(when three generators operate simultaneously on the total load);
S3_4 – is the machine state when the active power of the first generator exceeds by more than 2% the active power delivered to the load by the third generator (when three generators operate simultaneously on the total load);
S3_5 – is the machine state when the active power of the third generator exceeds by more than 2% the active power delivered to the load by the first generator (when three generators operate simultaneously on the total load);
dp2 – is the difference between the active powers of the first and the second generator;
dp3 – is the difference between the active powers of the first and the third generator;
dw2 – the value of the increment frequency of revolutions of the drive motor of the second generator;
dw3 – the value of the rate of rotation increment of the drive motor of the third generator;
s2 – is a logical variable that indicates whether the second generator is connected to the total load;
s3 – is a logical variable that indicates whether the third generator is connected to the total load;
p1_n – is the value of the first generator rated power;
p2_n – is the value of the second generator rated power;
p3_n – is the value of the third generator rated power;
pp2 – is the power value at which the proportional load distribution between the first and the second generator is ensured (when two generators operate simultaneously on the total load);
pp3 – is the power value at which the proportional load distribution between the first and the third generator is ensured (when three generators operate simultaneously on the total load);
p, p1, p2, p3 – variables that are used in functions for calculating the load values of the generators, which ensure the proportional distribution of power between them during their parallel operation;
entry – is the action performed once at the entry of the machine into a new state;
du is the action performed at the time (during the time) the machine is in a certain state;
get_dp_2, get_dp_3 – the names of functions that are used for calculating the load of the generators, in which it is distributed in proportion to the nominal capacities of the generators.

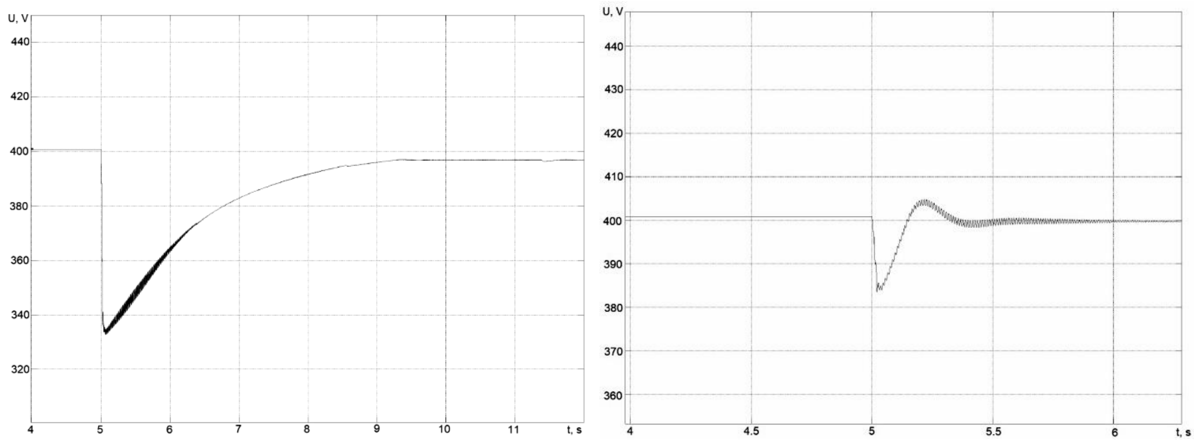

Fig. 6. Oscillograph records of voltages at the start-up of induction motors of various capacities: a – 55 kW; b – 14 kW

On the model development, the 55 kW and 14 kW induction motors start-up modeling were performed. The modeling results are presented in Fig. 6, a, b, respectively.

Based on modeling results, it was determined that the magnitudes of voltage dips at IM start are approximately 67 V and 16 V, respectively. Based on the data obtained, it is decided to change the IEPS operating mode, in particular, to connect an additional generator to the total load to provide power reserve and prevent significant voltage dips during IM direct start.

5 Conclusion

On conducting the study, the following results have been obtained:

1. A block-diagram of the IEPS simulation model with a configuration modified in real-time for the implementation of the above task has been developed. This solution allows, while monitoring the operation of the electric power system, to assess the possible consequences of an induction motor direct start under current conditions and, based on them, to decide on connection of an additional diesel generator to the network or disconnection of the least responsible consumers from the network. The developed IEPS model allows for a deep study of static properties and dynamic characteristics of generating units based on modeling, and for the development of necessary measures, hardware and software tools ensuring voltage stability in a wide range of loads.
2. The operating procedures of IEPS automation tools have been developed, which are presented in the form of transition graphs of finite automata. The methodology for modeling power plant automation tools based on an automate approach was further developed. The main advantage of the proposed approach is the complete documentation of the algorithm based on the functional decomposition of the control problem, as well as the simplicity of programs implementation for microcontrollers. The automate approach can be effectively used in the development of models and software for controllers designed to control various processes. The program design is based on an algorithm – a finite automaton in the form of a state diagram, intended for the formal description of the program logic. To describe the behavior of complex systems, not one automaton but a system of interconnected automata is usually used, which enables, in particular, the description of parallel processes, which was demonstrated in this paper.
3. The IM start-up modeling was performed and the oscillograph records of the voltage change in the electric grid were obtained. The information obtained as a result of modeling is the source information for taking measures to ensure the reliable operation of the electric power system and uninterrupted power supply to consumers. To prevent emergency situations, the developed IEPS and automation tools model can be used together with the means of the automated working station as part of the decision support information system in operating IEPS.

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