

THE FUTURE OF CENTRALIZED RIPPLE CONTROL SYSTEM IN HUNGARY – STATE-OF-THE-ART TRENDS

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Abstract: To keep life on our planet sustainable, reduction of carbon dioxide emission is indispensable. Therefore, today optimal use of electrical energy and efficiency of the power consumption are two of the most important questions of industrial management. The power changes on the electrical network can be influenced through *centralized ripple control system* by different power companies. This paper summarizes the scientific achievements running in Northern Hungary paying special attention to its *audio-frequency* and *radio-frequency controlled system*. A number of important results of our new scientific approach (new analyzing software) will be introduced delivering opinions about applying CRCS and SMART systems.

Keywords: centralized ripple control, stochastic power fluctuation, power control on electrical network, demand side management.

1. INTRODUCTION

During the transmission and transformation process of energy, the power suppliers (e.g.: *ÉMÁSZ: North Hungarian Electricity Supply plc.*; *ELMŰ: Budapest Electricity Works*) would like to buy electrical energy within the optimum time frame. The energy demand and instantaneous power consumption depend on the number of customers and their usual usage practice. Thus, the stochastic energy changes greatly affect the work of power companies [1].

Suppliers have limited possibilities to direct the customer's consumption, but one of the most effective tools is the kWh price, thus, the energy consumption can be influenced by electrical energy tariff. More energy will be consumed by users when it is cheaper.

The second most effective tool is to control the energy consumption directly on the network applying *centralized ripple control (CRC)* for heating units. Consequently, the power companies can control the operation of different heat-storage equipment groups (clusters) to minimize the energy changes. In addition, the public lightning and the

different alarm systems are controlled by CRC as well. The CRC, being a special "*mass-control possibility*" in the power suppliers' hand [2], and the correct tariff rate are effective tools for optimizing the daily power consumption.

This paper introduces the operation of *centralized ripple control system (CRCS)* and gives a general comparison between *audio-frequency (AF)* and *radio-frequency (RF) controlled system (AFCS, RFCS)*, furthermore, the results of a research work, which began two years ago, is shortly published drawing the attention to the optimization possibilities of CRCS [3]. Although today's SMART-control (*Specific Measurable Achievable Result orientated Time bounded*) oriented approaches try to disregard CRCS, the achievements of our research clearly indicate that this control method has highly significant potentials and worth paying attention to it. As a result of the research, ÉMÁSZ can control the CRCS more efficiently and cost-effective than before. In addition, this study gives a short description about the necessity of "*mass-control tool*" in Hungary.

2. GENERAL CHARACTERISTICS OF CRCS

Mass-control has long tradition and significance in Hungary, and currently, power suppliers cannot avoid the application of this efficient method of load control. Till now, two types of mass-control architecture have been spread: the AFCS and the RFCS. In the previous decades CRC systems were mainly applied, however, nowadays only the usage of RFCS, SMART and hybrid solutions are common.

Every CRC solution is suitable for one-way signal transmitting. The one-way control possibilities are only advantageous in those cases, where there is no need for the prompt checking of the reception of information and for feedback from the controlled units [4].

The complexity and system structure of these solutions are different from several aspects; however, their operation is quite similar. AFCS was examined through measurements at transformer

stations, but the findings of research are applicable to a RFCS as well.

2.1. Architecture and operation of AFCS

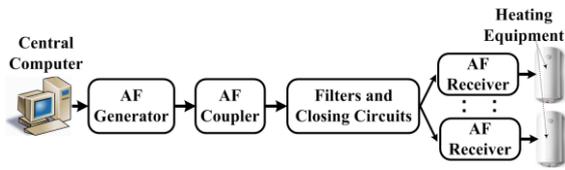


Fig. 1. Schematic structure of AFCS.

The *AF generators* start the AF messages at each transformer station. These highly-efficient generators create 3-phase AF signal to the network with amplitude between 1% and 2% of the mains voltage. Different frequencies are used for CRC; e.g.: ÉMÁSZ uses 183.33 Hz; ELMŰ uses 213.66 Hz.

The *AF coupler modules* are the most crucial elements of the AFCS. The previously generated AF signal will be coupled to the high-voltage network (50 Hz) in serial and parallel mode. The *filters and closing circuit modules* decrease damping and harmonic distortion of the AF signal.

The *AF receiver modules* are installed on the customer side which can switch on or off the heating equipment by relays. The AF receivers can be started by individual AF messages. The suppliers use different AFCS (e.g.: Pulsadis System; RiconticB System with Versacom Protocol). Both systems apply different structures of AF messages, with different lengths of pulse. Depending on the supplier, CRC messages (Fig. 2) differ in delay and structure of pulses which are used for controlling customers' equipment directly.

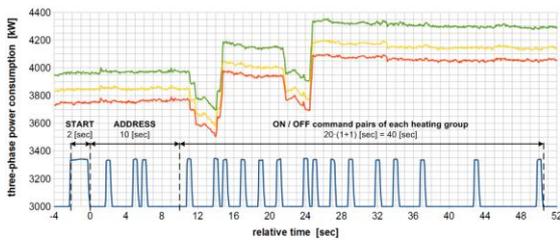


Fig. 2. Structure of generated AF messages.

The *central computer module* controls AFCS. AF generator modules at transformer stations (in different geographical regions) send AF messages (a series of pulses, about 60 seconds long) according to special scheduling. AF messages are sent in well-defined time intervals (usually in every 15 minutes) and are received by customer equipment, thus boiler heating starts or stops. These messages are synchronized and sent to the electrical network in order to provide accurate switching shifting.

The general used AF message consists of three elements: start pulse; followed by addressing, which determines the type of customer equipment; furthermore the control part which selects the switched heating groups and type of control on or off. The heating clusters are controlled by individual command pairs.

2.2. Architecture and operation of RFCS

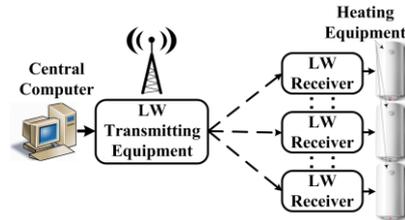


Fig. 3. Schematic structure of RFCS.

The architecture of RFCS (Fig. 3) is simpler than that of AFCS. There are missing modules, which played central roles in the previously examined system structure, such as VF couplers, filters and closing circuit modules. We can draw the conclusion that one central computer and *long wave (LW) transmitting equipment* can control a number of receivers on consumer side at the same time from one place. The transmitting equipment generates LW telegrams for broadcasting, which follows well the surface of the Earth; therefore, they ensure the safe data-transmission. The LW telegram can travel through objects (e.g. mountains, buildings, trees); moreover, it can get through the soil as well, while reducing its strength.

The RFCS was developed in the mid-nineties in Germany (*Europäische Rundsteuerung GmbH.*), after LW radio frequencies were de-allocated for industrial purposes. Three transmitting towers operate throughout Europe: two in Germany and one in Hungary. The 135 m high, 100 kW multidirectional (non-directed) antenna, operating on 135.6 kHz frequency, can be found in Lakihegy, Hungary, supplying the whole Central Europe.

The RFC broadcast uses FSK (DIN 19244) modulation, applying Semagyr-Top and Versacom protocols and continuously transmits the information via LW telegram (Fig. 4).

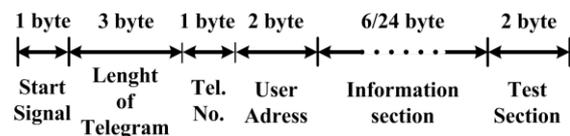


Fig. 4. Architecture of a LW telegram.

LW telegrams follow DIN 19244 FT 1.2 IEC 57 and ICE 57 CO 40 standards. The most significant parts of LW telegrams are: start (serves the purpose synchronizing), user address (identifies the

receivers) and information (controls the commands to the receivers).

2.3. Queries of CRC

The CRCS is controlled by one-way signal transmitting, thus, the heat-storage power is not known by the power suppliers during whole day. They do not know how many equipment will be switched on- or off on the electrical network in consequence of CRC's time-schedule.

Users have special habits in their usage and they have different needs in the daytime or nighttime, morning or evening, on weekdays or weekends, and in the summertime and wintertime. Therefore, certain parts of the controlled customer equipment do not regularly switch on after a turn-on command, or the time periods for remaining switched on are different, depending on the actual customer's needs. In addition, heating equipment has a very wide range of operational parameters and characteristics: some types will not start immediately on command, but have a delay of several seconds or several minutes, therefore some boilers remain off for a while after a turn-on command.

Some pieces of equipment may be temporary or continuously disconnected from the network, others were simply heated up in a previous heating term and not used, and therefore they will be kept turned off by their own thermostats. Also, there are huge differences in consumer needs depending on the geographical placement and socio-economic environment of the actual place. Due to these considerations the "built-in controlled power" (the constant maximal heating power of an electrical network) is not equal to the switched-on heating power of boilers. The difference between these two power levels depends on the actual place and the current time, day of the week and season.

3. INVESTIGATION IN NORTHERN HUNGARY

One main problem for the supplier is the lack of feedback on the switched power, e.g. how many boilers (heating equipment) were used on customer side (heating energy consumption equals hot-water consumption). The controlled heating equipment generate different power changes on the network; these are called *boiler* or *heating power*.

Power suppliers intend to know all consumption changes on electrical network caused by CRC. Thence, ÉMÁSZ (and all Hungarian suppliers as well) can only gather information on their own electrical network from repeated long-term (1-week) measurements of each transformer station in winter and summer seasons. Consequently, measurements had to be accomplished in the territory of ÉMÁSZ (Fig. 5) in order to study the operation of electrical network and the effects

caused by CRC. New methods had to be developed to be able to calculate the switched heating power during a day. Till now, the supplier could solely estimate the heat-storage power, but due to our new developed analyzing system, accurate computations are available. Although, measurements of AFC were carried out in Northern Hungary, but our conclusions characterize the whole area of Hungary. Currently, mainly AFC systems operate only in our country and in the forthcoming years the change for RFCS and/or SMART systems can be anticipated. Our analysis results and conclusions will help for the power supplier due to the similarities of the AFC and RFC systems.

3.1. Accomplished measurements

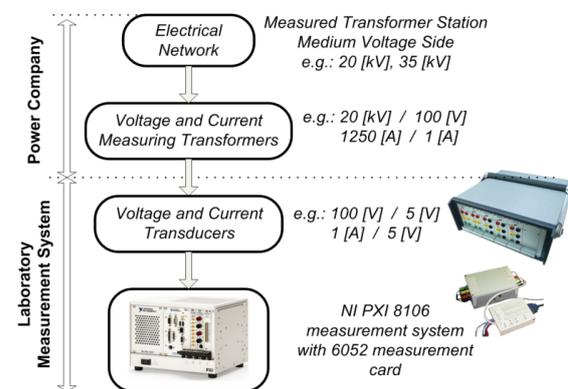


Fig. 5. Modular structure of the applied measurement system.

Northern Hungary stands in the centre of this research. The region involves four different counties across a 19,000 km² area, which is roughly 20% of Hungary. More than 1.7 million consumers can be found in this area, approximately 670,000 homes have to be supplied, from which less than 200,000 active heat-storage units can be controlled with approximately 400 MW maximum built-in heating power.

Our team (*Department of Electrical- and Electronic Engineering, University of Miskolc*) measured 35 different transformer stations (altogether 45 transformers) in *Northern Hungary* which needed the development of special data acquisition software. In more cases, the measurements were performed for 3 to 7 days, consequently, more than 600 GB data were acquired for 150 days. Obviously, the data processing had to be computerized for the easy evaluation of acquired files.

3.2. Developed detecting methods

New automatic analyzing methods have been developed for the examination of measured data. More central tasks have been solved before the development of diagnostics software.

First of all, a reliable method has been created to recognize the CRC pulses (messages) from the 3-phase voltage. The detection of CRC messages is accomplished with a sliding FFT-window (*Fast Fourier Transform*) which is moved on the voltage signal and detects the AF harmonic component. Based on the general structure of AFC messages the transmitted CRC message can be identified.

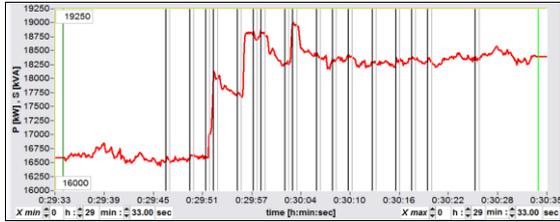


Fig. 6. Screenshot of an AF message containing three significant boiler power changes on the network (applying 60 ms averaging).

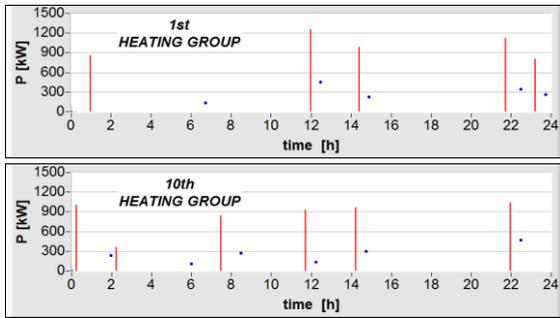


Fig. 7. Heat-storage power at a selected transformer station examining two different heating groups.

After this process, the computation of heat-storage power was accomplished. For the computation of power consumption data, two different time bases were used (one period long; three periods long). The application of one period long time base simplified the first recognition process of CRC because the AF pulses caused significant fluctuations on the 3-phase power wave. Thus, all AF pulses during the generated AF messages could be exactly identified. The averaging process is not adequate for the later applied computation of heating power. Based on our experiences, one period long time base is too short for reliable power averaging, thus three periods long time base is used later which ensures adequate elimination of undesirable fluctuations on the 3-phase power wave (*Fig. 6*).

According to the results of our research, the significant power fluctuation can be directly detected after the AF pulses, thus two critical parameters have to be defined for the automatic computation of heat-storage power: the *reaction time of the customer receivers* (the time between the CRC command and the equipment's real switching on or off); and the *operational delay of*

significant heating power fluctuation after start of equipment. In favour of easier examination processes, new displaying methods (*Fig. 7*) were used.

3.3. Generated heat-storage power profiles

The determined heating power changes are aggregated in order to enable the creation of power profiles which characterize the studied region of Northern Hungary. The previously introduced heat-storage displaying and computation processes (*Fig. 7*) facilitate the mentioned aggregation of heating power for determining the maximum switched power.

Due to the developed approximation solution, the heat-storage power profiles can be automatically generated by a fast and objective method. The profile-generation process uses a linear interpolation method combined with Fourier and inverse Fourier analysis (*Fig. 8*).

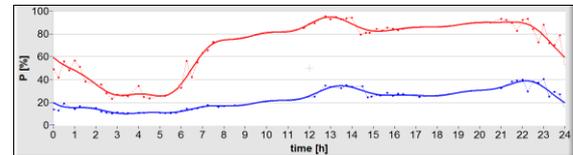


Fig. 8. Determination of heat-storage power profile using the new approximation process.

Each supplier should to know how large power changes occur after a CRC message [5-7]. The most important information is the maximum and minimum heat-storage power at a definite time.

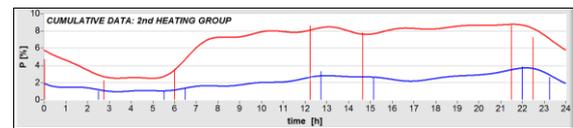


Fig. 9. Comparing the normalized heat-storage power profile with a heating group on a selected transformer.

Normalizing methods are used to enable the comparison of the created central heating profiles with a selected transformer station (*Fig. 9*) localizing the differences among the profiles. Analyzing the differences, the supplier can generate better heating profiles than before.

3.4. Developed online CRC module

Online software module was developed for detecting AF messages, for estimating the heat-storage power and for saving the results. This application continuously acquires the data samples from the 3-phase electrical network.

The developed online module utilizes a modern *multi-core data processing method with advanced thread communication* where three different threads are applied for efficient communication (*Fig. 10*).

Every thread operates parallel and is synchronized with the others: the *data acquisition thread* (*Thread I*) continuously measures the data samples; *Thread II* recognizes the CRC pulses (messages) and sends data into the other *buffer*; thus facilitating the work of *Thread III*, which computes and saves the 3-phase heating power.

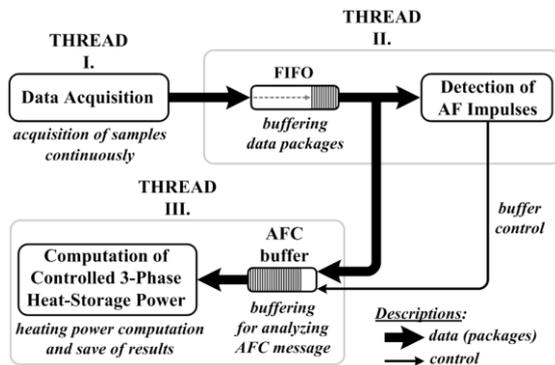


Fig. 10. Schematic structure of threads' communication applying the developed online module.

3.5. Universal diagnostics software and developed online module supporting the supplier

The above introduced methods could be easily applied for developing ultimate diagnostics software. The diagnostics program can be used for the comprehensive examination of measured data by the supplier. The developed general methods and universal software can be applied by different suppliers and countries for efficient analysis. Furthermore, the online module provides an opportunity for the supplier to examine its electrical network by real time mode.

Before the launch of our research, the supplier in Northern Hungary did not receive any feedback from AFC units and it could only estimate the heat-storage power on its network. Thus, emphasis was put on the reliable determination of power changes. With the help of computed power changes, exact *heat-storage power profiles* could easily be approximated, therefore, the supplier can optimize its electrical network.

Another advantage of the developed software is summarized as follows: currently, *Hungarian power suppliers* can control heating equipment only through AFCS and RFCS. The developed new solutions help suppliers to identify the heating power on their electrical network. Although this method was developed for AFCS, it can easily be converted to RFCS as well. In case of AFC, the 3-phase voltage can be used for the recognition of AF messages; while in case of RFC, the recognition process can be eliminated. Therefore, the exact scheduling of LW transmitting equipment has to be known.

4. STRENGTHS AND WEAKNESSES OF CRC AND SMART METERING

With the help of CRC the supplier can control maximum 10% of all power on the network; thus, the daily load (peak load, valley load) can be better planned. Without mass control Hungarian suppliers could only operate their network less effectively, moreover, they would cause unnecessary extra charge for the consumers. CRC cannot be avoided in several cases such as street or advertisement lightening, and has a central role in other tasks as well, which should be supported by upcoming systems.

SMART systems play an increasingly important role in everyday life, however, their complete application is strictly limited in some countries. These hindrances primarily involve the current financial difficulties of these countries, and secondly, they are caused by the unclarified questions of SMART. Therefore, it is more crucial to focus on the efficient and optimized operation of the existing systems, which is demonstrated by the above outlined results. For the shake of flexible applicability, such methods have to be developed, which are independent from suppliers or regions and which can be easily adapted to the different circumstances.

Due to the effective methods, the one-way communication of CRC and the lack of feedback on the controlled heating units do not cause any problems, since the operation of the network can be easily analyzed by the developed online or offline solutions. The created methods do not require local measurements by consumers, only the central transformers of CRC are needed to be examined.

Although RFC is a simple CRC solution, it has a number of advantages contrary to AFC, e.g.: more kinds of user groups can be addressed and an individual consumer can also be controlled. Obviously, there is no feedback in this case, either.

The most significant advantage of SMART metering is the possibility of two-way communication, so the availability of feedback [8-9]. Sometimes, it requires the establishment of completely new and sophisticated ways of communication between the central computer and the controlled consumer. High expenses can be born during the creation and maintenance of this communication system. The enormous amount of information is an asset; however, taking the low sample rate and averaging methods of current SMART meters into account, it is only possible to acquire information on the general consumption of the network. If all units had its own SMART communication channel, we could acquire exact data about the types of consumption. The online communication of SMART cannot be realized, since it infringes personal rights, thus, data acquisition is only allowed after certain periods.

For the purpose of saving money, consumers, who are aware of the advantages of the SMART system, can consume power in periods, different from peak load of the network. Based on statistics, in European countries the measurable savings amount to 1-2% as a result of using SMART meters, since 99% of consumers do not care about efficiency after a while, they just want to use their devices when it is necessary. Thus it can be stated that CRC plays significant role, as suppliers can optimize with it.

In several leading European countries such SMART meters are installed, which are capable of being used for traditional CRC solution as well. SMART control [10-11] will be the technology of the future, which is supported by pilot-programs, legislation processes and new application methods.

The efficiency of the research is also demonstrated by the fact that in the Northern Hungarian region further decrease in the costs could be accomplished, furthermore, the supplier could acquire precise knowledge on its network based on measured data. The exact information on the controlled power hindered the possible overload of transformers, which had occurred before in some cases after the sending of CRC message.

Although this research field is rich in theoretical results, there are few examples of practical applications of SMART metering. Furthermore, it is of crucial importance that only CRC solutions are going to spread over Hungary in the next decade, while SMART systems may not. For the practical implication of SMART systems there are financial and technical requirements that should be met, which are currently not available.

5. CONCLUSIONS

This paper particularly introduces the types of CRCS and the scientific achievements of our project running in Northern Hungary. These results currently help the power supplier creating an optimized CRC.

In today's Hungary it is a central question to decide which control system should be applied in the future. The available options are going to be the RFCS, the SMART or a hybrid solution. The AFCS is not up-to-date any more, therefore, it has to be changed to a modern control in the following years; nevertheless, the necessity of heat-storage equipment cannot be questioned during the optimization of control. On the other side, SMART control has significant advantages; however, it raises several drawbacks at the same time, since this system is in the development phase. Thus, the complete application of SMART system should be seriously considered, in addition require an adequate financial supporting. This paper addresses more issues and expresses opinion on the

previously mentioned systems, introducing the backgrounds of the different solutions.

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