Available online at www.sciencedirect.com
ScienceDirect
IERI Procedia 9 (2014) 117 – 122
Procedia IERI
www.elsevier.com/locate/procedia

2014 International Conference on Environment Systems Science and Engineering

Intelligent Power Consumption Management Systems

Ugleva E.M.*, Zmieva K.A., Kuznetsova E. V.

Research and Education Center «Energy Efficiency in Industry», Moscow State University of Technology «STANKIN», Moscow, Russian Federation, 127994

Abstract

In this paper we consider problems of creating and introducing intelligent management systems as one of the most important mechanism of increasing energy efficiency in industry. Operating principles of intelligent electric power distribution systems developed in MSTU «STANKIN» for AC and DC grids on industrial plants are described. Essential devices composing the systems are considered, their technical characteristics are described. Experimental results are presented.

Keywords: Intelligent systems, energy consumption, industry.

1. Introduction

Sufficient and constant energy providing is an important condition of national economy development. Permanently growing energy consumption, rates increase, significant losses while transmitting and distributing energy make necessity of energy saving and efficiency in all fields of national economy one of the major state problems. Nowadays creating effective energy supply systems is one of the world’s most prospective trends of fuel and energy complex efficiency increasing. Increasing of efficiency and stability of consumers energy supply systems is achieved by means of equipping them with firmware and information

* Corresponding author: Tel.: +7-915-234-12-59; fax: +7-499- 973-31-52
E-mail address: kotik-fox@yandex.ru.

doi:10.1016/j.ieri.2014.09.050

analysis and managing components which provide reliable and high-quality transmission of electric power from source to receiver at proper time and in proper amount [1, 2]. Such systems are called «intelligent» or «smart».

Globally speaking, «intelligent» network is a complex of technical means which allows to change characteristics of electrical grid immediately. On technological level aggregating of electrical grids, energy consumers and producers in united automatized system takes part, this system being able to monitor and control operating conditions of all its parts in real time [2].

Now in many developed countries active and successful introduction of intellectual energy supply networks is held. As a result of using intelligent systems in the USA electrical grid peak loads have decreased, electricity invoices have decreased by an average 10% , electricity cost having grown by 15%. In Europe financing programmes of «intelligent» networks in an amount of $750 bln for next 30 years is provided. Nowadays the most active and widespread development and distribution of technology SmartGrid is seen in Denmark [3, 4].

According to «Energy Strategy of Russia for the period up to 2030», one of top-priority directions of scientific and technical progress in the field of electric energy industry is creating new-generation highly-integrated intelligent system-forming and distributing electrical grids in United energetic system of Russia.

2. Developing intelligent energy-saving electric power distribution system on industrial plant

According to stated above, MSTU «STANKIN» is carrying out researches on creating on an industrial plant an intelligent energy-saving electric power distribution system designed to increase efficiency of using electric power by means of making an automatized adaptive system for managing consumers with regard to individual peculiarities of equipment used on the plant. Operational scheme of system under development is shown on fig. 1.

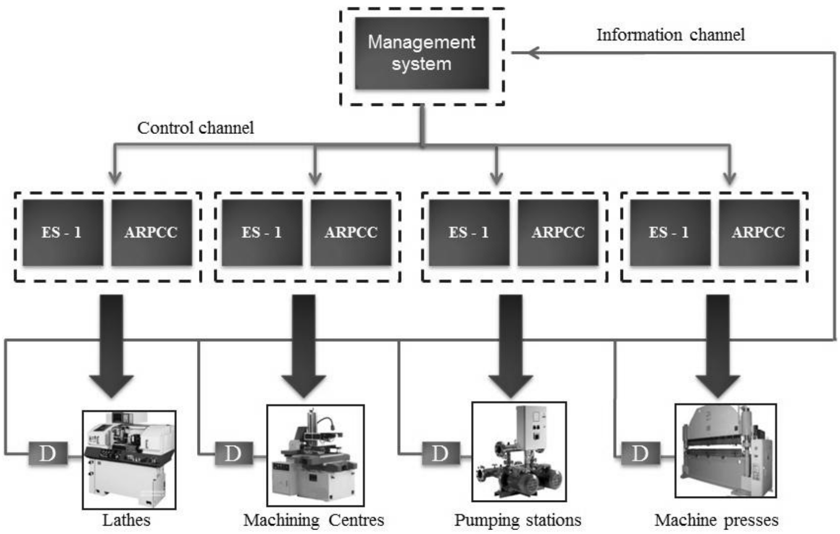

Fig.1. Principal scheme of intelligent electric power distribution system on industrial plant

The system under development includes:

- local devices correcting parameters of supply voltage (ES-1);
- devices compensating arising reactive power (ARPCC);
- group of detectors mounted on every consumer (D);
- unique automatized management system which provides fast-response collecting information about grid parameters in its every point and forming control signals to be send to all elements of the grid for the purpose of maximum decreasing of electric losses in the grid and increasing energy efficiency of the equipment.

All mentioned components of the system have been developed by researches from MSTU «STANKIN».

As device correcting parameters of supply voltage serves energy-saving power supply ES-1 (fig.2) developed and designed in MSTU «STANKIN».

Fig.2. Energy-saving power supply ES-1

Energy-saving power supply ES-1 converts parameters of supply line into those which are the most optimal for technical process fulfilling on industrial equipment and outputs corrected supply voltage to motor of the equipment, thus increasing its operational energy efficiency. This device has RF utility model patents Nos.106058, 106388 [5].

For compensating arising reactive power Automatic Reactive Power Control and Compensation device (ARPCC) is used. Advantage of reactive power compensation device is possibility of compensating reactive power when abruptly variable loads arise on output shaft of electric motor (fig.3).

(a) (b)

Fig.3. Automatic Reactive Power Control and Compensation devices ARPCC: (a). general view of ARPCC; (b). ARPCC connected to lathe 16K20

Main characteristics of the device are the following:

- control of power factor in automatic mode;
- possibility of increasing and decreasing settled power depending on needs;
- negligible losses of active power in limits of 0.30-0.45 kW for 100 kVAr;
- small mass of the device and its high mobility;
- ease of operation [6].

Devices described above are submitted to management system – a complex of software tools which allow to estimate data obtained from equipment, to make decisions and to send control signal to corresponding device. Software complex is protected by software certificate of registration Nos.2011613118, 2011619073, 2011613118.

Fulfilled researches of experimental and pilot samples revealed decrease of 20-30% in industrial equipment engines energy consumption (depending on type of technological process), equipment productivity staying at invariably high levels. Characteristics of change in electric parameters (power factor, total power, active power) of the grid and arising momentum depending on value of supply voltage amplitude are shown on fig.4.

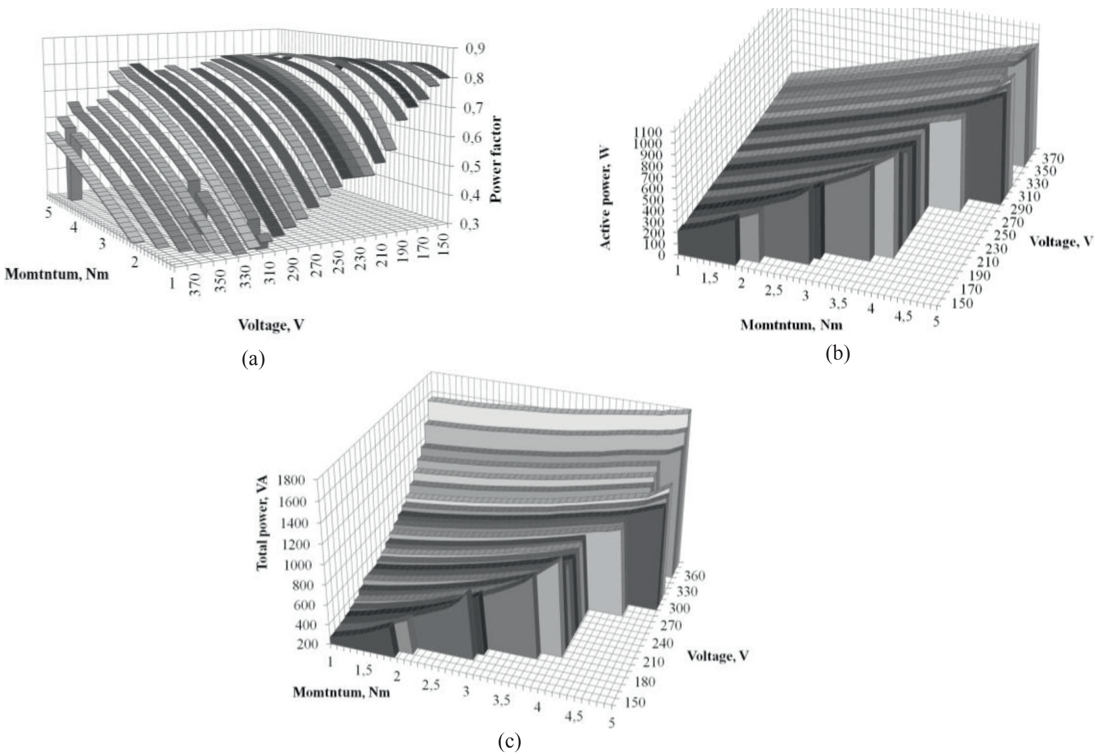

Fig.4. Characteristics of change in electric parameters: (a) power factor; (b) total power; (c) active power

Using described system will allow:

- to decrease energy consumption of industrial technological equipment working in mode of variable loads with saving and increasing equipment productivity and quality of manufactured product;
- to decrease total energy consumption;
- to increase reliability and security;
- to increase carrying capacity of electric grid of a plant;
- to increase (probable) connected load;

- to increase power lines and electrical equipment lifetime.

In this case economic efficiency is to result from decrease in energy rates of industrial plants which are to introduce the intelligent energy-saving system under development and from increase in reliability and lifetime of electrotechnical systems and complexes of the plant.

3. Developing intelligent system of power supply for consumers in DC grids

Activity of MSTU «STANKIN» is not limited to developing energy efficient devices powered by alternating current. Since in some fields of industry it is advisably to switch internal grids from alternating three-phase current to direct current, one of directions of the centre activity is investigating conditions of reconstructing industrial plants aimed to let them use direct-current power.

Adapting industrial plants to direct-current power is associated with gradual replacing of asynchronous three-phase motors as main electromechanical devices converting electric energy to mechanical one with engines of new generation – brushless DC electric motors which need direct-current power. Such motors have higher technical characteristics, so they allow to design up-to-date industrial equipment with advanced features. However, for a significantly long time machine tool stations and devices with three-phase asynchronous motors will work side-by-side with new equipment. DC motors mounted to new equipment are to get power from autonomous rectifiers the equipment contains. Modernization of old-fashioned equipment fitted with three-phase asynchronous motors is being accomplished by fitting it with individual frequency converters which allows to substantially improve operating characteristics of modernized machine tools. Modern frequency converters are usually designed according to two- or even three-stage scheme which means that each of them contains a DC link. Therefore, significant part of engines requires direct current for operating either immediately or at the intermediate stage of converting. When sufficiently great part of total consumed power falls within direct current it becomes economically reasonable to convert energy supply of section/division/group of machine tools from three-phase AC to DC.

Converting energy supply to DC allows to avoid fitting autonomous rectifiers to each machine and to significantly simplify frequency converters and make them cheaper by excluding segment of input rectification which includes minimum 6 power rectifiers with cooling system and high-voltage storage capacitors of high capacity.

Total power of rectifier needed to supply the equipment with AC is substantially smaller than sum of powers of individual autonomous rectifiers and rectifying units but its energy efficiency is significantly higher. Having one powerful rectifier, it is much easier to equip it with intelligent management system, by means of using up-to-date schematic and algorithmic solutions increase its power factor, hold value cosφ within given limits, decrease peak factor and provide symmetric loads on phases. Moreover, one may make given unit of electricity distribution grid to actively compensate asymmetry and distortions of supply voltage form and to increase cosφ of energy system in whole.

DC grids may contain autonomous or grouped storage capacitors being used to compensate starting currents and overload momenta and to decrease mutual influence of consumers. DC grids are easier to integrate into each other, algorithm of controlling such grids if they have several sources is much easier because of eliminating synchronization and phasing problems. Recuperation of energy in DC grid does not require complicated schemes of converters and synchronizers.

Systems of reserve power supply (e.g., autonomous diesel-generators) in DC grid may be combined with additional reserving by means of secondary accumulator power-supply sources which allows to make electric supply of vital objects or industries with continuous production cycle actually uninterruptible.

Controlling DC grids requires measuring devices, detectors, conversion and distribution devices (CDD) and intelligent management system.

To create proper conditions to reconstruct industrial plants so that they can use direct current, MSTU «STANKIN» holds active works on developing devices described above. We develop conversion and distribution units which are to provide converting three-phase alternating current 380/220 V 50 Hz into direct current 220/440 V, up to 10 hierarchically organized devices in master and slave modes and in mode of proportional load distribution having possibility of parallel operating using DC buses.

While operating as master, acceptable deviation of voltage should not exceed 5% of nominal value, while operating as slave, load of master is to compose 100% and slaves are to give lacking power distributing it between each other according to their priority. To provide cooperative load sharing between several CDDs information about current intensities should be available to all in-parallel units, so encoded current intensities come on communication and management bus connecting all the working CDDs.

Each CDD may be switched either to master mode or to slave mode by special key. Master unit provides DC supply within power limits from zero to nominal power of given CDD. When total consummated power exceeds nominal power of master unit, lacking power is given by slave unit. The system may contain any amount of master and slave units, which includes the case when one of them equals zero. Units of one range co-operates, i.e., power they bring to total load is being divided proportionally to their nominal powers.

In this case conversion and distribution units operate as part of information network using protocol MODBUS and/or CANOPEN and can stay functioning and stable in the event of information network failure by switching to autonomous mode with uniformly distributed load.

4. Conclusions

The devices and the system are recommended for using in production processes with continuous cycle of working, where reliability is the most important characteristic. Also this system is recommended to use the system processes with high variable loads. The modular design of the system allows to increase the total capacity by adding additional modules. Using devices and systems under development will allow to significantly decrease energy consumption, to increase electric grids reliability and life term and efficiency of electricity use.

Acknowledgements

The work was supported by the Ministry of Education and Science of the Russian Federation.

References

[1] IEC Smart Grid Standardization Roadmap, SMB Smart Grid Strategic Group (SG3).
[2] M. Tarafdar Haque, A.M. Kashtiban. Application of Neural Network in Power system, A Review, World Academy of Science, Engineering and Technology. (2005) 53-57.
[3] European Smart Grids Technology Platform Smart Grids, Vision and Strategy for Europe Electricity Networks of the Future, 2006.
[4] Technology roadmap, Smart Grid/International Energy Agency, 2011.
[5] Kolechitskaya N.A., Lazarev N.S., Shul'Gara R.N., Zmieva K.A. Ferroresonant phenomena on 6- to 10-kV substation buses // Russian Electrical Engineering. Volume 84, Issue 4, April 2013, Pages 177-184.
[6] K.A. Zmieva. Methods for using automatic compensators for reactive power to increase power efficiency of electric-drive control in metal-removal machine tools // Russian Electrical Engineering. 80(11) (2009) 604-609.