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Research Article

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Electricity Theft Detection Methodology using Energy Consumption Data of Residential Consumers

Behçet Kocaman

Department of Electrical and Electronics Engineering, Bitlis Eren University, Bitlis, Turkey
e-mail: bkocaman@beu.edu.tr

Abstract Due to electricity energy is used in every area of our daily lives, demand for this energy is increasing day by day. For this reason, every country tries to produce and save electricity. Electricity losses occur in energy production, transmission and distribution stages. These losses minimization is one of the most important problems of service providers. Especially, the non-technical losses (NTLs) which are caused by human in form of illegal use of electricity, electricity theft and billing fraud etc are caused financial losses. In fact, the financial losses from energy theft are billions of dollars per year in developed and developing countries. Thus, it is important to detect electricity theft. Studies on electricity theft detection methods have increased in recent years In this study, electricity theft detection methodology is proposed by using energy consumption data of residential consumers. The proposed method; tested taking into account the difference between transformer's output and customers' real smart meter data. In the settlement chosen for the test, 1 main meter at the entrance, 7 at the output of the transformers and 927 smart meters at the consumers have been used. It has been shown that the proposed methodology detects energy theft using one month of actual energy consumption data from these meters. By testing the methodology, electricity theft has been detected at the settlement.

Keywords Detection, energy consumption, electricity theft, non technical losses

1. Introduction

The need for electricity energy is increasing day by day due to the increasing population, technological developments and developing industrialization. To meet this increasing electricity energy need, it is necessary to use energy efficiently and especially to reduce the losses in its consumption. In this context, remote monitoring and control of energy has gained importance by adding communication technologies to the network. The automatic meter reading system (AMR) is one of the leading elements of this control center. This system is the monitoring of the data from a single center by making the electricity meters used for energy measurement on the consumer side suitable for remote communication.

The AMR system ensures that losses and illegal uses in networks are detected. In addition, it has many benefits to distribution organizations such as low operating costs, load control, monitoring of meter and network parameters, remote disconnection, fault detection and early warning of the center for possible faults.

Electricity energy has to undergo three stages such as generation, transmission and distribution stage before it reaches to the consumer. That's why, it's generation is both difficult and expensive. As a result of the incorrect and inefficient use of this energy, technical losses (TLs) and non-technical losses (NTLs) occur in the phases from the power plants where energy is generated to the point of consumption. It is not possible to completely eliminate these losses. But it can be reduced using some techniques. Reducing these losses makes more efficient use of existing energy systems [1]. TLs losses occur generally because of energy waste. This is inherently caused by interior electricity resistance and the affected components such as generators, transformers and transmission lines. TLs can be calculated easily. These losses are taken as 3-5% in the energy distribution system [2-6]. In this study, technical losses have been accepted as 5%. NTLs are purely losses caused by the way the consumer uses energy. Illegal energy use, unconscious energy consumption, and mistakes made by distribution companies in invoicing the energy with the interventions made to the meters are the main causes of losses. NTLs also known electricity theft. An energy distribution system may never be completely secure from theft of electricity. In plenty of systems the amount of theft is small such as 1–2% in account of the electricity generated [7]. However, the amount of theft is big such as 4–74% on account of the electricity distribution [8].

The financial losses from energy theft are billions of dollars per year in developed and developing countries. For instance, the financial loss due to electricity theft is around $6 billion a year in United States (U.S.) [9]. It is estimated that, the financial loss due to electricity theft is between 5.8 and 8.5 billion Turkish Liras (TL) every year in Turkey [10]. Therefore electricity theft is important issue for study.

In fact, electricity distribution companies can never be eliminate electricity theft. However it is possible to take measure to detect, prevent and reduce it. Transmission and distribution losses have been reported to be over 30% in several countries [11]. The rate of TLs and NTLs are around 14% in Turkey. This rate is 6% in European countries. The rate of energy losses in Turkey is much higher than the loss-leakage rates in developed countries [12].

Researchers have pointed out the issue of electricity theft and different studies have been achieved in recent years to detect and prevent it.

Karabiber, A. [13] presents an detection method of electricity theft to determine and price NTLs. This method includes utility energy meters over electricity distribution lines. Owing to utility energy meters, even if fraudulent consumers tamper with or bypass their own energy meters, their electricity consumption is right down recorded. In addition to, the proposed method detects and prices the electricity theft which is occurred between electricity poles.

Lekini Nkodo Claude Bernard et al [14] mainly focused on prepayment system for electricity energy or other utility commodity distribution using Global System for Mobile Communications (GSM) and Wi-Fi to transfer and store value from the client module to cut-off module then to platform of the system and deliver energy to the customer from the energy distribution system.

T. Jothi, et al [15], presents a framework for detecting NTLs using regression analysis. Sensible smart meter, energy consumption data, customer registration data are used by this model.

Rakesh Dwivedi et al [16] mainly focused on wireless data communication technique. Wireless technique, gives a wireless meter reading, which is also useful for power theft detection.

Madalina Mihaela Buzau et al [17] proposed a methodology for NTL detection using supervised learning. The methodology has been developed and tested on real smart meter data of all the industrial and commercial customers.

Sheikh Suhail Mohammad et al [18] proposed system we use power semiconductor switching systems at the low voltage side of distribution transformer in such a way that three phases & neutral is passed through this semiconductor based switched system.

The rest of the paper is organised as follows. Proposed detection methodology is presented in Section 2. The test results & discussion have been shown in Section 3. Section 4 concludes the paper.

2. Materials and Methods

NTLs such as electricity theft, cannot be prevented due to distance and limited number of personnel. However it can be reduced by using a simple and efficient method is proposed which detects electricity theft. Electricity companies face NTL problems such as direct hooking from line, injecting foreign materials into the meter, drilling holes in the electromagnetic energy meter, inserting film.

NTLs are difficult to calculate. For this reason, electricity distribution companies have proposed different methods for NTL problems. The most effective method used currently to reduce NTLs in the electricity distribution sector is the use of smart electronic meters such as Power Line Communication (PLC) meters [19].

The proposed method is tested on real time data collected from PLC meters installed in town which is Golbası of Bitlis city in Turkey. A simple model can be built up with data point identified using the power flow in the grid. In the settlement chosen for the test, 1 main meter at the entrance, 7 at the output of the transformers and

927 smart meters at the residential consumers have been used. Seven distribution transformers have been used in the settlement where the proposed method tested. Block diagram of proposed method is shown in figure 1.

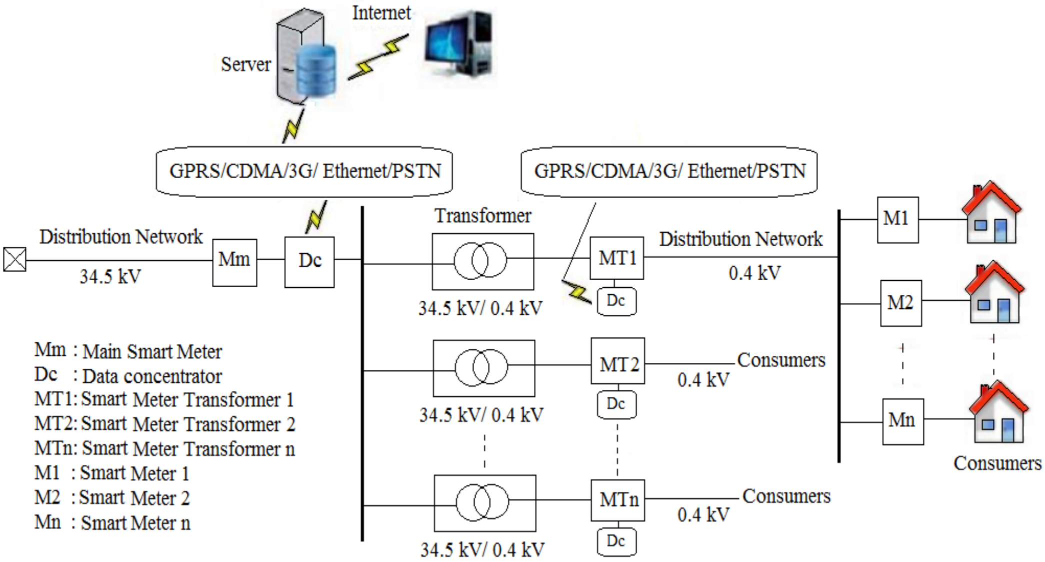

Figure 1: Block diagram of proposed method

The number of consumers connected to each distribution transformer is different. The number of consumers connected to the distribution transformers is given in Table 1.

Table 1: The number of consumers connected to the distribution transformers

Name of transformer	Number of customers connected to transformer
Transformer 1	67
Transformer 2	184
Transformer 3	116
Transformer 4	115
Transformer 5	90
Transformer 6	182
Transformer 7	173

A three-phase PLC meter is installed at the output of each distribution transformer. In addition, a single-phase PLC meter is installed for each residential customer. The schematic representation of the meter and Data Concentrator (DC) connections is given in figure 2.

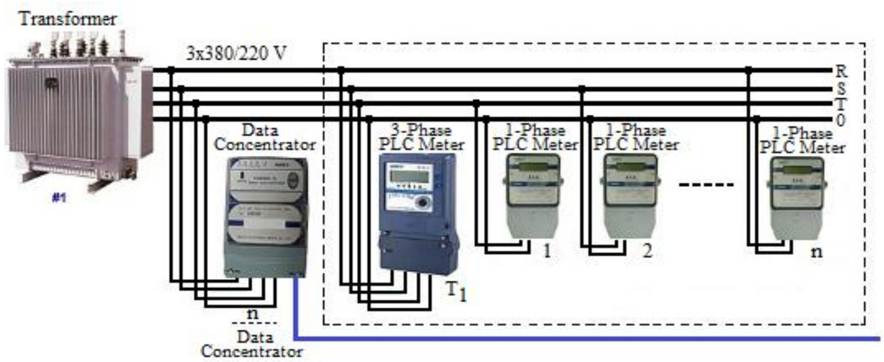

Figure 2: The schematic representation of the meter and DC connections

The information of all PLC meters is collected by DC and transmitted to the central processing unit. The data is transferred to the central operating unit via communication channels such as internet / GPRS / GSM. The connection diagram for collected energy consumption data is shown in figure 3.

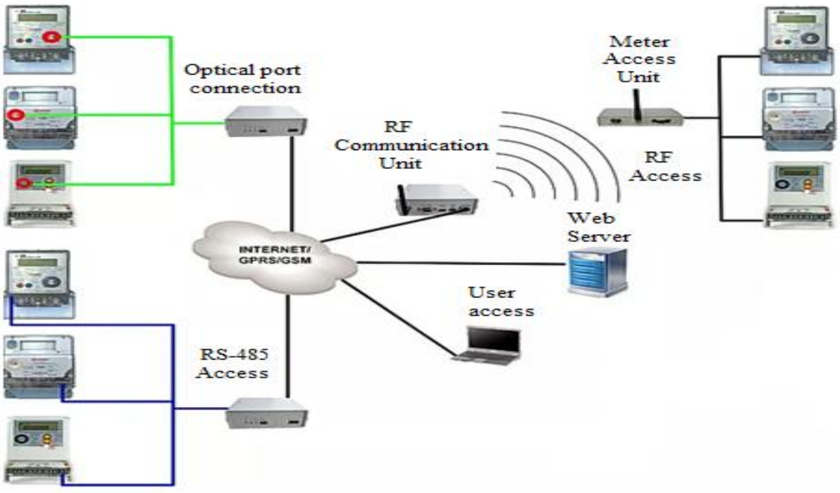

Figure 3: Connection diagram for collected energy consumption data

A simple model can be built up with data point identified using the power flow in the grid as shown in figure 1. It is assumed that energy is only consumed. In this context, equations for the total energy delivered to the grid, consumed energy and energy losses are given in equations 1-6. Flowchart of the proposed methodology is shown in the figure 4.

$$EI = EC + EL \quad (1)$$

$$EL = ETL + ENTL \quad (2)$$

EI: Total energy delivered to the grid, EC: Consumed energy, EL: Losses of energy, ETL: Technical losses, ENTL: Non-technical losses

$$E_I = \sum_{area=1}^{areas} E_{L_{area}} + \sum_{area=1}^{areas} E_{C_{area}} \quad (3)$$

$$E_I = E_{I_{area}} \quad (4)$$

$$E_{I_{area}} = E_{L_{area}} + E_{C_{area}} \quad (5)$$

Percentage losses are calculated as

$$Loss = \left(\frac{\text{Received Value} - \text{Sold Value}}{\text{Received Value}}\right)x100 \quad (6)$$

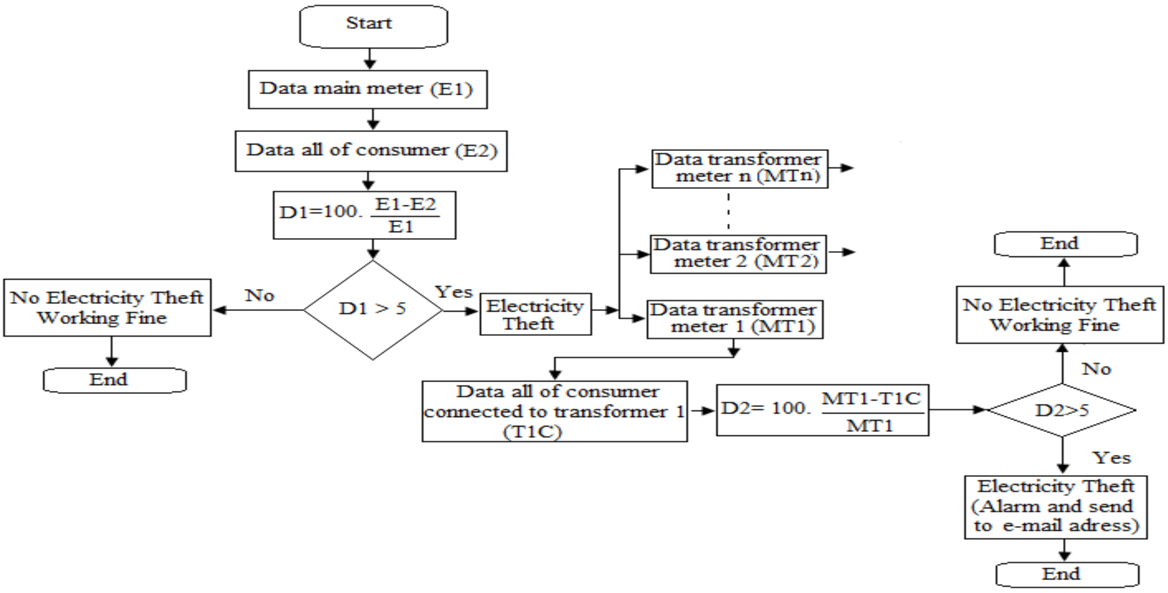

Figure 4: Flowchart of the proposed methodology

In the proposed methodology, electricity theft detection is carried out in two stages. In the first stage, the energy consumption value in the main meter and the sum of the energy consumption values received from the meters of all consumers are compared. The difference between the energy consumption value read from the main smart meter and the values read from the smart meters of the all consumers gives the energy losses. In the proposed system, technical losses are accepted as 5%. Therefore, if the energy loss value is more than 5%, there is electricity theft. If this difference is <= 5, the system operates normally and there is no electricity theft. Once it is determined that electricity theft is used in the residential area where energy consumption data are used, the second stage will be activated in the program to determine in which transformer region the electricity theft usage is made. A smart meter is installed to each transformer output used in the system. In the second stage, the energy consumption value in the each transformer output meter and the sum of the energy consumption values read from the meters of the consumers connected to that transformer are compared. If the energy loss value is more than 5%, there is electricity theft. If this difference is <= 5, the system operates normally and there is no electricity theft. This situation will be repeated with the same method for all transformers in the settlement.

3. Results & Discussion

When the energy consumption data of consumers fed from transformers are examined, it is seen that some customers are not reading values from their meters and the energy consumed is written as zero. These are thought to be reading errors or new consumers. For example, the distribution of energy consumption values of 90 consumers fed from transformer 5 between 01.01.2020 -30.01.2020 are given in Figure 5. When figure 5 is examined, it is seen that the energy consumption of consumers is different and some consumers do not have energy consumption.

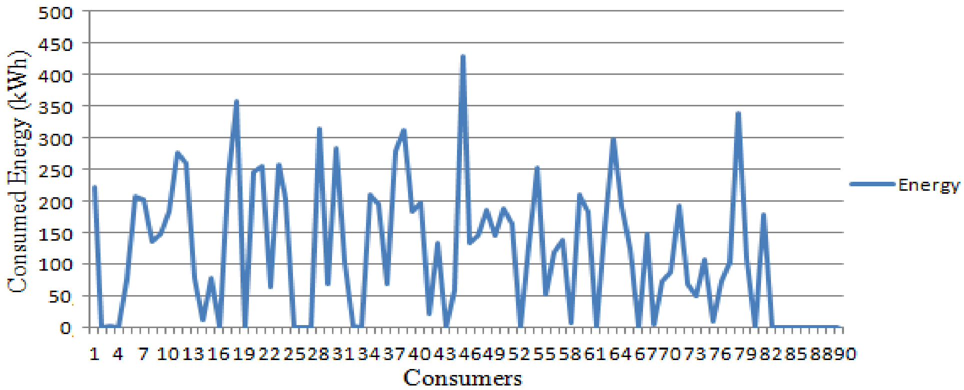

Figure 5: The distribution of energy consumption values

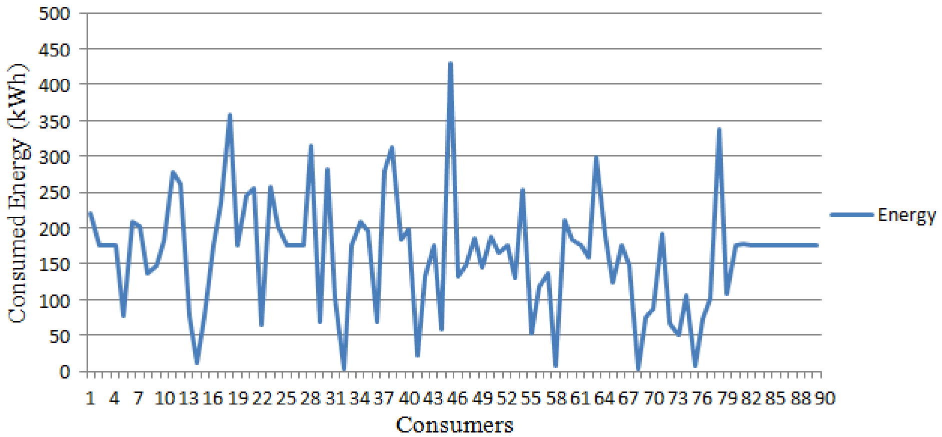

Figure 6: The distribution of energy consumption new values calculated of consumers

In order to make a more accurate assessment with energy consumption values, an energy consumption value has been determined for consumers whose energy consumption value is not read and written as zero. This value is calculated as the average of the energy consumption values of 20 randomly selected consumers fed from the same transformer and whose energy consumption value is different from zero. The distribution of energy consumption values of consumers fed from the transformer 5 according to the new values calculated is given in figure 6. The same process has been applied for consumers in the other 6 transformer areas.

In the proposed system, the energy consumption amount measured in the main smart meter used, the energy consumption value measured from the smart meters belonging to 927 residential consumers in the residential area, difference consumption, loss and result situations are given Table 2. The loss (%) in Table 2 is the sum of technical losses and non technical losses. In this study, due to the technical loss has been accepted as 5%, loss value more than 5% means there is electricity theft.

Table 2: Comparison of energy consumption values of the main smart meter and all consumers

Transformer Area	Measured Energy (kWh)	Measured Energy of All Consumers(kWh)	Difference Consumption (kWh)	Loss (%)	Result
Main Transformer	554.715.028	198.228.173	356.486.855	64.26	Theft

When Table 2 is analyzed, it is determined that there is 64,26% loss in the settlement selected and as a result, an electricity theft occurs. The comparison of the energy consumption values of the consumers measured at the output of the transformers used in the settlement and connected to these transformers are given in Table 3.

Table 3: Energy consumption values of the transformers output and consumers connected to these transformers

Transformer Area	Measured Energy (kWh)	Measured Energy of Consumers(kWh)	Difference Consumption (kWh)	Loss (%)	Result
Transformer 1	74.522.400	15.231.490	59.290.910	79.56	Theft
Transformer 2	124.857.120	37.883.230	86.973.890	69.66	Theft
Transformer 3	24.212.640	21.801.190	2.411.450	9.96	Theft
Transformer 4	60.764.280	23.485.130	37.279.150	61.35	Theft
Transformer 5	71.037.920	14.715.483	56.322.437	79.29	Theft
Transformer 6	126.432.600	44.971.640	81.460.960	64.43	Theft
Transformer 7	56.731.320	40.140.010	16.591.310	29.25	Theft

When Table 3 is analyzed, it is observed that there is an electricity theft in the all of transformers areas. The minimum loss in the selected settlement was in the transformer 3 area with a value of 9.96%.

The highest loss has been in transformer 1 area with a value of 79.56%. Graphical representation of energy consumption is given in figure 7.

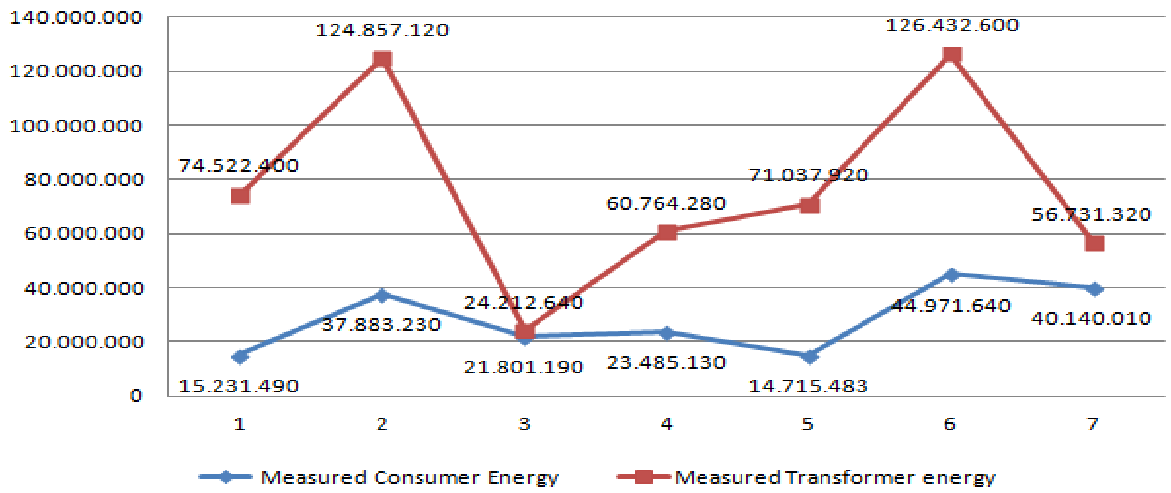

Figure 7: The distribution of measured consumer energy and transformers output energy

The numbers 1-7 on the horizontal axis in the graph indicated in Figure 7 represent the transformer areas. For example, the expression 1 shows both the transformer 1 (red line) and the consumers connected to the transformer 1 (blue line). The vertical axis expresses values of the energy consumption.

4. Conclusion

Losses such as TLs and NTLs occur from the power plant where electricity is generated to the consumption center. It is not possible to completely eliminate these losses. However, it can be reduced by some methods. NTLs are also known as electricity theft. Electricity theft is a big problem in developed and developing countries. The most important of these problems are financial losses. In order to reduce these losses, it is important to detection electricity theft. In the proposed methodology, electricity theft detected using energy consumption data of residential consumers. In the settlement where the proposed method has been tested, at 927 residential consumers and transformers' outputs energy consumption data which is between the dates of 01.01.2020 and 30.01.2020 has been used. By testing the methodology, electricity theft has been detected at the settlement. Accordingly, energy losses are 79.56% in transformer 1 area, 69.66% in transformer 2 area, 9.96% in transformer 3 area, 61.35% in transformer 4 area, 79.29% in transformer 5 area, 64.43 in transformer 6 area, 29.25% in transformer 7 area. These loss rates are quite high. There are different techniques of electricity theft such as direct hooking from line, injecting foreign materials into the meter, frilling holes into electromechanical energy meter, inserting film, using strong magnets like neodymium magnets depositing a highly viscous fluid, resetting energy meter reading, outgoing terminals of the meter and changing the incoming, damaging the pressure coil of the meter, exposing the meter to mechanical shock and improper or illegal calibration of energy meters. After the electricity theft is detected in the settlement thanks to the proposed system, the distribution company should make the necessary checks at the settlement to reduce the electricity theft. Thus, financial losses are reduced.

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