be put into operation first following the prescribed order of putting into operation from the PLC, while other motors will be put into operation after these groups. PLC type EASY 719-AC-RC with twelve digital inputs and eight outputs is connected to the motors. All motors are connected to the main power supply via circuit breaker Q1 with rated current within 125-160 A. This circuit breaker can be remotely controlled via shunt trip mounted between connection terminals Xs1 and Xs2 (Fig.1) which trips the main power supply protection in case of faults. Fuses F1 to F7 are permanently connected and consecutive putting into operation of motor groups does not influence them. Each motor is connected to separate connection terminals (Fig. 2). Similar distribution is presented for motor group nr. 7 and nr. 8 in Fig. 3.
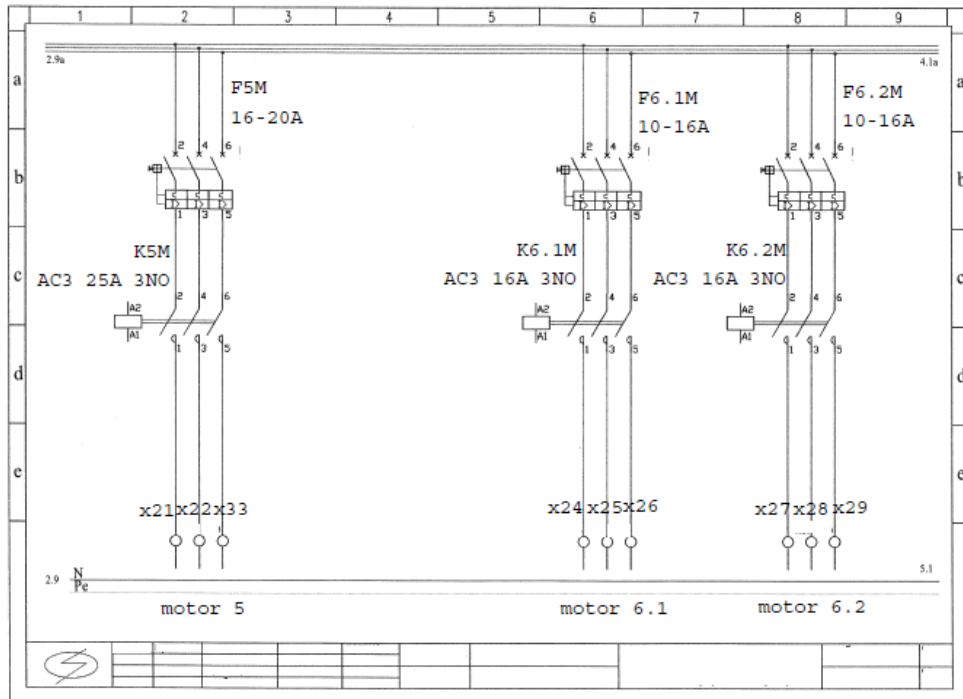

Fig. 2. Distribution of power supply to first group of motors

Connection of the PLC with the process is presented in Fig. 4. Power supply of the PLC is via fuse FK. FK also supplies clamp switch Gk, connected to Input 1 and further more to outputs Out 1 to 8. When PLC outputs are active, signal is transmitted to the shunt of contactors K1.M to K8.M and they will be switched on via circuit breakers F1M to F8.M.
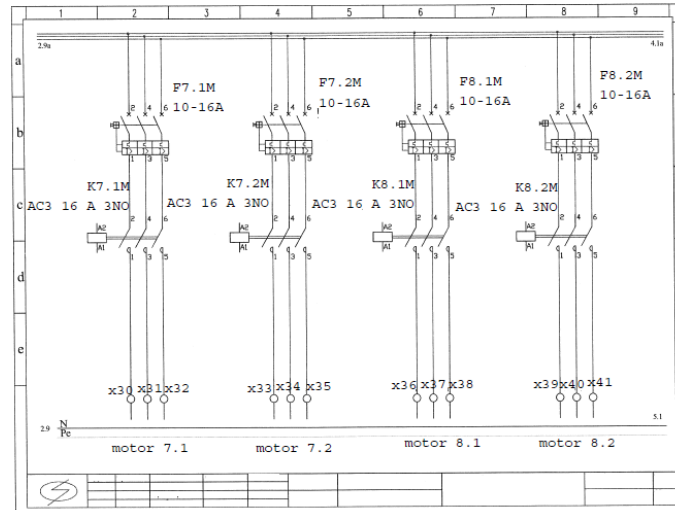
Fig. 3. Distribution of power supply to the second and the third group of motors
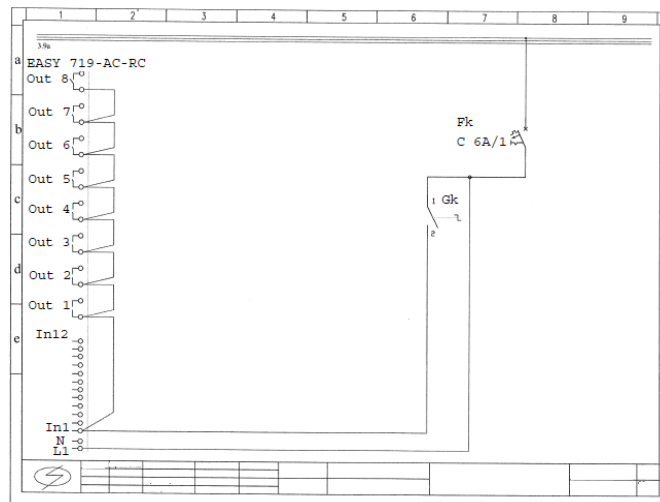

Fig. 4. Wiring of inputs and outputs of PLC

In case when output from the PLC is damaged or there is a failure in PLC outputs, switching on of the motors is done via clamp switches Gm1 to Gm8, which are aimed for manual switching on of the motors (Fig. 5). This manual switching is frequently used during the maintenance periods of the PLC, or when the PLC should be replaced with the new one.

In Fig. 5 are presented electrical connections of contactors K6.1M, K6.2M, K7.1M, K7.2M, K8.1M and K8.2M to the outputs Out6, Out7 and Out8. For

switching on the contactors K6.1M and K6.2M, which will cause switching on of the motors M6.1, and M6.2 it is necessary both motor protections F6.1M and F6.2 M to switched on (serial connection of contacts F6.1M and F6.2M). This means that independent operation of motors 6.1 and 6.2 is not allowed. The similar design is applied at motors 7.1 and 7.2 and motors 8.1 and 8.2. In case of fault at the outputs of PLC-Out 6, Out 7 and Out 8, clamp switches Gm6, Gm7 and Gm8 are used for manual switching on of the motors.
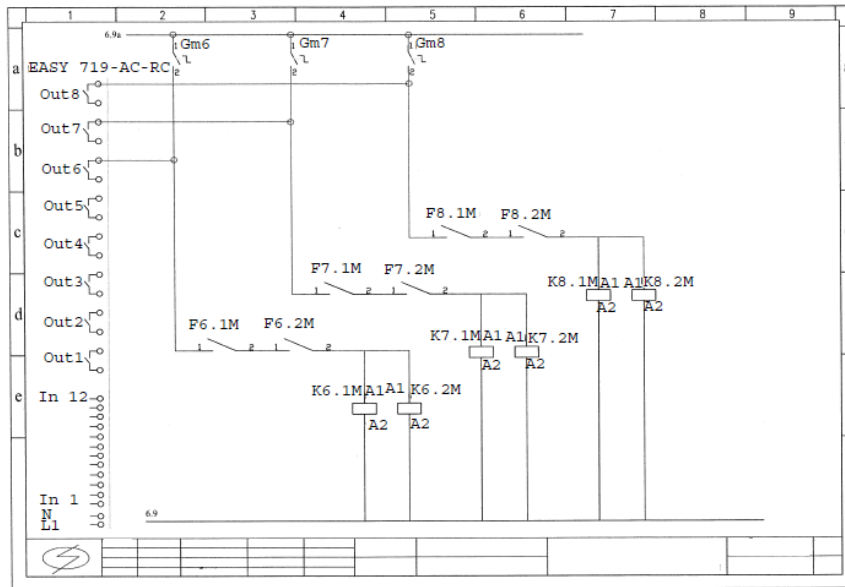

Fig. 5. Wiring of three group of motors to the PLC

Switching on simultaneously of contactors K6.1M and K6.2M is the only condition imposed by the industrial process. Starting current of these two motors is multiple value of the rated current of both motors and it decreases gradually in accordance to the moment of inertia of the drive system (motors and the connected loads). Time which is needed starting current to be decreased up to the rated current is know as time for putting into operation or time for acceleration of motors. This time will determine the delay time for switching on the second group of contactors K7.1M and K7.2M. Delay time of K7.1M and K7.2M should be longer than the time for putting into operation of motors 6.1 and 6.2. Additionally it must be taken into consideration average value of total current taken from the network at fifteen minutes time interval (measuring interval of maxi graph). If these conditions are fulfilled for time interval t6 and after this time interval elapses, the contactors K7.1M and K7.2M are switched on. This condition is valid also for switching on the contactors K8.1M and K8.2M with respect to the contactors K7.1M and K7.2M. Putting into operation of these three groups of

motors is the hardest operation regime with respect to the starting of motors. After these three groups are switched on, switching on of the contactor K1M is following. After acceleration time of motor M1 has elapsed and taking into consideration the total current taken from network, the second motor M2 is switched on. The schedule of operation of the motors is following: motor group 6, motor group 7, motor group 8, motor nr.1 and consequently up to motor nr.5. Times for switching on are t6, t7, t8, t1, t2, t3, t4 and t5. These times are fixed and set during PLC programming. Presented electrical design is suitable for independent operation of motors. In case of failure of one of the motors, the rest of them can continue with their operation. The layout of the PLC is presented in Fig.6.

Fig. 6. Physical layout of PLC and its connections

3. SOFTWARE SOLUTION

Next step in project development is the programming of the PLC. Ladder diagram is often used as language for programming the PLCs [3]-[6]. In this case, software EASY soft developed by the producer of the PLC-EATON is used. Adequate type of PLC is input in the working window i.e. PLC type EASY 719-AC-RC (Fig. 7). Here it can be also chosen the format of the diagram and in this case is chosen to be DIN/IEC. It has horizontally marked fields 001, 002, 003 …etc where the necessary operands i.e. elements from the electrical drawings are input.
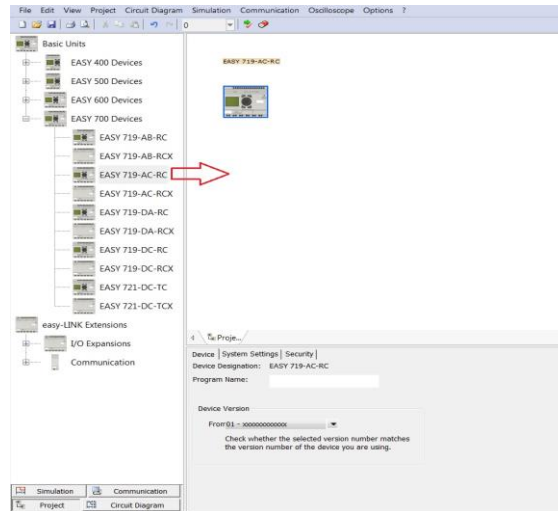
Fig. 7. PLC in the working window

First it must be input in the program the first digital input of the PLC-I01 in the field with coordinates (A001) as it is presented in Fig. 8.
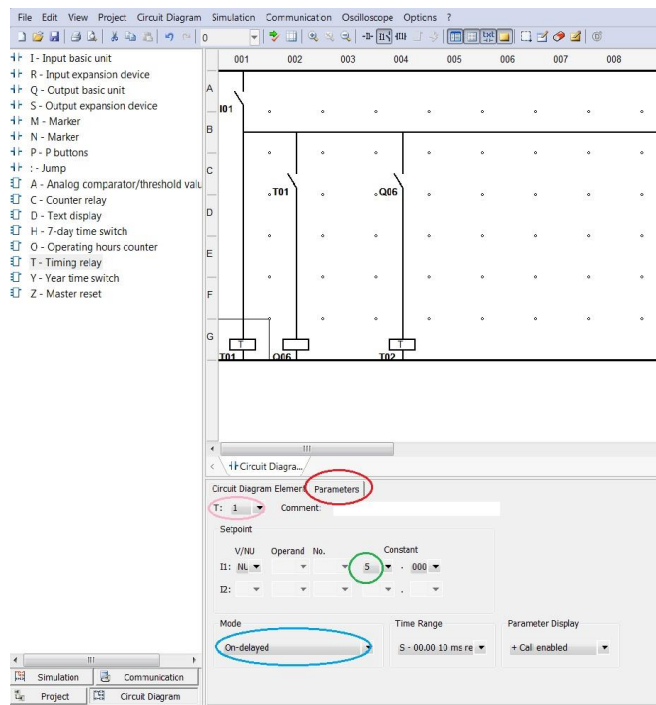

Fig. 8. Electrical connections in software of PLC

The positioning of the element in the working area is very important. The diagram compiling is always done from left to the right and from upper part of the window to the bottom, considering the chosen format DIN/IEC. Next inputted element is the time relay –T01 in the field with coordinates G001. The relay itself occupies the position G001 while its auxiliary contact is placed on position C002. In general, all control elements such as relays are placed under G coordinate while their auxiliary contacts are placed under C coordinate. Once they are placed in the working window the software, assign them the adequate symbols. If one of the elements is selected, for example T01 (Fig. 8) in the bottom part of the working area additional window is opened in which can be defined parameters of selected element. If the option Parameters is selected, the number of the element can be defined, type of the time relay (in this case with delayed switching on). If auxiliary contact of the time relay is selected (coordinate C002) additional window is opened where can be defined the type of the contact, normally opened or normally closed contact. The procedure continues with inputting element Q06 in this case it is a contactor of the motor nr. 6 (Fig.9). Consequently, all elements from the electrical drawing are input into working window of the PLC software but the schedule of their inputting is very important since they will be switched on in direction from left to the right. This means that first will be switched on element T06 and Q06, than T07 and Q07, T08 and Q08 etc..up to the T05 and Q05, following the restriction imposed by industrial process that first must be switched on group of motors nr. 6, 7 and 8. Afterwards consecutively are switched on motors from one to five (Fig. 9.). From Fig.9, it can be noticed that the first element is marked with number six as with this element output nr.6 from the PLC is switched on, which means that both contactor K6.1M and K6.2M (Fig. 5) are closed simultaneously. First, these contactors are switch on according to the defined schedule from industrial process afterwards output nr.7 from the PLC is active which enables switching on of contactors F7.1M and F7.2M and putting into operation group nr.7.

After all elements are input the programmer can proceed with the on-line testing of the program i.e. simulation of the program execution. As it can be seen from Fig. 9 all elements, which are switched on, are coloured in red colour and the corresponding outputs from the PLC, which are switched on, are also coloured in green colour. If the simulation is successful the next step is loading the program in the PLC. Loading can be done after physical connection of PC with PLC is done by adequate cable as well as the communication between the devices is established. Afterwards the program is run from the PLC by choosing the function "Run" from the display of the PLC. This is the end of the PLC programming and the PLC is ready for independent operation.
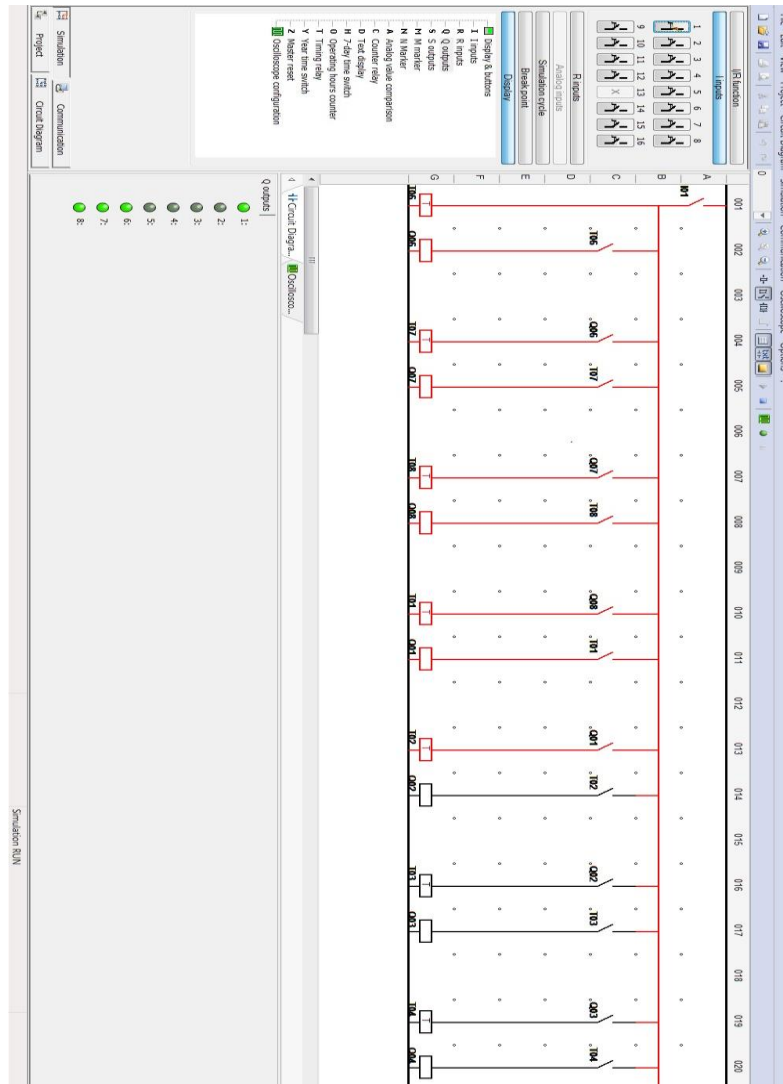
Fig. 9. Simulation of the program operation

4. CONCLUSION

Main idea in this paper, developed and applied, on small electrical drive system is how to control the switching on of the large electricity consumers in order maximal current, taken from the network not to be exceeded. Reason behind this idea is that usually exceeding of allowed maximal current is additionally billed by the utility. PLC is used for consecutive putting into operation of three different groups of motors with adequate time delay that allows starting currents of the

motors to be decreased up to the rated currents. On that way the maximal current is not exceed and consequently operational costs are reduced. Proposed solution is relatively cheap in comparison to electronic devices soft starters used for "soft" putting into operation of motors i.e. for decreasing the starting currents of the motors. Another advantage of proposed solution is that in case of failure of one of the motors the others continue with undisturbed operation. The proposed solution can be further expanded with more complex control logic that includes switching off of already active consumers.

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