The method of detecting illegal electricity consumption using the AMI system

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***Abstract*—There are no proven systems on the market that deal with the detection of illegal electricity consumption. The AMI system gives new possibilities in this area. Based on the network configuration data, electric energy consumption and voltage values at the customer connection point (in phases), the analysis of electricity consumption was carried out. For the analyzed place in the network, the current was calculated from the voltage drop and the current resulting from the consumption of electricity. If the current determined from the voltage drop is greater than the current determined from the electricity consumption, it means that in relation to the recipient connected at a given point in the network, suspicion of illegal electricity consumption may be suspected.**

Index Terms-- distribution network, illegal electricity consumption, system AMI.

I. INTRODUCTION

A. Definition of illegal electricity use

Act on Power, art. 3 pt. 18, illegal electricity use involves consumption without having signed a contract with a distribution company or violating the contract. All cases of energy consumption that violate the stipulations of the contract, or when no such contract has been signed, are to be considered illegal.

More specifically, illegal energy use may involve:

- destroying seals on meters in the power supply system and/or destroying verification marks on a meter;
- destroying conductors in the power supply line;
- consuming electricity partially or completely bypassing the electricity meter;
- mechanical damage to a meter.

B. Classification of methods of stealing electricity

There are various ways enabling illegal consumption of electrical energy [1]:

- The end user connects devices to the grid bypassing the meter. Such a situation can be easily detected because the meter indicates zero or very low energy consumption. The same applies to cases of blocking the disc of the meter or when the contacts of the current circuit are closed.
- The user connects only one device illegally. Detecting such a case is very difficult on the basis of the meter indications.
- Some devices are temporarily connected to the grid bypassing the meter, so the amount of legally consumed energy is lowered.
- A separate category of theft is consuming electricity illegally by extremely poor people, who cannot afford to pay their energy bills. This is a social problem, then. Such consumers may not even conceal the fact that they use electricity illegally, but they simply lack the means to cover their expenses. Some of them may have had their meter disassembled.

There are no universally applicable and accurate methods of detecting illegal electricity consumption. The current state of art is that analytical methods based on statistical (or other mathematical) functions can be used to determine the probability of consuming electricity illegally by a given consumer. They include:

- The method based on calculating energy balance [2], [3], [4] in which the total energy read from meter indications is compared to the energy introduced to the system. The difference comprises energy loss and illegal consumption, if any. This method is inaccurate because energy loss cannot be calculated with high precision.

- The traditional method with a monitoring meter. An additional monitoring meter is installed to indicate that the consumer's meter underregisters consumption of energy in kWh. Strictly speaking, this method is not used to detect premises of illegal consumption but to prove that energy is stolen at premises previously suspected of theft.

- Partial crawling measurements, described in [5], [6]. This method is similar the movable meter method, but there are some differences as well:

    - in crawling measurements a monitoring meter is equipped with current clamps so that it can be easily moved;

    - it is assumed that partial energy balances will be available after the period of 15 minutes, after which it will be possible to carry out the next balance in order to find premises of illegal consumption.

  Error in this method is at the level of an average consumer's consumption.

- Psychological methods. Distribution companies use a whole array of psychological methods, which are typically confidential. These methods do not rely on electricity measurements.

Besides, a scarce number of remote methods of detecting illegal consumptions have been described. These include:

- A method presented in the publication "A Solution to Remote Detection of Illegal Electricity Usage via Power Line Communication" [7]. In this method, users consuming electricity illegally can be detected by comparing indications of two measuring devices: a digital energy meter installed at a user's premises and an additional meter located at an initial point of the grid connection. The measurement data are sent to a central system, which compares the two indications. A significant difference may suggest that one of the meters is damaged or that the user steals electricity. A disadvantage of this method involves installing two meters, which increases the cost of installation.

- A method presented in the publication "A Solution to Remote Detection of Illegal Electricity Usage Based on Smart Metering" [8]. In this method illegal consumption is detected on the basis of variation in voltage at network nodes. To determine impedance in sections of the power supply line between consecutive users, the system switches off basic power supply at certain time intervals and sends short pulses, of frequency about 150 kHz, to the network. It is then possible to obtain impedance on the basis of voltages and currents measured. The presence of illegal connections causes local alterations in impedance and because of that it is possible to detect a user stealing electricity.

- Methods developed within the project "Badania Naukowe: Domykanie Łańcuchów Bilansowych" (Research on closing balance chains) [6], based on a stream of measuring data, by means of which it is possible to locate measuring anomalies in the network analytically. The estimation method of locating anomalies uses an estimation of the power system condition to detect anomalies in electricity measurements. The anomalies are approached in terms of problems with detecting large errors in data sets. The method of backward and forward calculations [7] involves bilateral determination of voltage in the power network nodes. At each point the voltage is determined twice – for the first time from the side of the supplying transformer and for the second time from the side of the most remote user. If the two voltage values are identical, there are no anomalies in the circuit under scrutiny.

C. The System AMI

It is expected that new tools for detecting illegal energy use will be afforded by the system AMI [9]. The system will provide access to real measurement data on power and energy flow through MV/LV transformer stations and in LV networks. Besides, data on voltage in the network nodes will also be available.

The system AMI can contribute to reducing illegal electricity consumption in the following ways [10]:

- tampering with the measuring instruments of a meter installed at residential premises will become very difficult due to the meter's capacity to register such events as opening the lid, opening the case, or presence of a magnetic field. Once detected, such events can be automatically reported through a hub to the Central Application of the System AMI;

- information campaign conducted during the implementation of AMI may successfully deter potential illegal users from stealing electricity by making them aware of the anti-theft properties of the system;

- the possibility of carrying out energy balance for small areas, such as an area supplied from a single LV/MV station, accompanied by advanced analytical tools will narrow down the location where electricity is potentially stolen.

II. Analytic Method for Detecting Illegal Energy Use Taking into Account Voltage Drops

The main point of the solution proposed here involves determining the current at a given section of a line on the basis of voltage drop and comparing it to the current calculated on the basis of active and reactive power flow. Voltage drop is caused by consuming energy by all users, including those using electricity illegally. A meter will indicate only the energy actually flowing through it. If the current calculated on the basis of voltage drop is the same as the meter indication, no illegal use is taking place, but if there is a difference, with the current obtained from voltage drop being higher, this is a strong indication that electricity is used illegally by a consumer. The measurements should start from the end of a line.

Simulations were carried out for a MV/LV station, supplying power to 20 users with AMI meters. Fig.1. presents voltage drops at one of the circuits supplied by this station.

Figure 1. Voltage drops in sections of a LV line

Voltage drops in the sections of a line are very small, or even negative. This should not be taken as an indication of a capacitive character of energy use, but of the inaccuracy of measurements. Voltage drop is calculated as a difference in voltage between two points in the network. What is measured is the voltages and not voltage drops. A measuring error resulting from the class of the meter can exceed voltage drop. The voltage drop at the section z-c should be the highest, since the current flowing in the first section is the highest, and the differences resulting from resistance in the particular sections are not high enough to account for such a low voltage drop. This can be explained by the fact that the meters are not synchronized in time.

Fig.2. presents voltage drops and load in a line supplying power to only one user

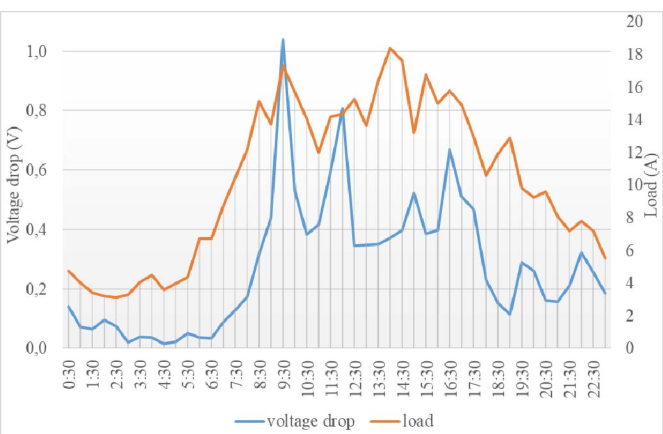

Figure 2. Voltage drop and load in a line supplying power to one user

Voltage drop depends on a load because the line parameters do not change and the power coefficient varies very slightly during the 24 h interval. This dependence is however not visible on the plot. The greatest voltage drop does not occur at the greatest load, and when the load is the greatest, the voltage drop is small. These differences are, unfortunately, due to measuring inaccuracy. Fig.3. presents currents calculated on the basis of voltage drops and measured power.

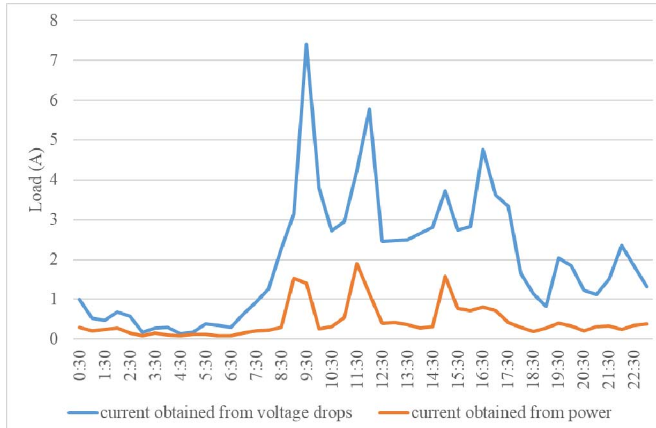

Figure 3. Juxtaposition of current obtained on the basis of power and current calculated on the basis of voltage drops

The current calculated on the basis of voltage drops may be even 4 times greater than the current obtained on the basis of the power. Measuring errors typical of the class of the measuring device affect the results to a great extent. As can be seen, the errors are too high and they render the method based on voltage drops ineffective. It has to be emphasized that the problem does not stem from the class of the measuring device as such but from the fact that the quantity measured is voltage and not voltage drops.

III. DEVELOPING THE PROCEDURES FOR IDENTIFYING ILLEGAL ELECTRICITY USE ON THE BASIS OF SIMULATIONS TAKING THE BALANCE INTO ACCOUNT

The solution proposed relies on Kirchhoff's laws. First, it has to be verified if the sum of currents received by users it equal to the current transmitted from the station. In this method it is not possible to find out which user is consuming energy illegally, it is only possible to establish whether or not illegal consumption takes place.

On the basis of powers consumed by users and voltages at users' premises it is possible to calculate currents for particular users. Then the sum of these currents is compared with the supply current. The following limitations hold:

The stations supply power to users with static meters, not AMI meters, so power measurements are not taken every 15 minutes, as required in the method. No measurement of reactive power is taken either.

Measurements of voltage at users are involved and as has been shown before, the measuring errors are significant.

Simulations were carried out for a MV/LV station supplying power to 20 users. One of the meters (street lights meter) is not an AMI meter. The results are presented in Fig.4.

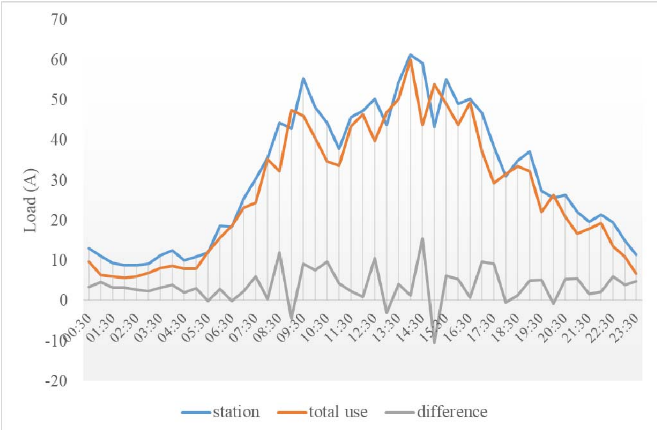

Figure 4. Current at the station supply and the sum of currents at users. The user without an AMI meter has not been taken into account

The difference between the two plots is due to the current consumed by the user with a static meter and illegal use, if any. At some time during the day (at 9.30, 13.30 and 15.30 hours) the difference is negative. It does not mean that the user is a prosumer and generates power, but that for such short measuring periods the class of meters significantly affects the accuracy of the results. The mean current consumed by the user with a static meter was calculated as 3.64 A. According to the data on the actual use by this consumer, the mean current was 1.21 A. Since no illegal use was detected in the area supplied by this station, the difference of 2.43 A corresponds to the level of measuring error. This demonstrates that this method is not suitable for detecting illegal electricity use, since the average current consumed by a single user is about 1A, which is significantly lower than the measuring error.

IV. Developing the Procedures for Identifying Illegal Electricity Use on the Basis of Load

As is evident, none of the above-described methods is suitable for identifying premises of illegal energy use. The errors result not from flaws in the method itself but from measuring inaccuracies. Another potential method for detecting illegal use could be based on load of individual consumers with AMI meters. This method was tested on a sample of 20 such meters, with illegal use detected among them. It was assumed that the characteristic quantity for these users will be daily energy consumption rather than a 24-h profile of use. During the analysis it turned out that the optimal period for carrying out the comparison was one week. Consequently, a mean energy consumption was established for a week and then for each day of the week a difference between real and mean weekly energy consumption was calculated. The results obtained for 4 users are shown in Fig.5 to Fig.8.

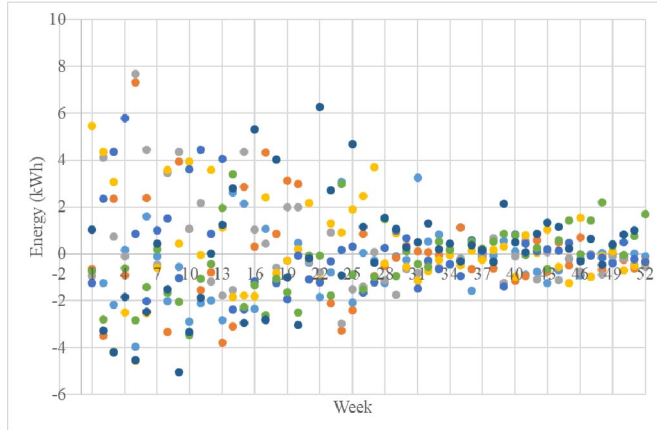

Figure 5. Difference between daily energy consumption on a given day and mean daily consumption in consecutive days of the week

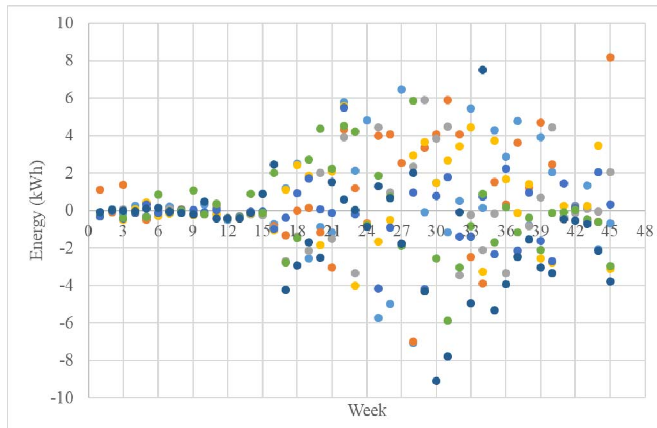

Figure 6. Difference between daily energy consumption on a given day and mean weekly consumption in consecutive weeks for a consumer

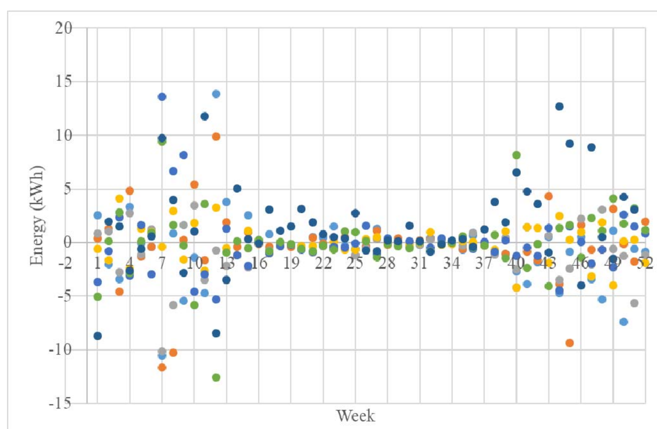

Figure 7. Difference between daily energy consumption on a given day and mean weekly consumption in consecutive weeks for a consumer

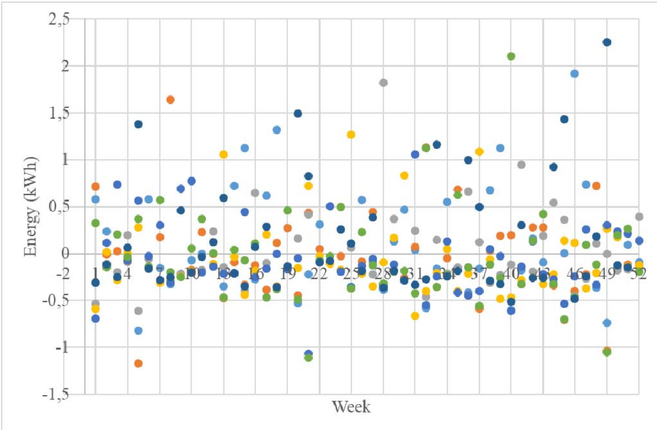

Figure 8. Difference between daily energy consumption on a given day and mean weekly consumption in consecutive weeks for a consumer

In Fig.5-Fig.7 differences are shown between energy consumption on a given day and mean energy consumption in a week when illegal use was detected. Fig.8 represents the condition with no illegal use. Illegal consumption takes place when the difference between real and mean weekly use is small, not exceeding ±0,3 average energy consumption in the analyzed period.

V. CONCLUDING REMARKS

This paper presented three analytical methods for detecting illegal electricity use. The method based on voltage drops and the method based on Kirchhoff's law are burdened with too high errors to be applicable in practice, due to insufficient accuracy of measurements. The third method based on load appears to be more promising in establishing the premises of illegal electricity use but has yet to be tested in practice.

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