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Proposed An Intelligent System for Electricity Theft Detector at Smart City Scenarios

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ABSTRACT

This is a conceptual proposal which is aimed at describing an intelligent security system to early detect cases of electricity theft which is claimed effective to cope with ICT based cases of electrecity theft. The method employed in the detector is computation system, which is the computation of phase differences (Φ), current voltage in real time and losses detection of electrical power grid by 220V. The losses calculation employs Kirchoff's law I which is Kirchoff's current law. The current sensors are put on the output distribution transformer and on customer's APP connection. The working principles are (1) reading output current and phase differences at the load point (of the customer's) in the distribution transformer using the current sensor, (2) comparing the output current (Io) with the sum of certain variables on consumers to be discussed in this paper. (3) Knowing the data of electric current usage by recording data of losses in real time and by sending them to teh control center monitoring in in real time.

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1. INTRODUCTION

In electrical terminology, there are two causes of power losses, namely technical losses and non-technical losses. The former is caused by the power quality, as found in too long network wires, too loose wires connected, worn out cubicles, and the use of worn out wires. This factor, however, is easier to calculate compared to the latter. The latter cause, non-technical factors, is caused by electricity theft, in which imbalances on the load can emerge if the use of current exceeds the determined current, thus may lead to neutral current on the transformator [1]. The current in the neutral current transformer may cause losses. When this factor occurs, simple calculations may not work; it will require particular method to indicate any electricity theft.

To complete the identification of electricity theft, there are two common methods to use, which are physical detection, which is to observe physically. This method may be very hard to perform if the connection is hidden thoroughly thus hardly identified when observed without assisting tools. The second method is customer consumption, which is a method based on customer's regular consumption. The associated officers have particular tools like clamp power by measuring the input path of electric supply and then matching the shown value with the current breaker specification. Should imbalances be shown, electricity theft will be indicated. Even though this method might not be 100% accurate, any anomalies found in the identification process can be further investigated to the customer concerned. However, if the tools used for electricity theft is sophisticated, it might even be harder for the detector to indicate if such electricity theft really occurred.

The problem of non-technical losses is also a concerned in many countries in the world such as India [2] and Malaysia [3]. Various methods are conducted for detecting this problem [4], namely: tampering with energy meters to ensure the meter recorded comparatively lower consumption reading, tapping of wires on LT lines, arranging false readings and ignoring unpaid bills by bribing meter readers, un-metered supply, errors and delays in meters reading and billing, and then errors in technical losses computation [5] using: Support Vector Machines (SVM), Genetic SVM, SVM and fuzzy inference system, data encoding and SVM, SVM and high performance computing, fuzzy clustering and classification, Neural networks ensembles, ARMA models, P2P computing, EPTDNA models [6].

There have been identified cases of power losses at some Current Transformer Relays where the electricity distributed to customers are not paid or recorded thus cause losses for the side of PLN as the electric provider in Indonesia. Consequently, PLN suffers from financial losses of billions of rupiah. Another impact is the current transformer overload, caused when the load exceeds the capacity for the current transformer. Indeed, the act of electricity theft brings harm to other people. For example, such overload can cause short circuit and thus trigger fire in the neighborhoods. It is obvious that such illegal use of electricity harms other people's rights of benefitting electricity facility in Indonesia.

In case of Indonesia, PLN as the authority to this matter has been trying out a variety of methods to prevent the increasing number of these thefts. In addition to socializing and raids by officers, some theft detection systems are also being developed. While some methods have been proven to decline the number of cases, still some cases can escape the surveillance system since the theft methods are also improved to be more sophisticated.

This paper focuses on the intelligent system of electricity theft detector models of Kirchoff Current Law Approach Algorithm at the Smart city order in which the transmission communication and reception of data and are sufficient as well as the communication is uninterrupted by external intervention, including weather conditions and does not depend on any providers. This paper concerns more on the technical study of electrical system, which is the computation on the proposed detector. Another discussion is written descriptively, whereas its technical communication system is discussed in a separate paper.

2. REVIEW OF RELATED LITERATURE

This paper employs literature review by studying the related literature on electricity theft detectors and understanding suggestions for future research from the respective authors. This indicates that each system has its own advantages and disadvantages in detecting the theft.

- Based on Power Line Carrier [7], which is to inspect the use of electric current distribution, meaning that any excessive use of a customer can be detected and assumed as theft on the line. This system consists of a transmitter and receiver. In its massive application, the system is recommended to generate signals with a frequency of 60/50 Hz with amplitude of 220/380 or 20KV, and in the more advanced research it has been found that it is necessary to concern on the development of communication process, since it is plausible that noise or intervention caused by other transmission occur. Such research has been conducted by [8] with 230V/50Hz.
- Based on a comparison of electricity use [9] a detector prototype possessing the working principle of detecting the current to every customer. The prototype will indicate normal if the detected current is lower or equal to the amount of distribution transformer, otherwise if the detected current is greater than the allowed amount, the tool will trigger an alarm from the buzzer as a sign of electricity theft. There needs for further research on ac summation computation, for this research is still in the stage of DC summation that it haven't tell the shift of the phase angle of the ac source. A similar study has been done by [10].
- Based on smart metering [11]-[16]. It is presumed that this application is able to prevent customers from committing such electricity theft because the flow of electricity meters can be accessed online and monitored by a central server. In fact, some irresponsible customers could still find a way; one of the most common techniques is to connect the cable prior to the kWh meter. This makes the kWh meter unable to detect any indications of theft.
- Based on an automatic switch called ELCB [17]. This system is able to cope with electricity theft employing a common way which is tapping (bypass) before kWh in either case of 1-phase or 3-phase. It works following the principle of differential by detecting differences on both phase currents and neutral current. At the time of bypass this device will automatically perform protection; therefore the company will not lose too much electrical power. However, further research on the real implementation for investigating the effectiveness and efficiency of the system is still required.

- Based on the pattern of electricity consumption monitoring [18]. Any anomaly change (load profile) in a particular area can be identified as three things, namely electricity leakage, meter interference or power lost due to electricity theft. This research took place in a house with type of 900VA that was monitored on the web. Other prototypes were developed by [19] using RS232 communication wire and Delphi 7.0, and [20] through the WAN connection and Intelligent Electrical Devices (IED).

3. PROPOSED SYSTEM

3.1. Kirchoff's Law

Kirchoff's law was initially introduced by Robert Gustav Kirchoff's, Kirchoff's law I reads "The algebraic sum of all currents entering and leaving a node must equal zero". It means that "the number of strong electric current that flows into a branching point is equal to the number of strong currents which flows out of the branching point". Or, it can be expressed mathematically as follows:

$$\Sigma i\ in = \Sigma i\ out \quad (1)$$

$$i = i1 + i2 + i3 \quad (2)$$

Meanwhile, the application of Kirchoff's law for early detection of electricity theft can be shown as in Figure 1.

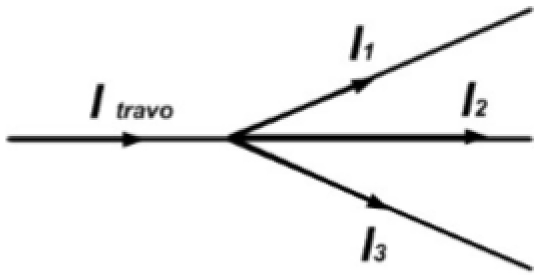

Figure 1. Representation of Kirchoff's Law I KCL in distribution transformers

Based on the equation 2, the following rules are obtained:

$$i1 + i2 + i3 = i\ customer$$

$$i\ travo = i1 + i2 + i3 + i\ losses \quad (3)$$

$$i\ travo - i\ customer(s) < i\ losses \quad (4)$$

$$i\ travo - i\ customer(s) = i\ losses \quad (5)$$

$$i\ travo - i\ konsumen(s) > i\ losses \quad (6)$$

"Equations 4 and 5" state that the system is declared safe from any theft. On the other hand, the system can indicate problematic connection if losses are greater than the i of the transformer. These problems will then lead to two types of problems, namely technical factors and electricity theft.

3.1. Realtime Shift of phase V & I

Power is divided into three parts namely: active power (S) which is the power actually used, reactive power (Q) which is the power required for the formation of magnetic fields and that represents the difference among all power and active power, and finally, apparent power (P), an electric power that flows through transmission conductor and distribution

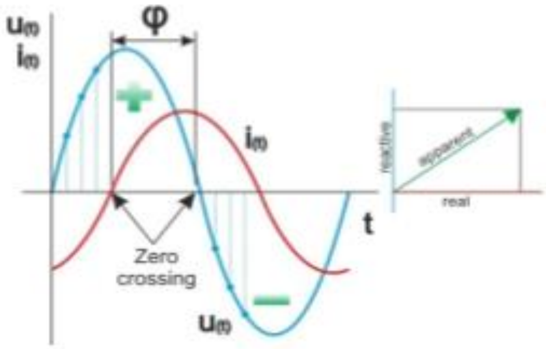

Figure 2. The graph showing phase shift between the voltage and electric current 220Vac in the real time. Φ can be identified using zaro crossing detector circuit employing certain formulas [20]

In distribution transformers, there found an imposition of an imbalance state in which one or both conditions of the balance state is not met [21]. If the current (i) is the magnitude of phase currents in power distribution by (P) in a balance state, so it will yield equal power distribution, however in an imbalance state the magnitude of the phase currents can be expressed by the coefficients a, b and c, as follows:

$$IR = a.I;\ IS = b.I;\ IT = c.I \tag{7}$$

Should the power factor in all the three phases are regarded equal, though the magnitude of current is actually different, then the distributed magnitude of power (for RST) can be expressed as in the following:

$$P\ (watt) = (a + b + c)\ V.I\cos\Phi \tag{8}$$

$$Q\ (VAr) = S - P \tag{9}$$

$$S\ (VA) = (a + b + c)\ V.I \tag{10}$$

$$\cos\Phi = P\ S \tag{11}$$

Ac voltage measured by the measuring instrument is effective voltage (Veff) or Vrms, whereas the ac current is effective current (Ieff) or IRMS. But the value of RMS voltage, current and power are unable for calculation using standard formulas as in “equation 8, 9 and 11” since it is located in discrete areas. The equation should be modified from continuous to discrete areas [20]. RMS value formulas can be calculated using the following equation:

$$URMS = \sqrt{\frac{1}{T}\int_{t0}^{t0+T} u^2(t)dt} \tag{12}$$

Which is,
U_{RMS} = voltage value of continue Root Mean Square ↕
T = period of ac voltage
t0 = starting time
u = to be defined voltage value
t = time ↕ (0; T)

Nonetheless, “equation 12” does not include the continuous disposition from of the voltage value of the continue areas. In the discrete areas, on the other hand, the integral formula will change to be summation and the derived formula becomes as in the following:

$$URMS\ discrete = \sqrt{\frac{1}{n}\sum_{i=1}^{n} u_i^2} \tag{13}$$

Which is,
URMS discrete = *voltage value of discrete Root Mean Square* ↕
i = sample value of current
n = *total samples of a single period*
ui = sample of defined voltage value
t = time ↕ (0;T)
Apparent power (S) can be discretely defined as follows:

$$Sdiscrete = uRMS.iRMS \quad (14)$$

Then the active power is,

$$Pdiscrete = \sqrt{\frac{1}{n}\sum_{i=1}^{n} u_i^2} \cdot i_i \quad (15)$$

which,
Pdiscrete = real power
i = sample value of current
n = total of samples of a single period
ui = sample of defined voltage value
ii = sample of defined voltage value
Variable n is any number of samples used; this value is the value of the grid voltage (220V).

$$(if\ (ui > 230)\ therefore\ 230 = ui)i{=}1\ n \quad (14)$$

Which is,
ui = sample of defined voltage value
n = total of samples of a single period

As for the output current of the GTT transformer distribution is determined by the ratio of I_SC / I_ (L.)

$$IL = \frac{S}{\sqrt{3}V} \quad (15)$$

$$ISC = \frac{S}{\%Z\sqrt{3}V} \quad (16)$$

$$RatioSC = \frac{I_{SC}}{I_L} \quad (17)$$

Which is,
I_{SC} = short circuit current
I_L = nominal load of fundamental current
R_{SC} = ration of short circuit

Equation 2-17 is implanted in a microcontroller or FPGA in the form of computation thus the maximum value of voltage, power lost, phase current shift current and voltage electricity grid are possible to be calculated in real time.

3.3. Intelligent System Monitoring and Electricity Theft Detectors

The system proposed in this paper is equipped with smart sensors to perform sensing of losses due to either technical or non-technical, and to complete understanding that such losses are caused by electricity theft. Afterwards, a clerk may act for further investigation by going to the crime scene. Also, this system is supported by intelligent computing systems. System installation is performed in the beginning, such as calibrating technical losses. This way, the officer can start mapping the losses caused by technical factors and those planted in embedded systems in the form of computing. If the losses detected have greater value than the mapped losses, electricyty theft may be positive. Connections from SMP to JTR should also be taken into concern, that each connection must be balanced (e.g. T-N = R-N = S-N as many as 10 customers). Although in different capacities (450, 900, 1300) mapping can still be done if any current anomalies at a certain phase occurs, such in, R/S/T. By then the officer can survey the area where the indicated anomalies are found to check if electricity theft really happens.

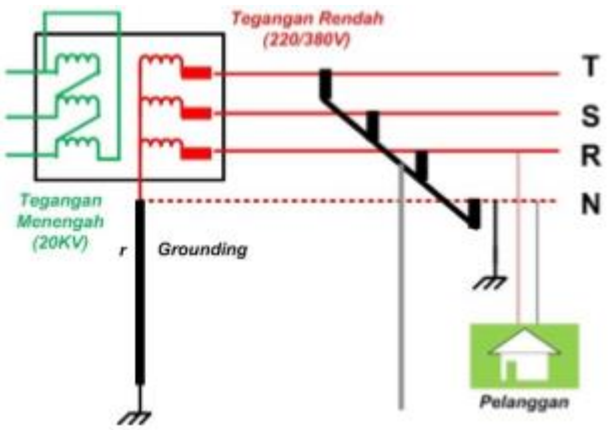

Figure 3. Distribution Transformer of Voltage Reducer from 20,000 volts to 220/380 volts through GTT and Low Voltage Network (JTR) and Connection Log Services (SMP) to customers

Figure 4 is an electrical distribution from distribution transformers to customers. For distribution transformers, voltage sensors are placed on each system of every phase that is R-N, S-N, T-N and the current sensor on each phase. Moreover, the sensors on every customer are put at the JTR stake. Figure 5 represents the explanation. A voltage sensor is placed before the customer's SMP; the customer in question here refers to houses, offices, workshops, schools and other buildings. Sensor system + microcontroller are placed in a sealed installation. Should the seal is found broken, and then the PLN officers can provide specific penalties to the damaged area.

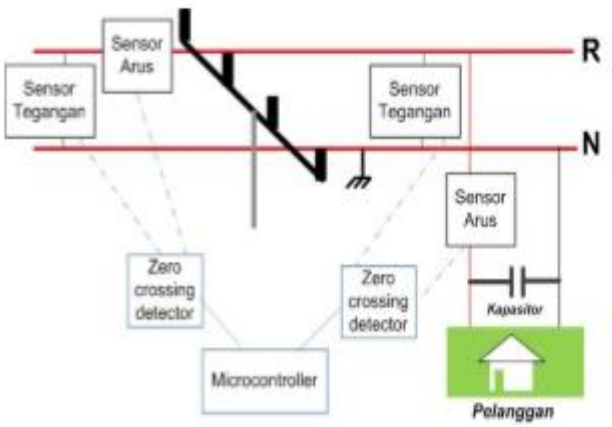

Figure 4. Installing current and voltage sensors on the output of distribution transformers (GTT) and voltage sensors at JTR stake in phase 1 by 220V and installation of phase current sensor before entering the customers' kWh meter

Several found modes of theft are replacing/tapping/bypass immediately before customers' KWh meter/SMP, so the microcontroller will automatically read the current losses and transmit data indicating electricity theft to the main monitor. These data of losses are recorded by the monitor in real time for 24 hours and stored in a database so it does not escape the scrutiny unless certain things happen, like disturbances in the data center, etc. Actually, the lay of the voltage sensor before the the SMP can also minimize chances for theft using bypass mode for Street Lighting (PJU).

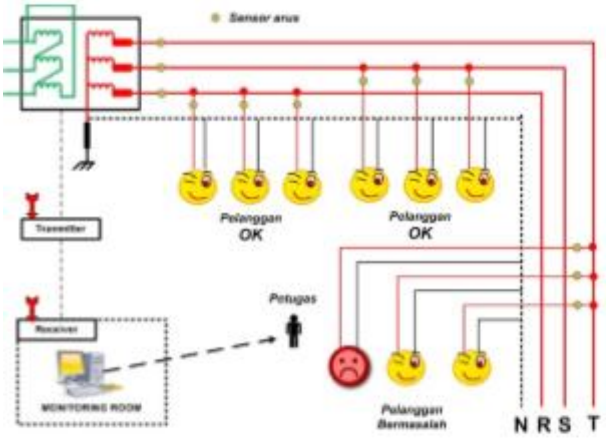

Figure 5. Illustrations for how system works on the 3-phase

Should the illegal action of theft lead to harming others, the authority can immediately inspect the crime scene. For storing and processing data for losses, a large database is recommended for use since a distribution transformer may contain data of many customers. It means that a central monitoring system covers several distribution transformers. At the first try, the monitoring might only cover one or two distribution transformers. If the try turns out successful, then a broader scope of up to 20 distribution transformers may be applied. At the control center, the officer can tell in real time about the cos value Φ at RST, IRST, VRST on the output transformer of GTT, IRST and VRST on the connection to customers and an indication of losses due to electricity theft.

4. CONCLUSION AND FUTURE WORK

ICT Technology has participated in addressing the problems of electricity which in this regard is the case of electricity theft by conducting mathematical modeling to calculate the phase differences (Φ), V-I, in real time and to detect losses of power by the use of flow which is then planted in an embedded system. The author uses algorithms of KCLAA, whose principle is the comparison of current consumption in output distribution transformers with the inflow on SMP and losses thus when losses are greater the system will be able to detect the anomalies. There are several claims of benefits on the proposed system, as follows: 1. The system can measure voltage, ac electric current from the output and Φ precisely on the output of distritbution transformer and on SMP, later the data can be employed to detect losses. 2. In terms of electricity, there are two types of losses, namely technical and non-technical losses. This system can distinguish between these types. If the losses tend to be stable (within a period of>24 hours) can be ascertained that the problem is due to technical factors, such as tree branches that interfere with the wires, kite string, outdated component, etc. While the nontechnical losses fluctuate, it may be component from the data flow sensor. 3. In addition to reducing monitoring costs and saving physical energy, the officer can quickly respond to the occurrence of losses as area mapping has been performed in prior to the monitoring. If losses occur in phase area of R-N, it can be assumed that a case of electricity theft has been committed in one of the customers' area. 4. Modern modes that have been recently found are: bypass before kWh/bypass on SMP and JTR/ electricity supply for home/office. Bypass 3 phase supply for workshop equipment. Bypass for PJU. This system can indicate any lost of power committed under the aforementioned modes. 5. The system is monitored in real time for 24 hours and the data are stored in the database, so it may not escape the scrutiny despite the electricity theft is done at night and it can economize the company budget for electricity theft because any indicated cases can be solved immediately.

Further studies will concern theory application and system design in prototypes.

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