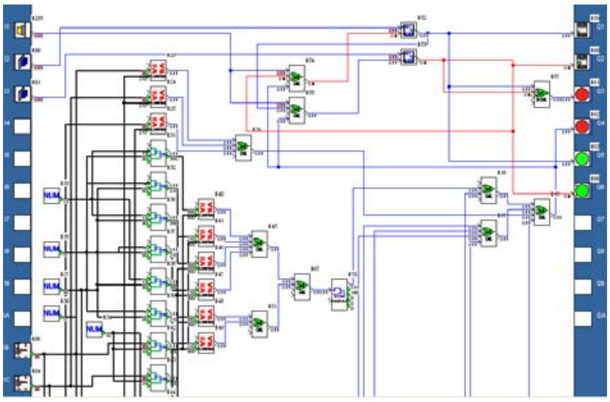

Fig. 13. The FBD program during backward starting of the induction motor.

If the protection doesn't work (P = 0), when I2=1 (S2 is switch on, forward switch), Q1=1 (K1=1, forward start contactor), the motor starts in forward, Q2=0 (K2=0), Q3=Q4=0 (H1=H2=0), Q6=0 (H4=0), and Q5 = 1 (H3 = 1, forward motor lamp) – Fig.12.

If the protection doesn't work (P = 0), when I3=1 (S3 is switch on, backward switch), Q2=1 (K2=1, backward start contactor), the motor starts in backward, Q1=0 (K1=0), Q3=Q4=0 (H1=H2=0), Q5=0 (H3=0), and Q6 = 1 (H4 = 1, backward motor lamp)– Fig.13.

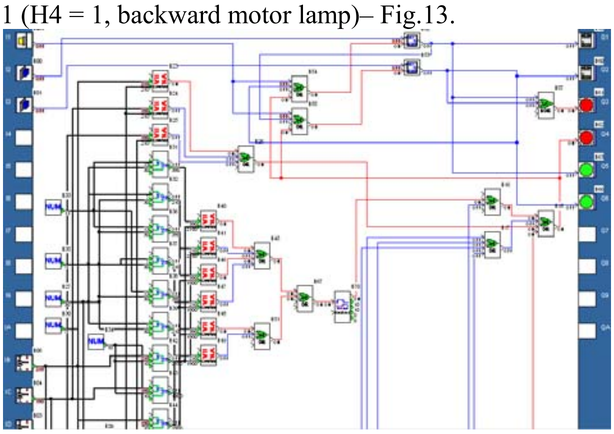

Fig. 14. The FBD program during short circuit protection of the induction motor.

If a short-circuit occurs (I≥7·In, 210 decimal) inside the motor, the short-circuit protection is switched-on, and the motor stopped immediately. The switching time is 25-30 ms and depends the program cycling and the response time of the contactor (Fig.14). The motor must be protected with fuses on each phase.

At every faults detected by the protection: Q1=Q2=0 (K1, K2 is switched off), Q3=1 (H1=1 motor stopped lamp), Q4=1 (P=1, protection lamp), and Q5=Q6=0 (H3=H4=0).

If the line voltage is under ≤0.7·Un (280 V, 105 decimal), after the time t1 (10 s), the motor is turned-off (Fig.15). If one of the line voltage is 0, the motor is stopped immediately (protection against two-phase voltage operation).

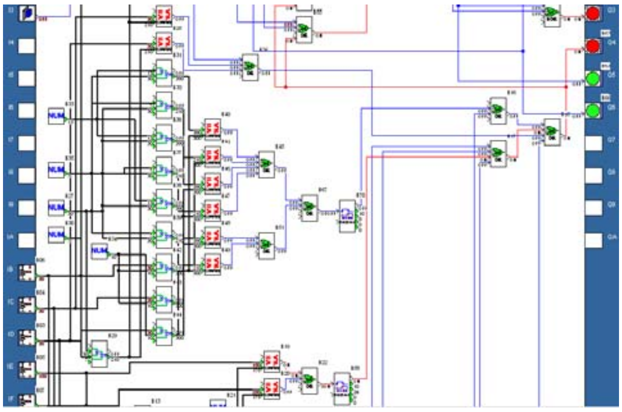

Fig. 15. The FBD program during under voltage protection of the induction motor.

During normal motor operation, one phase current it is different than nominal value (0.7·In≤In≤1.3·In, 21 to 39 decimal), the asymmetrical protection work and after the time t2 (30 s), the motor is turned-off (Fig.16).

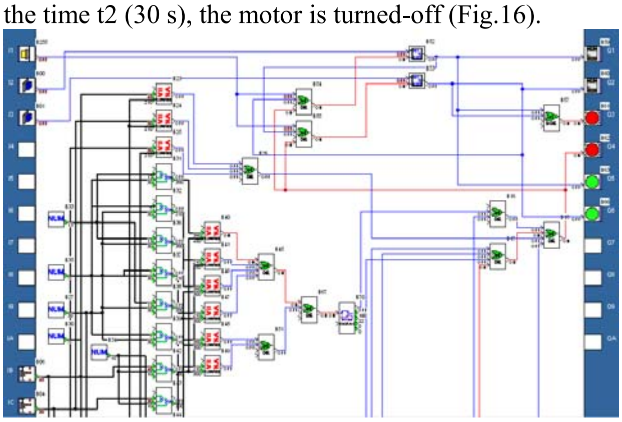

Fig. 16. The FBD program during asymmetrical currents protection of the induction motor.

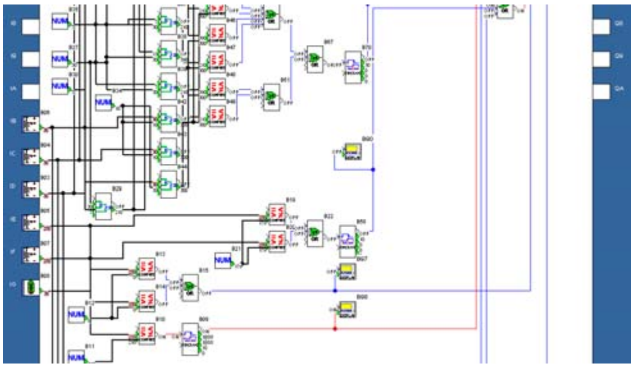

Fig. 17. The FBD program during over-temperature protection of the induction motor.

If the temperature inside the motor exceed the maximum temperature (t_{max}=95 ^{0}C, 26 decimal), after the time t_3 (30 min.), the motor is turned-off (Fig.17). The heating of the motor during experimentation is presented in Fig.18.

If one phase-current is 1.05·In≤I<7·In (3A to 19.88A, 31 to 210 decimal), then the overload protection is detected and the variable time tk (Table 1) that depends on the current value is triggered. After the timing passes, the motor is stopped (Fig.19).

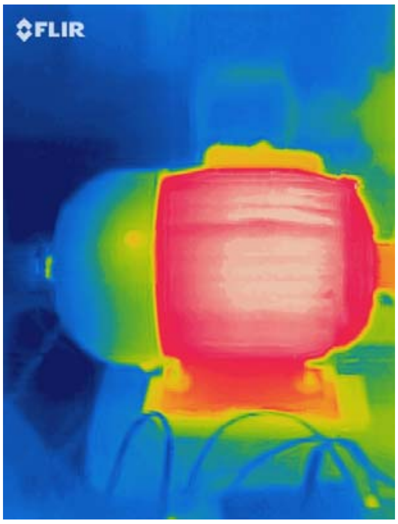

Fig. 18. The heating of the motor during experimentation.

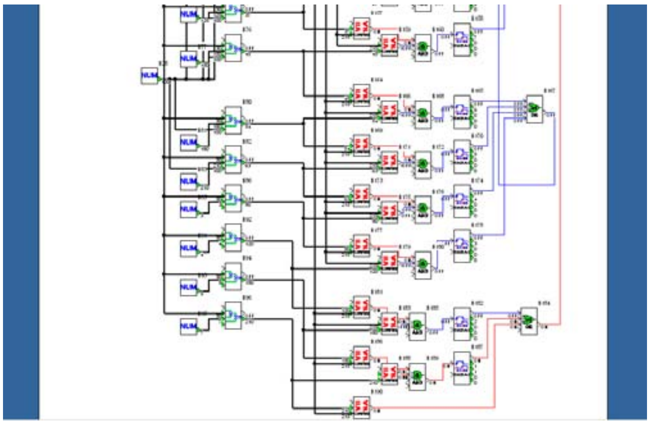

Fig. 19. The FBD program during overload protection of the induction motor.

6 Conclusions

PLCs have multiple industrial applications. It has been shown a complex electronic protection (short-circuit, two-phase operation, under-voltage, asymmetrical currents, over-temperature and overload) for the low-voltage three-phase squirrel cage induction motors. The main components from electronic protection are: electronic devices that convert AC current to DC voltage, AC voltage to DC voltage, temperature to DC voltage, a low-capacity PLC with a FBD program, which is not expensive. The FBD program is easy to design, debugging, and modify.

Using the components presented in the paper, the complex electronic protection can be used for the squirrel cage induction motor with the power up to 11 kW. The protection can be adapted for different motors, by easily modifying numeric values such as: nominal current, currents limits, voltages, temperature and time. This protection can be easy used, also, for wound rotor induction motors, and with different type of electronic devices, at the PLC input (to measure DC currents and DC voltages), can be used for power DC motor.

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