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Automatic Control of Industrial Peak Loads

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Abstract: Automatic control of equipment is anticipated to represent the next logical step in the progression from passive monitoring toward plant wide automation. Automatic transfer functions, load-shedding and load sequencing are expected to find increasing application. In this paper a device named PeakLoad for monitoring and control of power consumption in industrial plants is presented. It is a PLC based maxigraph developed upon the analysis of efficient and optimized use of the electrical energy and is planned to be used by medium and big industrial energy consumers with purpose to decrease the cost of their production

Keywords: Controlling, energy efficiency, load-shedding.

1 Introduction

IN order to control energy costs, the plant engineer needs to be aware when energy and power are being consumed and by whom. By importing energy and power data into a standard spreadsheet, energy and power usage can be tracked by time of day and costs allocated back to responsible departments. Costs are then reduced either through careful reduction of individual consumption or by rescheduling energy-intensive operations from peak times to off-peak times.

In many cases, the demand charge is based on a single peak loading level set by the industrial plant. The plant pays demand charges based on this level, even during subsequent months when actual power consumption may be far less. To reduce demand charges, the industrial plant's average power consumption for each demand period (usually 15 or 30 minute intervals) is logged to a spreadsheet. Demand

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plots are generated from these data. By balancing the loads and spreading power-consumption levels more evenly across demand periods, dramatic savings can be achieved.

New power equipment assemblies such as low-voltage and medium-voltage switchgear, switchboards, and motor control centres can be supplied with monitoring equipment to provide remote access of power system information. In addition, this equipment can be augmented to perform various automatic control functions and provide elaborate local display of system conditions in the power equipment [1].

In order to make an appropriate design of the system for monitoring and control of the power loads, it is necessary to provide the following data: Electricity bills paid by the consumer (large industries) for at least one whole year; and Graphical presentation of data of electric power, measured (with the controller) for certain period of time when the industry works with full capacity.

Active and reactive power data are common data for analysis of energy efficiency events [2]. The collected data are used to forecast the active power in a period of 15 minutes by performing the following tasks:

- If the forecasted active power is above the limits, the machines and apparatus will be cut off in accordance to the previously agreed priority list, or
- If the forecasted active power is below the limits, the power supply for machines and apparatus will be switch on with respect to the previously agreed priority list.

The switching on and off of machines and apparatus will be decided by the local operators, or, as proposed in this paper, automatically by control system. The device named PeakLoad, proposed in this paper, integrates monitoring, controlling and optimizing functions, related to the power and energy consumption of industrial consumers in order to reduce the operating costs. It has been developed by the team of researchers at Faculty of Electrical Engineering and Information Technologies in Skopje and manufactured in cooperation with company SIMT-Skopje. The device is a new product manufactured by local SME.

The new device is planed to be used by medium and big industrial energy consumers, i.e. factories and plants, with purpose to monitor, analyze and optimize their electrical energy consumption.

2 The PeakLoad Device

The PeakLoad is an intelligent maxgraph that analyzes the current state of the user's system (the devices and machines connected to it) and controls the power consumption. It is a peak load controller which provides optimized and efficient use of electrical energy based on the needs of the users. The user can define the maximum and minimum power consumption as well as priority of work of the connected devices. According to measured power the industry loads will be connected or disconnected by the controller. That way the user has a powerful tool to control the power consumption and reduce the expenses for it. This controller serves as the power factor correction controller and peak load controller.

The device is composed of two parts: hardware and software. The hardware part is the controller itself. The software part consists of two programs. The first one runs on the PLC and the second one runs on the computer. These programs provide configuration of the process parameters, supervision of the process and alarming.

Graphical user interface (GUI) provides a friendly user interfaces for application programs such as: load-shedding, power-quality control etc. [3].

2.1 Principle of work

Input measurements of the maxigraph are the total power consumption of all machines and the machine's demands when turned on. As an output the device approves or denies the turning on of the machines. Based on the collected requests and the current total power consumption the device selects to turn on and turn off the machine. Beside this function, the device should signalize (alarm) whether the average power consumption is out of the given limits, the system is above the given maximum power consumption, or the system is in condition in which there isn't enough energy for the technological minimum consumption. The technological minimum is quantity of electrical energy that is needed for powering the machines that are the basis for the technological process in the user's factory plant (the machines that assure minimal conditions of the technological process).

The parameters that should be defined for correct work of the maxigraph are:

- Power consumption of each machine in the user's system.
- Priority of work of the machines - priority of each machine. It is defined by the importance of work that a machine is doing for normal flow of a technological process.
- Maximum allowed average power consumption Pmax - power consumption that a factory plant must not overstep during its work.
- Minimum allowed power consumption Pmin - technological minimum. Minimum quantity of electrical energy that is needed for powering the machines that are the basis for the technological process.

- Alarm level Psred $->$ Pmax. It defines the threshold of the alarm that occurs when the current average power consumption Psred is getting closer to the maximum allowed power consumption Pmax.
- Alarm level Pdozv $->$ Pmin. It defines the threshold of the alarm that occurs when the reminder of the power to spend in the current cycle Pdozv is getting closer to the technological minimum Pmin.
- Number of pulses per minute for 1 kWh. It defines the number of pulses per minute that are given by the power consumption measurer if the power consumption is 1 kWh.
- Tolerance - it defines the deflection of the substitution of power consumption that should be turned off to eliminate the overstepping and the power consumption of the machine with lowest priority that is turned on.
- Turn off momentum - it defines when (which minute) the device should automatically turn off some machine(s) in order to eliminate the overstepping of given parameters (P_{max}, P_{min}).

The measurements of the power consumption are made with digital power consumption measurer.

Measurer gives series of pulses whose number depends on the measured power consumption. Pulses are proceeded to the input of the maxigraph. According to the pulses received, the device analyzes the condition of the system. The analysis shows if an alarm should be signalled or some machine should be turned off. The blocking switches of the machines are connected to the output relays of the device. Figure 1 shows the Block schema of connection of the device in the controlled factory plant.

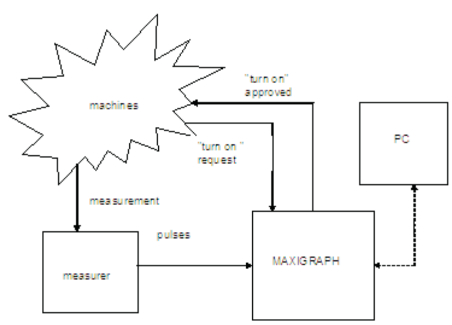

Fig. 1. Block schema of connection of the device in the controlled factory plant.

When the operator tries to turn on a machine, the request is sent to the maxigraph for analysis. The maxigraph then checks if the system would be overloaded in the next time interval. In case there is no overload the machine will be turned on.

In cases of overstepping of the input parameters (Pmax, Pmin) the device shows alarm states that indicate that the system is approaching to the given limits of work. It also makes a prediction when the overstepping will occur. The operator should take action according to the given signals. Otherwise, the device will turn off the machines according to their power consumption and priority.

2.2 Working logic

Upon the measurements the device continuously analyzes the state of the user's factory plant. Figure 2 shows the state of the factory plant graphically

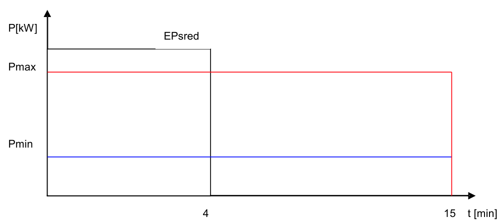

Fig. 2. State of factory plant.

The maximum allowed power consumption Pmax for the cycle of 15 minutes is shown with red line, the technological minimum is shown with blue line, and the current average power consumption with black line. The ongoing minute is 4 during the cycle of 15 minutes. If it is assumed that the average power consumption will stay the same for the rest of time intervals of the cycle, it can be spread equally in the rest of the cycle. Remaining energy to spend is the maximum power to spend in the next intervals without overstepping.

Figure 3 shows all the parameters that are involved in limitation of the power consumption.

The maximum allowed power consumption Pmax is shown with red line, the blue line shows the technological minimum, the allowed power to spend in the next interval Pdozv with green. The alarm levels Psred $->$ Pmax and Pdozv $->$ Pmin with dashed red and blue lines respectively.

In order to give better picture of a system state the device predicts the moment when the given parameters are overstepped.

According to that prediction and the chosen moment of turning off, the device turns off the machines automatically depending on their power consumption and

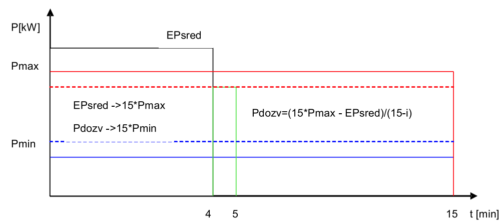

Fig. 3. Parameters that are involved in limitation of the power consumption.

priority. This feature helps to avoid overstepping caused by delayed reaction of the operator.

2.3 Hardware part

The heart of this device is the programmable logic controller (PLC) Vision 230 from the company Unitronics, Figure 4 and Figure 5. It has an integral operator panel which contains LCD screen and keyboard by which the operator is supervising and controlling the system. Communication with the PLC can be done by RS232 protocol or by CANbus protocol. It has real time clock (RTC) and if needed it can be expanded with large number of input/output modules. The PLC has embedded input/output module V200. This input/output module has three analog inputs which can be configured for voltage or current, sixteen digital inputs type PNP/NPN including two high speed inputs PWM (Pulse Width Modulation), ten relay outputs and four PNP/NPN transistor outputs including two PWM.

Fig. 4. PeakLoad controller.

The pulses from the measurer are connected with the PLC through optocoupler and the machine switches are connected through relays. Blocking switches of the machines are connected with relays and enable or disable turning on the machines

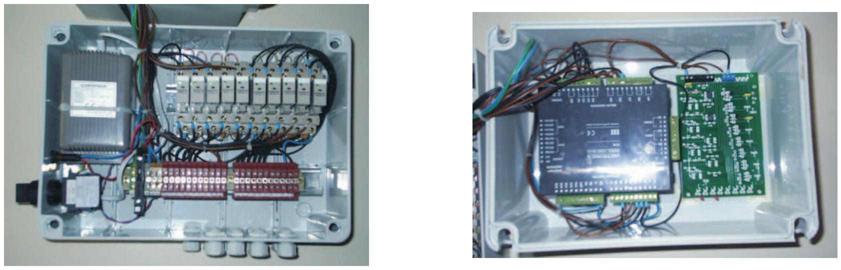

Fig. 5. Inside the box of the PeakLoad controller.

(Figure 6). The blocking mechanism uses four parameters: maximum allowed power consumption, current power consumption, rated power consumption and the priority of the machine. These parameters should be configured when the device is turned on for the first time.

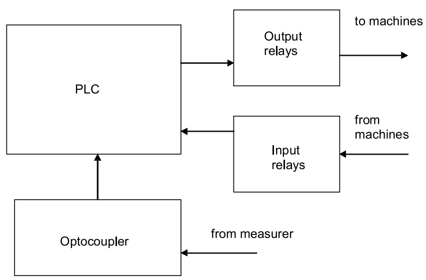

Fig. 6. PeakLoad controller block schema.

After a request for turning on by any of the controlled machines, the system checks if the sum of the current power consumption and the machine's power consumption passes the limited value. If it doesn't, the machine is turned on. When the machine's power consumption exceeds the limit, the machine's priority is checked. If it is the machine with the highest priority, the working machine with the lower priority is selected and turned off. That way we reduce the power consumption and we enable turning on of the machine with higher priority.

2.4 Software part

The software of the PeakLoad consists of two programs. The first one runs on the PLC and the second one runs on the computer. Both programs have the same functionality and provide configuration of the process parameters, supervision of the process and alarming.

The program running on the PLC is much simpler due to the limitations of the PLC display. Graphic charts are shown as vertical bars, and the numeric data have max. two decimal places (Figure 7, Figure 8, Figure 9 and Figure 10).

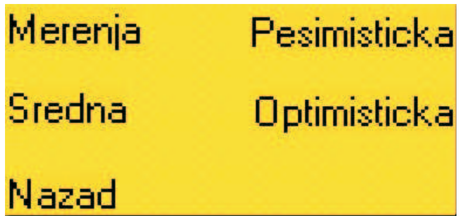

Fig. 7. ”Chart menu” screen.

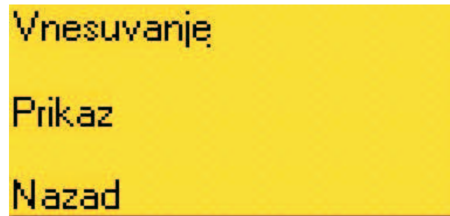

Fig. 8. ”Parameters” screen on which: F1 - Vnesuvanje - ”Parameter menu” screen for inserting parameters. F2 - Prikaz - ”Parameter menu” screen for viewing the parameter values; F3 - Nazad - Back to main menu.

There are several possibilities on ”Chart menu” screen for viewing: F1 - Merenje - Measurements; F2 - Sredna - Standard deviation of the average power consumption; F3 - Nazad - Back to main menu; F4 - Pesimisticka - Pessimistic curve; F5 - Optimisticka - Optimistic curve.

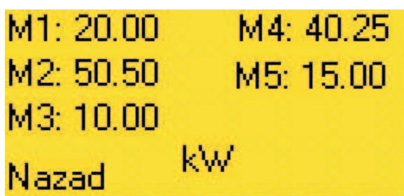

Fig. 9. ”Machines power” screen on which the power consumption of each of five machines connected to the PeakLoad controller can be viewed or edited.

Fig. 10. ”Chart” screen appears after we chose which parameter we want to view as a chart. Values of the parameter and the current minute are displayed.

The computer program communicates with the device and reads the process parameters. It enables configuring of the process parameters and the state of the machines. This program shows the process parameters with three decimal places, it has better charting capabilities and it can display the history of the parameters. As illustration the windows showing several parameters are presented on Figure 11, Figure 12, Figure 13 and Figure 14.

The window ”Real time parameters” displays charts of real time changes of the

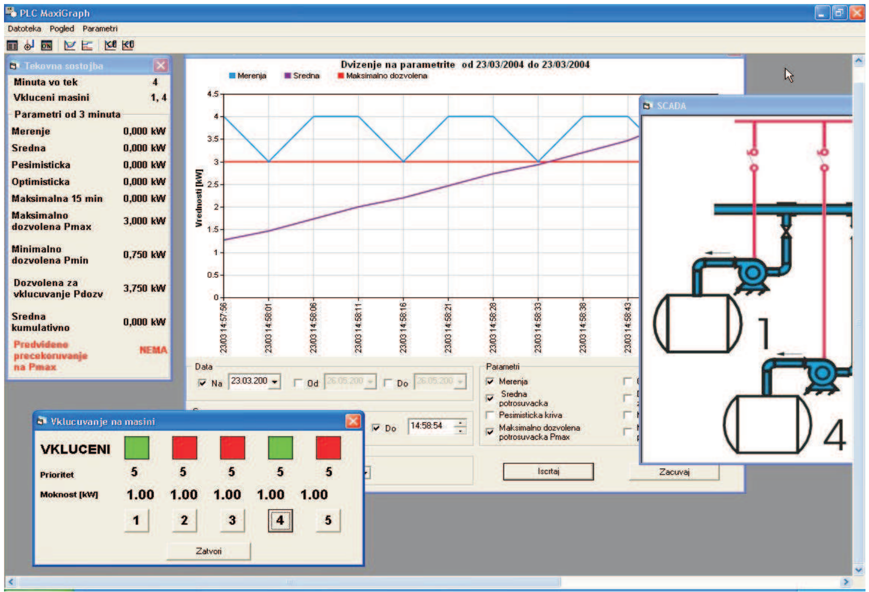

Fig. 11. Windows "Current parameters", "Parameters in the past", "Machines parameters".

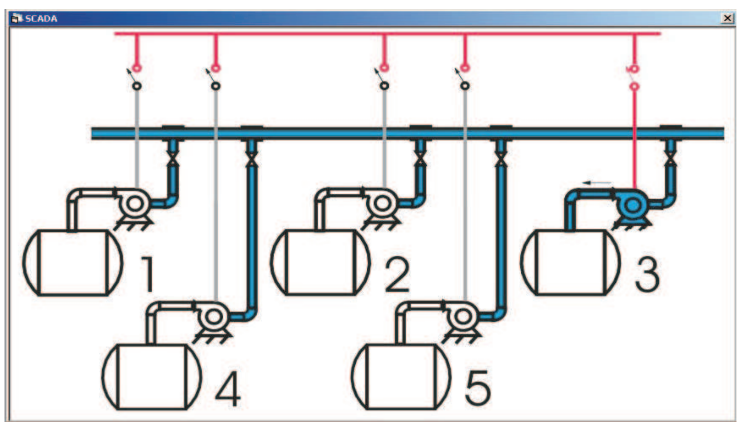

Fig. 12. Window "SCADA" shows the current state of the five machines as a simulation of pump station. On the picture shown the third machine is working.

parameters. Which parameters will be shown depends on the selection in the lower - right part of the window. In the lower left corner of the window the type of the chart can be chosen. It can be line or bar chart. Clicking on "Zacuvaj" saves the current chart to the disk.

Window "Alarm" shows the alarm state. There are two alarm levels. The alarm level 1 shows that the average power consumption is above the maximum allowed

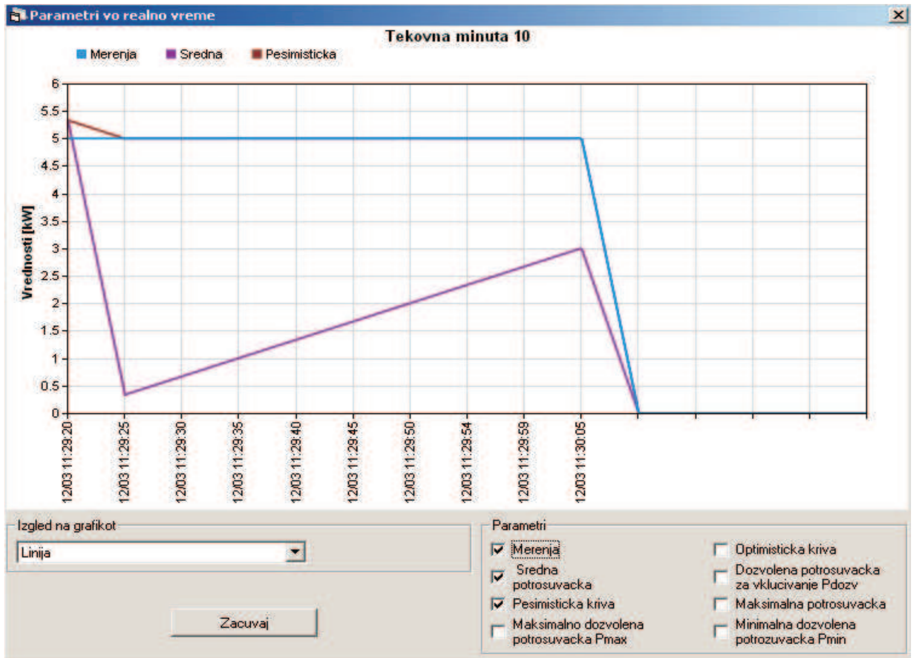

Fig. 13. Window "Real time parameters".

Fig. 14. Window "Alarm".

or the rest power to spend is below the technological minimum. Alarm level 2 shows that the average power consumption is getting near the maximum allowed or the rest power to spend is getting near the technological minimum.

3 Conclusion

The automatic control device presented in this paper is designed to monitor and optimize user's energy consumption with appropriate decrease of the production costs. It was designed as a typical research project connecting the academia and the industry. As such, there were two kinds of beneficiaries of the project: industrial plants and project participants. The benefit for the project participants is expended cooperation between Faculty of Electrical Engineering and Information Technologies and SMEs.

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