PEAK LOAD CONTROL SYSTEM FOR LARGE CONSUMERS

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Abstract

This paper describes a Peak Load Control System (PLCS) dedicated for the large consumers. Particular significance *in this description was given to a new algorithmic approach that is applied in PLCS. The paper also describes organization of the system, the functional features and benefits that the system can provide in practical implementation.*

The above description uses diagrams, which are recorded on the realized system.

Keywords: p*eak load, electricity consumption, electricity control system, large consumers, rationalization of electricity*

INTRODUCTION

The implementation of various rationalization of electricity consumption is today an imperative. It is known that any rationalization is today economically more justified than investment in the construction of new power generating capacity and associated facilities and services.

In particular, very large losses exist in practice due to excess of consumption, which appears as variable peak load for large consumers and for citizens in wide consumption of electricity. The generalization of peak load solutions for large customers was very complex in practice, because of the very wide variety of large customers and a number of parameters that have influence on the solution of this task. Therefore, the general solution, which would be applicable in all cases, or at least for a large set of cases, must provide adaptation to the characteristics of consumers who are to use it. Such a solution should provide a high degree of flexibility in operation, so that the operator can, using his experience and creativity, step by step, reprogram factory settings in order to stabilize and minimize peak load, but without to disturb technological process or work productivity of that factory.

This approach offers the implementation of the optimal and simple way of peak load control for all kind of large consumers, regardless of the configuration and power consumption in a factory and the technological process and organization of production. This solution also covers all consumers regardless of the variability of the used current power, the size of the space and position of the factory and regardless of the other parameters that might have influence on the peak load control.

Approach described in this paper is applied in the project "Expert system for peak load control", within the national projects of the Ministry of Science and Technology in Serbia.

The described algorithm was created through years of experience and contributions in the field of rational energy consumption and other results in the field of electronics, control, and usage of PC to control various processes. However, the references selected in this paper were initial basis for this project.

Ref. [1-2] are used for the basic concept of the new approach, ref. [3-5] are used in the realization of interface between PC and PLCS, ref. [6-7] are used in the field of contemporary approaches in the implementation of electronic modules and ref. [8-9] are used in software support.

SYSTEM ORGANIZATION

Taking in account that PLCS is not to disturb the technological process, and at the same time to be applicable for a wide range of large consumers, makes this problem a complex

task, both, from the theoretical and practical point of view. In order to solve this task optimally, one must respect the following basic principles:

• Electricity consumption, which is to be controlled, must be taken integrally in the whole factory, but not only in one part of it.

• The used algorithm for control of peak load, must be based on the synchronization of all PLCS parts with a 15-minute time clock or MTK (subsystem in a factory controlled from a distance center).

The PLCS consists of two main hardware parts. These are the central part and the executive part of the PLCS. The first one collects data and according to the corresponding incorporated algorithm manages the whole real time control. The executive part switches different consumers throughout the factory. Fig. 1 illustrates the principal scheme that shows how the central part of PLCS links with photo sensor, 15-minute time clock or MTK receiver, and the PC. In order to meet the two basic requirements mentioned, the photo sensor supplies impulse rate S2, whose frequency corresponds to the current power consumption of the whole factory. The 15-minute time clock or MTK provides a 15-minute impulse signal S1, which is to enable synchronization between PLCS, PC, MAX and MTK. Signal S3 in Fig. 1 represents a double side communication between the central part of PLCS and PC. Signal S4 is distributed to the executive part of the PLCS and represents coded information that are used for switching plant consumers. Also, signal S4 timely provides sounds, early on 15-minute time, if the energy state in the factory is going to overload the desired value of the peak load at the end of the 15-minute time period. Such a situation leads to switching of certain categories of consumers from the factory process. An operator of PLCS system generates criteria for the real time control, and he can change them periodically if necessary. The signal S4 is generated in the serial code.

This serial code enables the transmission of sound and coded information via a telephone wire, signal or power cable, which simplifies and makes cheaper the implementation of the PLCS. At the same time, this approach makes it possible to transfer signals wirelessly.

SHORT DESCRIPTION OF PRINCIPLE

The main idea of the algorithm described in this paper, is based on the discrete frequency locked loop. The paper [1] has described phase locked loops (PLL) model based on measurement of time difference of two pulse rates. The paper [2] describes a frequency locked loop (FLL), which is a special case of the previous PLL. This FLL generates the pulse rate, whose frequency is equal to the frequency difference between two pulse rates fed at the inputs. This FLL is very suitable for a wide range of applications in the field of measurement, telecommunications and control.

Algorithm described in this paper actually represents a complex FLL, whose basic principles is described in the paper [2]. The whole process at the inputs and outputs of such FLL takes place in the real time. The main inputs in the FLL are the pulse rate from photo sensor and pulse rate whose frequency represents minimum power consumption of the factory. This minimal power consumption is achieved when all consumers are switched off, whose short exclusion will not disrupt the process of technological work. For any factory, it is necessary to define the initial conditions of the loop, especially the content of the FLL accumulator. In the manner described in paper [2], pulse rate whose frequency represents the total consumption of a factory are subtracted from the FLL accumulator contents, and the pulse rate whose frequency represents the minimum consumption of the plant, are added to the FLL accumulator. By defining the initial content of the FLL accumulator and the frequency which represents the minimum power consumption of a plant, the maximum energy which is allowed to be spent during 15 minutes time is automatically defined. Of course, the desired peak load for a factory, which is not to be exceeded, mast be also defined in advance. The sum of the initial value of the FLL accumulator and the pulses from mentioned pulse rates, makes the FLL accumulator content, which provides complete information about energy state of a factory at any time. This content certainly depends on feedback affects that are established by the executive part of PLCS. The executive part, by switching of some consumers, reduces frequency of pulse rate, which represents the total consumption of a plant. The main criteria for the control of the factory consumption are formed, at any time, on the basis of energy

state of a factory, i.e. on the FLL accumulator content. It is known in theory that phase and frequency loops are used for many applications in which the transient time to a stable state is as short as possible. In this application, the stable state of the FLL is only an extreme case, and the FLL works in transient mode, all the time. The FLL accumulator content is, at the same time, fed to PC. On the basis of the obtained data, PC creates, at any time, visual presentation of the current energy situation, as well as the predicted energy state and predicted peak load of a plant, for the current 15-minute time.

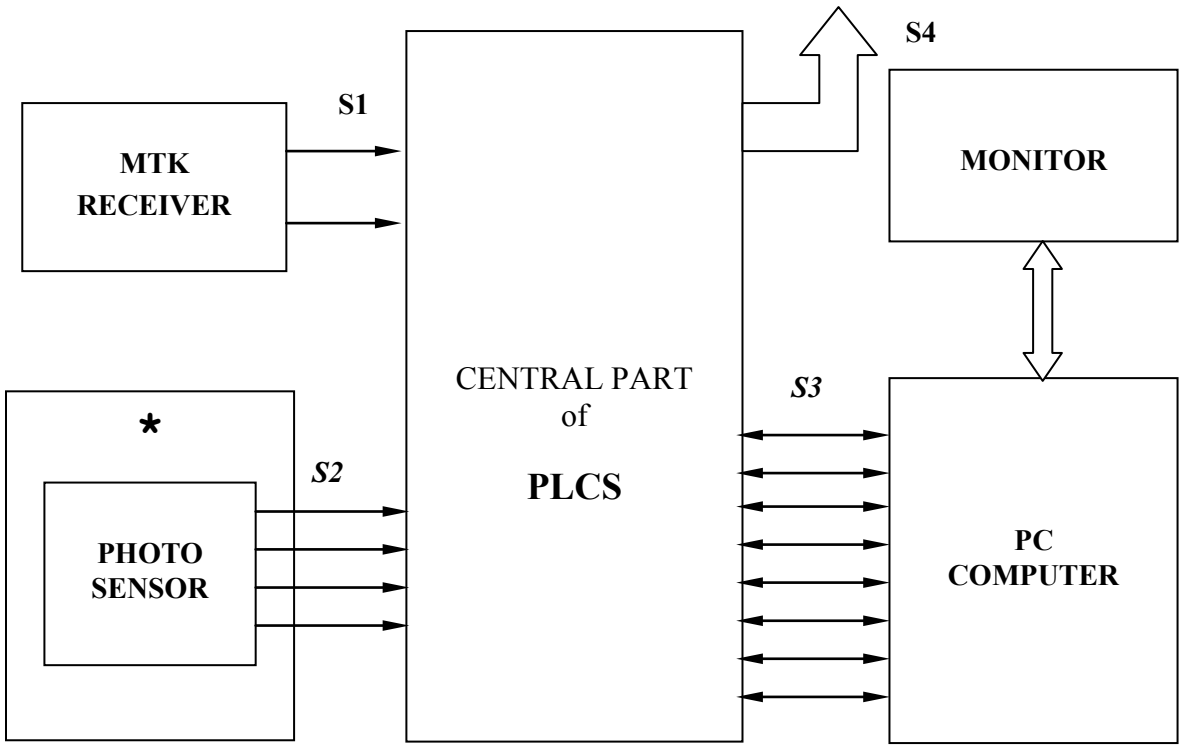


Fig. 1. *Organization of the peak load control system (PLCS)*

S1: Synchronous signal for the 15-minute MAX (device for measurement of average power during 15 minutes) process,
S2: Pulse rate frequency from the photo sensors represent measured data of the instant consumption power. Photo sensor is implemented in MAX
S3: Measured data, parameters of criterion curves of the factory and control signals,
S4: Predictive multilevel information signals that are used for consumption control.

* Installation of photo sensor in MAX makes the laboratory of Electrical Distribution-Belgrade. Checking the functions and verifications of extended MAX makes SZMDM-Belgrade.

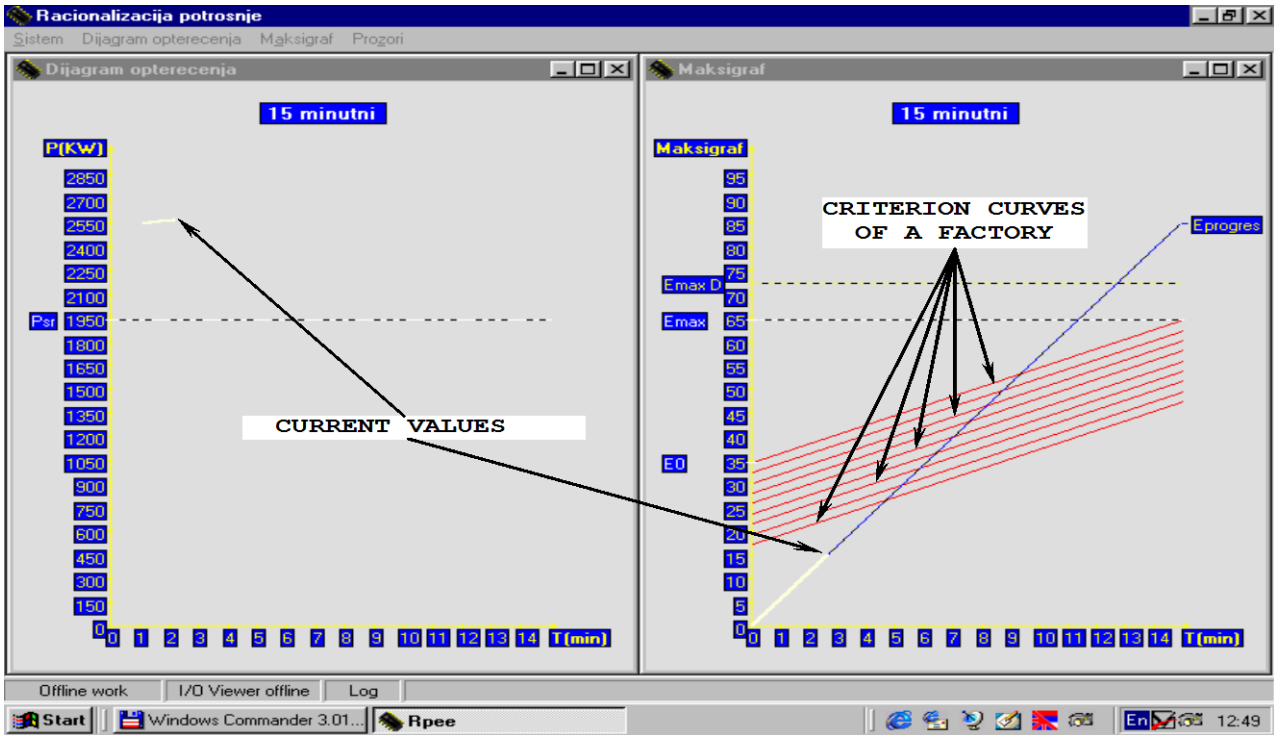


Fig. 2. *The current value of total power consumption and MAX - criterion curves of a factory*

GRAPHIC PRESENTATION

The central part of the PLCS, shown in Fig. 1, consists of several components such as the FLL, energy state decoder, block for time shifting of simultaneous pulses, audio signal coders, multiplexers, programmable generator for generating pulse rate whose frequency represents the minimum consumption of a factory, clock generator, different counters, timers, displays, communication interface between PLCS and PC and the others.

In addition to the FLL accumulator content, all data and parameters mentioned and the others related to a factory are entered into PC. Using this data, as well as the parameters defined by system operator, PC generates criterion curves of a factory, shown in Fig. 2. Using the same data, the central part of PLCS generates pulse rate whose frequency corresponds to the minimum power consumption of a factory, and digitally codes energy state bands, which completely correspond to energy bands between criterion curves, shown in Fig. 2. This enables visual tracking of energy states on the PC monitor, in full and at any time.

In addition, graphical presentation of the current values of a factory power (white color) and consumed energy during 15 minutes period (white color), are also shown in Fig. 2. The first one is on the left side, and the second one on right side in Fig. 2. Software predictor "E progress" (blue color) is also shown in Fig. 2. It shows that, providing the current consumption keeps the same value during 15 minutes, the whole energy would exceed the desired value "E_{max}" (see Fig. 2) during that time. This means that the planed peak load would be exceeded.

The field covered by the factory criterion curves in Fig. 2 is actually the detection field of the factory energy states. This field may be either expanded or narrowed. That depends on the type of factory consumers and on the choice of parameters to achieve the optimal peak control. When the process (white line) enters the detection field, the PLCS will react at each of the nine state-level or at the intersection with the criterion curves. At these points, the PLCS will activate the appropriate switching of consumers, which are so programmed that at every next level the switching is more intensive. On the last level, the minimum of the factory consumption will be reached. In this case the factory consumption (white line) will follow the highest criterion curve

and enables that peak load reaches the planed value "E_{max}" at the end of 15-minutes time. If however the predictor "E progress" does not show exceeding, as it is in Fig. 2, the PLCS will not react, no matter if the factory consumption (white line) enters the detection field.

The energy value "Eo" in Fig. 2, represents the initial constant that is entered in the FLL accumulator at the beginning of each 15-minute time.

The PLCS, in accordance with the description, detects nine energy areas or states in the dynamic mode. These nine states are coded with the corresponding audio and control signals. Due to the nine areas, all participants in the factory have information about the current energy situation at any time and may well in advance to plan their necessary actions. Complete management strategy is created in one place. The corresponding priority level of switching is assigned to each consumer, providing these are planed to be switched off, either partly or fully. The percentage of peak load reduction can be in the factory continuously increased through the applications. The "fine" settings in the management of consumption will be gradually improved. This improvement partly depends on the creativity of the system operator. The PLCS is adaptive, so that it may be reprogrammed from month to month, aiming in this way the minimum possible peak load in relation to the planned production.

CONCLUSION

The applied theoretical and algorithmic approach to the PLCS provides:

• Optimal utilization of all possible resources for reducing peak load, including those consumers who may be only occasionally switched off, as well as the consumer whose consumption can be only reduced occasionally.

• A change of priority of every consumer in the function of the technological process of work and workload, and if necessary, replacement of a consumer assigned priorities, every day, or according to current needs.

• Monthly or seasonal reprogramming of the system in order to achieve the maximum possible optimizations of peak load, in the function of the current production volume.

• Avoidance of fixed switching that prevent adaptation to changing conditions and do not provide optimum reduction of peak load.

• Maximum exploiting of energy for the chosen peak load, during every 15 minutes.

• Easy visual, sound, current and long-term monitoring of the factory consumption. Good education and understanding of the influences of different parameters and reaching the optimal peak load, systematically, but without to disturb the already established technological process work.

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