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Application of Frequency Locked Loop in Consumption Peak Load Control

Abstract. *This article describes the application of the Frequency Locked Loop (FLL) in the Consumption Peak Load Control (PLC). The digital content of FLL represents the main information for optimal control. Particular significance was given to the description of the extended FLL, which is suitable for this application. Detailed solutions of FLL input module and FLL adjustments are given. The performances of the realized PLC System are demonstrated by the graphics, which are recorded on the applied PLC System.*

Streszczenie. *W tym artykule opisano zastosowanie Frequency Locked Loop (FLL) do sterowania obciążeniem szczytowym Peak Load Control (PLC). Szczególne znaczenie nadano opisowi rozszerzonego FLL, który jest odpowiedni dla tej aplikacji. Podano szczegółowe rozwiązania w module FLL wejściowych i korekt FLL . PLC. (**Zastosowanie Frequency Locked Loop w kontroli zużycia obciążenia szczytowego**).*

Keywords: Frequency Locked Loop, Frequency Synthesizer, Electricity Peak Load, Consumption Control.
Słowa kluczowe: FLL – pętla częstotliwościowa, synteza częstotliwości,.

Introduction

Generally, Phase Locked Loop (PLL) and Frequency Locked Loop (FLL) systems, if they are in the stable states, generate the output signals whose frequencies are the same to their input signal frequencies. However, there is the difference between them. The PLL input and output signals are, at the same time, in phase. That is not case with FLL input and output signals. In many applications in the field of control, measurement and telecommunication, the frequency appears as the only signal parameter, which carries information, so that it is not necessary to care about the phase difference between input and output. In such applications, in comparison with the PLL, the FLL is more suitable for usage.

In this article, an application of the FLL for the development of a consumption peak load control (PLC) is described. This FLL, described in [2], possesses powerful ability to average the periods of non uniform pulse rate, fed at the input. This FLL is used for addition and/or subtraction of unlimited number of non uniform pulse rate frequencies. Any number of pulses per second might be add or subtract at the inputs of FLL, to match synthesized frequency of the output pulse rate. However, the FLL will still generate uniform pulse rate at the output, no mater what level of irregularities exists in the input signals periods.

The approach to Peak Load Control (PLC), based on the FLL [2], offers the optimal, but simple and natural way of peak load control for all kind of large consumers, regardless of the consumption in a factory, the technological process, organization of production, 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.

In practice, very large losses of electricity exist due to excess of consumption, which appears as variable peak load for large electricity customers and for citizens in wide consumption. PLC systems for large electricity customers was very complex in practice, because of the very wide variety of large customers and a number of parameters that might have influence. Therefore, the general solution, which would be applicable in all cases, must be adaptable to all kind of customers. Such a solution should provide a high degree of flexibility in operation, so that an 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.

The 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 of the Republic of 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 and control, as well as in the field of PLL and FLL applications. Ref. [1-2] are used for the basic concept, ref. [3-4] are closely related to this work. Ref. [5-8] are used in the realization of interface between PC and electronic block, in electronics implementation and software support.

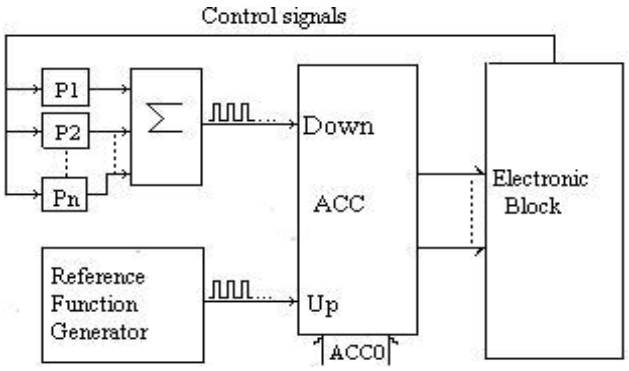

Fig. 1 Organization of the extended FLL

Organization of the extended FLL

The FLL, described in [2], is extended, as shown in Fig. 1. It contains UP-DOWN counter (accumulator), then electronic block with decoders of accumulator contents, logics and control signal generators, which altogether are to control processes P_1 to P_N, according to the requirements of a system where the extended FLL (EFLL) is applied. The affection of any process P_1 to P_N is added or subtracted and convert to pulse rate, which is fed to input DOWN. The frequency of this pulse rate carries information about controlled or measured physical parameter. On the other side, pulse rate from the reference function generator, whose frequency might be any kind of function in time, is fed to the input UP. The third input is parallel one, which represents the initial value of accumulator ACC_0. The initial value ACC_0 is to be entered to accumulator usually at the beginning of the control process, but it may be entered at any time, if it is necessary. In some applications, ACC_0

might be used as very useful and powerful control parameter.

The extended FLL, shown in Fig. 1, represents general model, which is more suitable for wide range of applications in comparison with FLL, described in [2]. The output pulse rate of extended FLL is not generated at the output, like in case of FLL, described in [2]. Instead of that, the current accumulator content is continuously decoded, and according to the content state, generated control signal are used to affect to the processes at the input, leading so control to the desired direction. Classical PLL and FLL, in most of their applications, are to be in the transient mode as short as possible. In comparison with them, the stable state of extended FLL might be rather short, because it works in transient mode all the time, while reducing the error to zero. The extended FLL is in the stable state, providing that the frequencies of pulse rates, which are fed to inputs DOWN and UP, are equal. It should be noticed that the current accumulator content, in the mathematical sense, represents the time integral of the difference between two pulse rates frequencies, added to ACC_0.

The PLC system based on the extended FLL

It was emphasized that, in FLL and many electronic applications, pulse rate frequency may carry information about any physical parameter, which is to be controlled or measured. In the extended FLL, which is applied in PLC system, pulse rate frequency represents information about the power consumption. Every pulse in the PLC system corresponds, automatically, to the constant amount of consumed electricity energy.

The organization of the PLC system, based on the extended FLL, is shown in Fig. 2. The principles of the

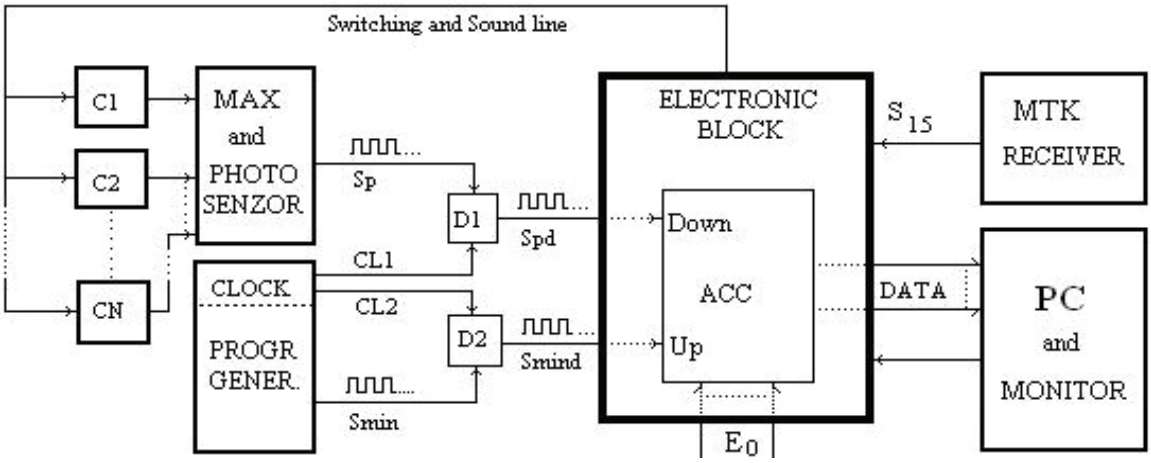

Fig. 2. The PLC System: installation of photo sensor in MAX is under control of the laboratory of Electrical Distribution; checking the functions and verifications of extended MAX makes Republican Bureau for Measures.

extended FLL, Fig. 1, are completely incorporated into the PLC system in Fig. 2. UP-DOWN counter (ACC) is represented as a part of electronic block in Fig. 2.

Processes P1 to PN are consumers C1 to CN. Addition of consumption C1 to CN, is realized by device MAX (Maxigraf measures the average consumption power during 15 minutes and, at the same time, the all energy consumed in the factory).

Two photo sensors are built in MAX to convert, in real time, current power consumption to pulse rate frequency of Sp.

The reference function generator from Fig. 1, is changed by the binary programmable generator with crystal oscillator frequency of 32 768 Hz, in Fig. 2.

The programmable generator generates pulse rate Smin, whose frequency corresponds to the minimum consumption power of a factory. This minimal power consumption is achieved when all consumers are switched off, whose short exclusion will not disrupt the process of technological work. The consumption which corresponds to frequency of Smin, will appear as the main criterion curve of the factory on the graphics, later on, in Figs 6 and 7.

The next important parameter, which is used for consumption control is the initial content off FLL accumulator Eo. It appears physically as energy in Fig. 2, instead of ACC0 in Fig.1. Device MAX is synchronized (this is not shown in Fig.2) by pulse rate S15 form MTK receiver. The period of S15 is 15 minutes. MTK receiver is device, controlled from a distance center. All the system is synchronized by signal S15, including electronic block, PC computer and programmable generator.

The FLL accumulator content is entered to PC, using communication interface between electronic block and PC computer. PC computer serves in this PLC system for the graphics presentations of current parameters and energy states of the factory as well as for the prediction of the consumption power (MAX value) at the end of the 15-minutes time period. At any time, this is used for the decision in electronic block, if action of switching is necessary. The prediction makes software packet, which will appear as Eprogres on the graphics, later on, in Fig. 7. At last, PC computer is used as base of data, which enable to show daily, monthly and yearly presentation of different energy parameters.

Switching and sound line brings serial coded signals. They are used for switching consumers C1 to CN and to inform all the participants about energy state in the factory.

The input module of Extended FLL

The general scheme of the input module of extended FLL, applied in PLC system, is shown in Fig. 2. The accumulator, in Fig. 2, is 16 bit UP-DOWN counter, consisting of four 4-bit binary UP-DOWN counter CD 40193. It is of practical interest to consider the solution for the input module of extended FLL, because of two reasons. The first one is the fact that UP-DOWN counters, as well as the other integrated circuits with two counting inputs, are not allowed to accept counting pulses in both inputs UP and DOWN simultaneously. The second one is the need to consider how to apply the extended FLL in some other

applications. In such ones, it may be necessary to add or to subtract more pulse rates, in case that they are not added like in case of PLC system, where device MAX performs this function. The addition of two or more pulse rates, can not be performed by the logic circuits only. Actually, before addition by the logic circuits, it is necessary to disable the appearance of any two pulses simultaneously. At the same time, these pulses carry information, and they must not be lost. They should be only separated in time, i.e. de-synchronized.

For the purpose of de-synchronization of any two simultaneous pulses in pulse rates Sp and Smin, Fig. 2, de-synchronizers D1 and D2 and clock pulse rates CL1 and CL2 are used. The frequencies of pulse rates CL1 and CL2 are equal, i.e. 512 Hz, but they are phase-shifted by 180 degrees. It is very easy to get CL1 and CL2 by pulse rate CL0 from the programmable generator, whose frequency is 1024 Hz. This solution is shown in Fig. 3. It consists of one flip-flop, which acts as divider by two, and two AND logic circuits. Time relation between CL0, CL1 and CL2 may be seen in timing diagram, Fig.5.

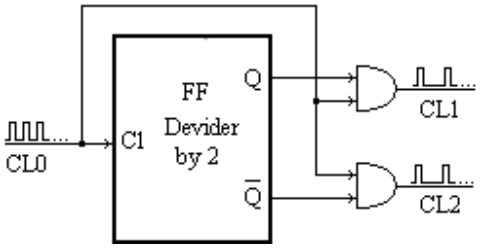

Fig. 3 Generation of clock pulse rates CL1 and CL2

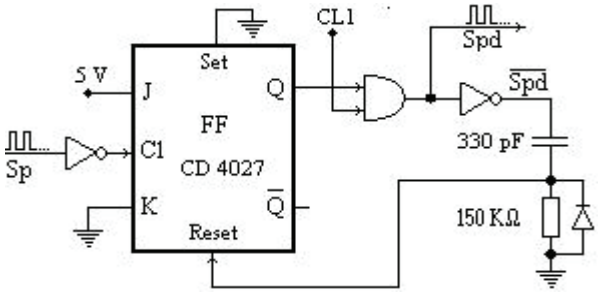

Fig. 4. Detailed scheme of de-synchronizer D1

Detailed scheme of de-synchronizer D1 is shown in Fig. 4. Timing diagrams, for all signals shown in Fig. 4, are presented in Fig. 5. The de-synchronizer D1, using clock pulse rate CL1, generates pulse rate Spd instead of Sp. Allpulses in Sp are shifted in time. Actually, pulse “a” from CL1, is extracted instead of pulse number 1 in Sp, Fig. 5. In the same way, pulse number 2 in Sp is changed by pulse “c” from CL1. It should be noted that every pulse in Sp is changed with the first next pulse in CL1. It is obvious, that the frequency of pulse rate CL1 must be grater than the maximum frequency of pulse rate Sp, which could appear in one factory. In the practical solution of PLC system, the frequency of CL1 is 512 Hz and that is much grater than the maximum frequency of pulse rate Sp, which is in practice about 3 Hz. This frequency depends on the resolution, which one would use in measuring of the total power consumption, but the frequency of 3 Hz, provides acceptable resolution for the purpose of the consumption peak load control.

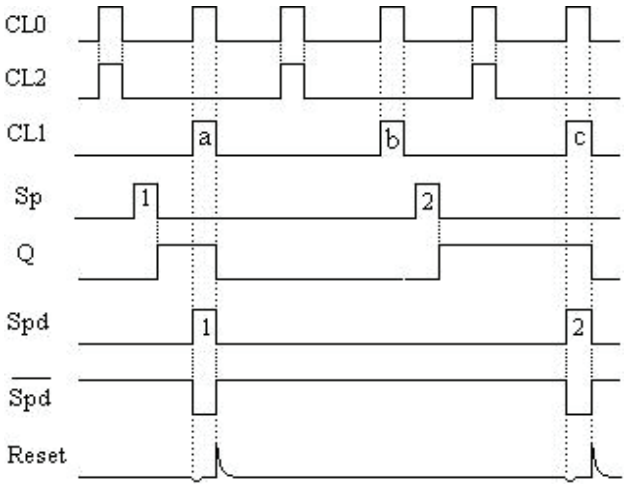

Fig. 5. Timing diagram for the signals shown in Figs. 3 and 4

The scheme of the de-synchronizer D2 is completely the same like that one shown in Fig.3. The only deference is that module D2 serves to generate Smind instead of Smin and that for this purpose uses CL2 instead of CL1. That means every pulse in Smin will be changed in Smind with the first next pulse in CL2. Due to this fact, pulses in Spd and Smind can never occur simultaneously.

It is of interest to notice that, for some other applications, the described approach might be extended to any number of pulse rates, which are to be added. For this purpose, it would be necessary to extract, as many phase-shifted clock pulse rates as there are pulse rates for addition.

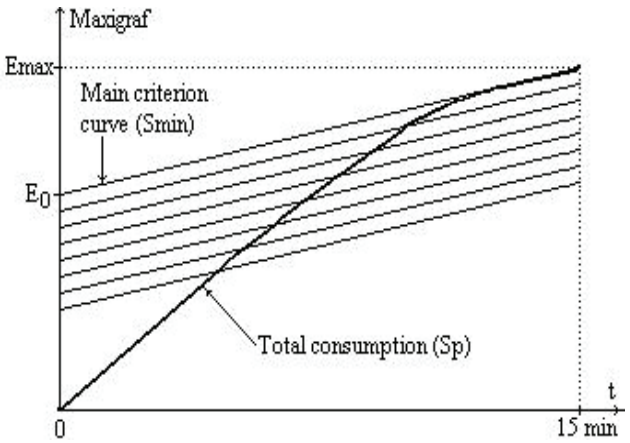

Fig. 6. The basic functioning principle of PLC System

Brief graphic presentation on the realized PLC System

The basic functioning principle of PLC System is demonstrated in Fig. 6. This figure is generated on the PC monitor. The main and the other criterion curves (altogether nine) are fixed for one factory and they are drown using manually entered data into PC, like E0 and the frequency of Smin. Total consumption of a factory is drown in real time, using data from the electronic block. The maximum ofenergy which is not to be exceeded in the factory, during 15 min, is Emax. It depends on E0 and frequency of Smin. Detection field is defined by criterion curves. Whenever total consumption curve reaches any of the criterion curves, providing that total consumption would exceed Emax at the end of 15 min time, electronic block would switched of some of consumers. At last, if the previous switching of is not sufficient, the total consumption curve will reach the main criterion curve and the rest of consumers will be switched of.

If all consumers, whose exclusion does not disrupt production, are switched of, the total consumption curve will follow the main criterion curve and the consumed energy of a factory will be exactly at planed Emax, at the end of 15 min time. The distance between the criterion curves and E0, may be chosen according to the control needs. The real time graphic presentation on the realized PLC system is shown in Fig. 7. In addition to the parameters

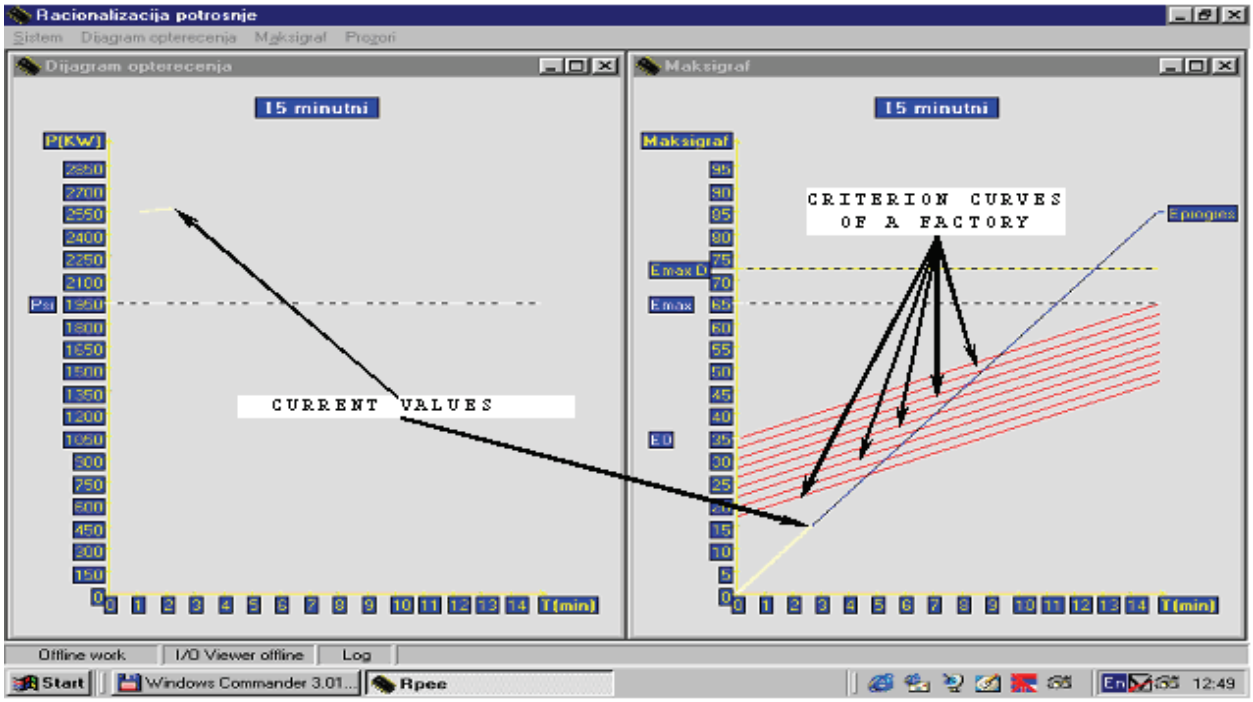

Fig. 7. The real time graphic presentation of the current MAX and total power consumption on the realized PLC System

shown in Fig. 6, the effect of software packet Eprogres may be seen in Fig. 7. Eprogres shows that, providing total consumption keeps intensity which has at the beginning, the total consumption will exceed Emax at the end of 15 min time. The current power consumption is shown on the left side. It corresponds to the current total consumption.

Conclusion

The described extended FLL, due to decoding of digital state inside of FLL and ability to control its content by many outside pulse rates and by preset of the whole FLL content, is suitable for development of many different applications in the field of control, measurement and telecommunication.

The approach to PLC system, based on the extended FLL, offers the optimal, but simple and natural way of peak load control for all kind of consumers. It was successfully applied in practice regardless of the amount of consumption, the technological process, the organization of production, the variability of the used current power, the size and position of the factory and regardless of the other parameters that might have influence on the peak load. It enables change of priority of every consumer in the function of the technological process, monthly or seasonal reprogramming of the system, visual, sound, current and long-term monitoring (daily, monthly, annual) of the factory consumption and the other benefits.

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