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Principles of operation of energy management controller

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Abstract. *This paper discusses the basic principles of operation of a controller intended to limit the electrical energy consumption. The energy consumer is controlled depending on the amount of energy used, the magnitude of the load current and the pre-set permissible twenty-four-hour limit of electricity. The following possible situations are covered: the consumer has used energy equal to or less than the limit set within a 24-hour period; the consumer has used up the entire energy limit in less than 24 hours; the current through the consumer periodically exceeds the pre-set current limit; and training the consumer to use energy wisely by applying sanctions - temporary disconnections of the power supply. The method for programming and configurating the controller by means of a specialized remote equation is shown.*

Keywords: electrical energy, single-phase current, limiting the energy consumption

Introduction

The energy management controller is designed to facilitate and simplify the relationship between the electricity supplier and the energy consumer (most often a household user) under conditions of prior agreement on the amount of electricity provided or the amount to be paid (Dorf and Bishop, 2000) To achieve this purpose, the controller compares: the pre-set 24-hour energy limit (**Elim**) and current limit (**Ilim**) with the measured amount of energy consumed and the value of the load current (García et al.,1997). The energy management controller is time synchronized with the electricity meter of the consumer according to the day/night tariff (**D/N)** signal generated by an external clock (Ivanova, 2021) The accumulation of the amount of electricity consumed starts at the beginning of each day. The load current is estimated based on the averaging of its instantaneous value over a period of ten seconds (Redl, 1998).

Depending on the comparison between pre-set and measured values, several basic algorithms for switching the power supply on or off are set in the controller‘s actions (Zaborszky, 2000). The controller is designed to control consumers of both active and reactive energy (Power engineering, 2002). The applied algorithms are designed to encourage the consumer to use the predetermined amount of energy reasonably by implementing sanctions - temporary disconnection of the power supply, and also the interface to be convenient for both the energy user and the electricity distribution company.

Material and methods

Operation algorithms of the energy management controller

First algorithm: a situation where the consumer has consumed electricity equal to or less than the pre-set Elim for a period of 24 hours. The process can be visualized with the following timing diagram in Figure 1.

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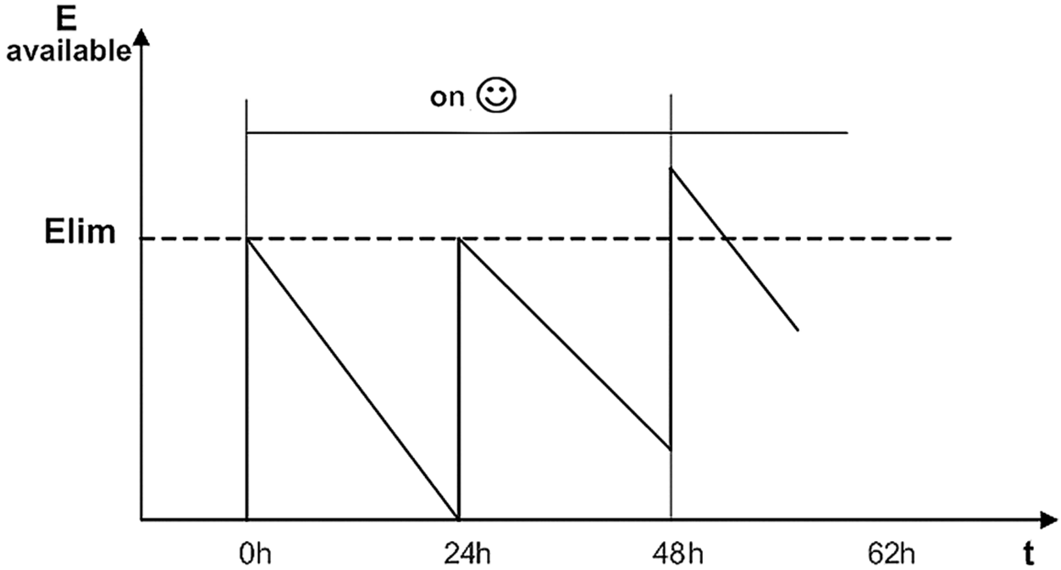


Figure 1. Timing diagram of First algorithm

During the first 24-hour period the full limit was used by the consumer. The second 24-hour period begins with available energy equal to Elim. At the end of the second 24-hour period, not all of the available energy is consumed, and the rest is transferred as savings for the next cycle.

The third 24-hour period begins with available energy equal to the sum of the remaining energy from the previous cycle – one **Elim**. The amount of energy saved can be programmed in the range of 0 to 10 daily limits (**El)**.

Second algorithm: in a situation where the energy consumer has used up the entire limit of energy **Elim** in less than 24 hours. The process can be visualized with the following timing diagram (Figure 2):

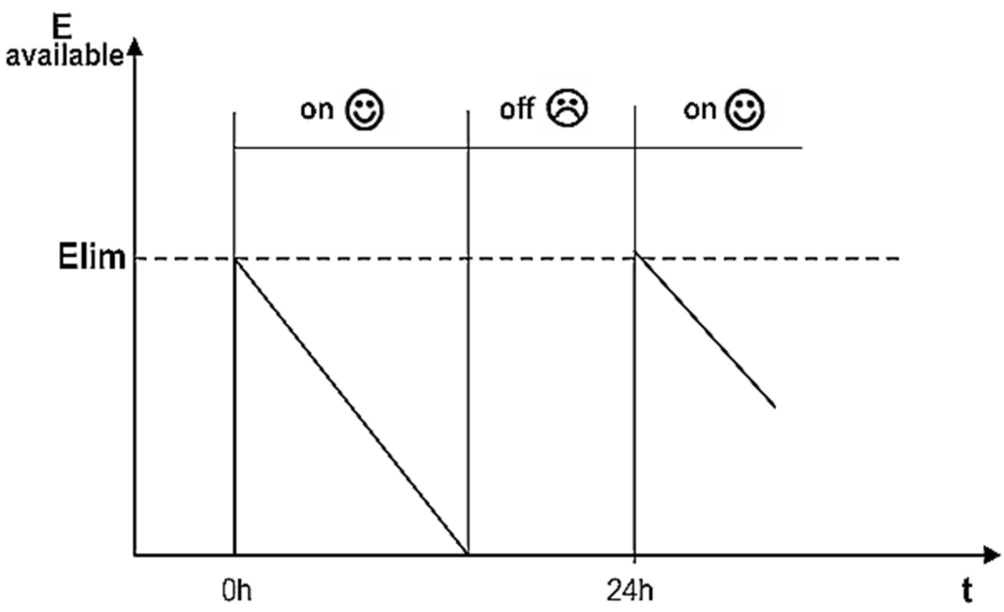


Figure 2. Timing diagram of Second algorithm

Third 24-hour period begins with available energy equal to the sum of the remaining energy from the previous cycle plus one Elim. A new activation will only take place at the beginning of the next 24-hour period.

Third algorithm: A scenario in which the energy consumer constantly draws a current exceeding Ilim. The process can be visualized with the following timing diagram in Figure 3.

Where:

$\mathbf{T_{10sec}}$ - load current test time with a duration of 10 sec. If the average current during this period exceeds **Ilim**, the device turns off the consumer's electricity for the time period of the corresponding sanction.

Tsanct$_1$ - time for the first sanction – 2 min.

Tsanct$_2$ - time for the second sanction – 5 min.

Tsanct$_3$ - time for the third sanction –1 h.

Tsanct$_4$ – time for the fourth sanction – this is the time remaining until the end of the 24-hour period. Turning on the electricity of the consumer after applying sanction 4 can occur in any of the following cases: start of a new 24-hour period or reset of the controller.

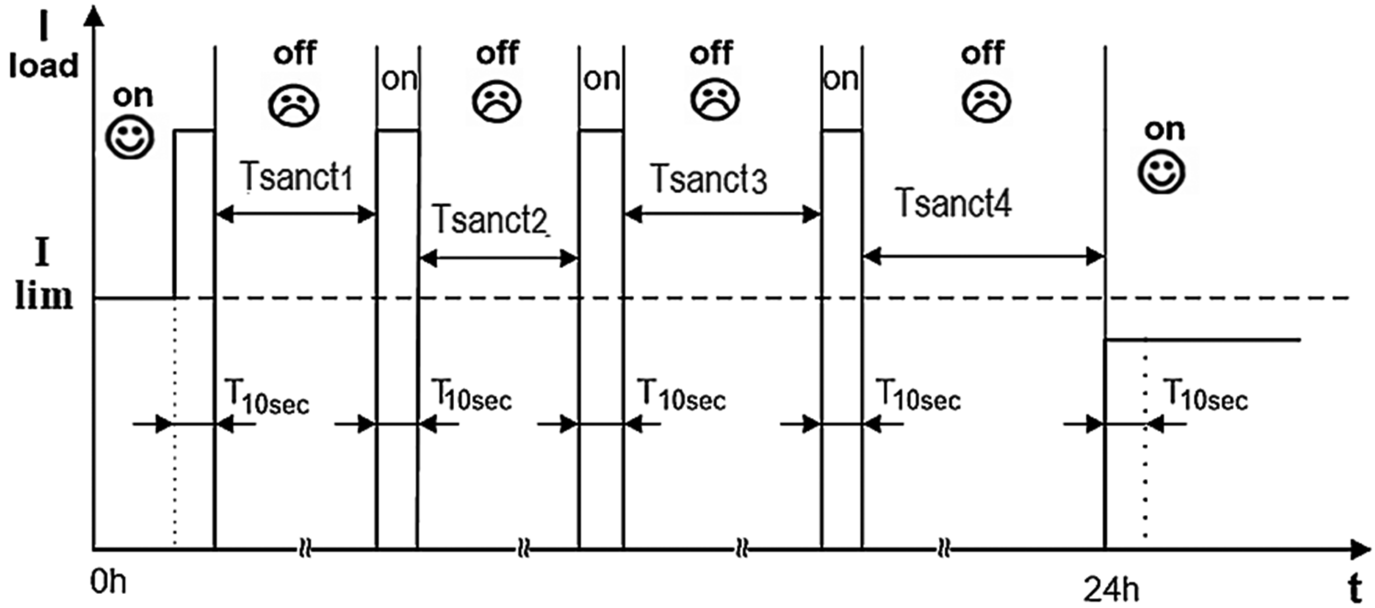


Figure 3. Timing diagram of Third algorithm

Fourth algorithm: A scenario where the energy consumer is „trained" and a sanction has already been applied. The process can be visualized with the following timing diagram:

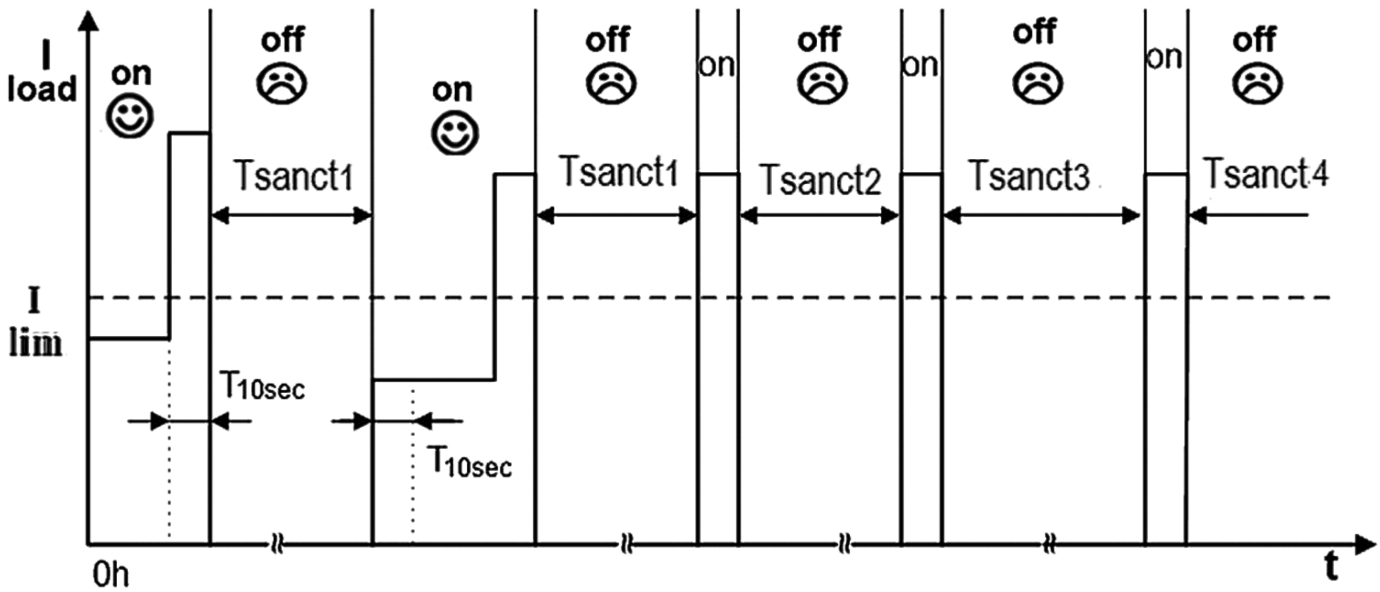


Figure 4. Timing diagram of Fourth algorithm

If during **sanction1** to **sanction3** the load to the electrical grid is reduced and no overload above **Ilim** is detected through the test connection **T10sec**, the electricity of the consumer remains permanently turned on and the previously applied sanctions are ignored. Cancellation of already applied sanctions occurs in any of the following cases: start of a new 24-hour period; no current pause; resetting the device or setting new device parameters.

Results and discussion

Settings and reading information from the energy management controller

To avoid unauthorized interference with the controller settings, the device is encapsulated, i.e. it must not be opened during its operation. All parameters and settings can be accessed through its infrared port via a specialized remote control. [1]. Information is entered into the remote control via a keyboard and is displayed on a two-line screen with a menu in Bulgarian. Pressing each button is accompanied by a short beep. Incorrect operation or value is signaled by a long beep. The remote control can communicate with all controllers located in the same mounting cabinet, or individually with each controller, recognizing it on the basis of its individual identification number (ID). The possibilities of exchanging information with the remote control are illustrated by a few basic examples:

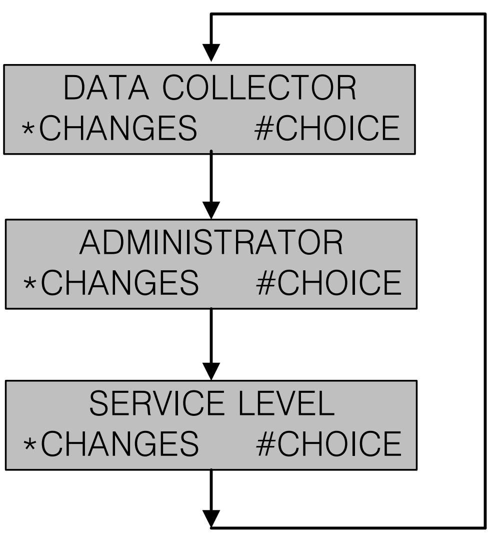
• When the power is switched on, the remote control automatically measures the voltage of its power supply battery and possibly gives a recommendation to replace it with a new one.

POWER SUPPLY 8.4 V
SERVICEABLE BATTERY

or

POWER SUPPLY 7.3 V
BATTERY REPLACEMEMT

• The access to the information available in the energy management controller is organized into three hierarchical levels: level **Data Collector**, level **Administrator** and level **Service level.** The choice of who will work with the remote control is controlled by the main menu:



Selection is made using the „*“ button and confirmed with the „#“ button. The access to the three different levels is provided by entering the corresponding 8-digit password:

DATA COLLECTOR
PASSWORD: 00000000

• The following procedures with the device can be performed in the Data Collector level:

INITIAL RESET
*CHANGES #CHOICE

- *Initial reset* - this procedure performs complete synchronization of the time period - month - during which the individual meter reads the energy consumed on the one hand, and the value of the limited energy from the controller, on the other hand. The *Initial Reset* procedure shall be performed simultaneously on all devices in one mounting panel at the end of each reporting period by the data collector during his visit to the consumers. The procedure does not require entry of an individual controller identification number (ID);

- The procedures *Read limit* and *Saving limit* read or write the programmed limit levels /from 0 to 10/. The *Read limit* procedure can be used to see what limiting level a controller has been programmed to (limit 0 to limit 10).

READING LIMIT
*CHANGES #CHOICE

In order to perform this procedure it is necessary to enter the personal identification number (ID) of a specific device from which you want to read:

READING LIMIT
INDENTIFICAT. N:00000

Successful execution of the specified procedures is signaled by a light indicator from the controller and visualization of the data read on the display of the remote control.

The communication between the specialized remote control and the controller is achieved and visualized in a similar way for the other hierarchical levels.

• The following procedures can be performed at the **Administrator** level of the energy management controller:

- Editing the password for access to the level **Data Collector**;

- Editing the programmed limit levels (from 0 to 10). In this procedure, the basic parameters of the device are set: the limit for energy limitation for a 24-hour period (**Elim**), in [kWh] or [BGN] at BGN equivalent of the consumed energy; current limit (**Ilim**).

• At **Service level** of the the energy management controller, the following procedures can be performed:

- Editing the password for access to the level **Administrator**;
- Reading the electricity consumed by the energy consumer at day and night tariff in kilowatts or BGN (in this mode the energy management controller operates similarly to an electronic energy meter);
- Reading the status of the device and the presence of a corresponding error detected during the self-diagnosis of the device.

Using hierarchical levels of access simplifies the maintenance and operation of the energy management controller. The controller is delivered with pre-programmed parameters at the **Administrator** level. During the operation of the device, only simple monthly actions are carried out by the service **Data collector**.

Conclusion

The application of the algorithms described above and the organization of the energy management controller operation not only facilitates the relationship between the electricity trader, electricity distribution company, and the buyer (who is most often a household consumer), but also simplifies them. The controller offers the energy consumer two main benefits: 1. Daily access to electricity, which is pre-limited in quantity; 2. Trains him to use the electricity provided wisely and sparingly. At the same time, the controller protects the interest of the electricity supplier: 1. Protects the electrical grid from overload and, therefore, from damage; 2. Reduces the energy consumer payment problems. If the equivalent monthly energy consumption limit in BGN input to the device is equal to the social benefits for energy of the household consumer and this aid is received directly from the electricity distribution company, the company will be maximally protected to receive the amounts due.

References

Dorf RC and Bishop RH, 2000. Modern Control Systems. 9th Edition, Prentice Hall, pp. 828.

García O, Cobos JA, Alou P, Prieto R, Uceda J and Ollero S, 1997. A new family of single stage AC/DC power factor correction converters with fast output voltage regulation. Proceedings from IEEE Power Electronics Specialists Conference (PESC), 1997, Session 12. Single-phase Power Factor Correction - II, paper 12.3, 536-542.

Ivanova Y, 2021. Study of the basic methods for electricity conversion in AC regulators. 5th National Scientific Conference with international participation, TechCo 2021, 2-3 July 2021, Lovech, Print: University Publishing House «Vasil Aprilov» Gabrovo, ISSN 2535-079X, pp. 21-25.

Redl R, 1998. An economical single-phase passive power-factor corrected rectifier: Topology, operation, extensions, and design for compliance, in *Proc. IEEE Appl. Power Electron. Conf. (APEC)*, 1998, pp. 454-460.

Zaborszky J, 2000. Dynamics and control of the Large Electric Power Systems. Wiley Interscience Division.

POWER ENGINEERING, 2002. Series Editor H. Lee Willis ABB Inc. Raleigh, North Carolina Advisory Editor Muhammad H. Rashid University of West Florida Pensacola, Florida, ISBN: 0-8247-0737-0, 2002 by Marcel Dekker, Inc.