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Electricity Theft Detection Techniques and Reduction Methods in Energy Distribution System

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Abstract Electricity theft is a big problem faced by all energy distribution services and continues to rising. Therefore, studies on electricity theft detection techniques have increased in recent years. Unsuitable calibration and illegal calibration of energy meters during production may cause non technical losses. In most of the meter tampered locations, damaged meter terminals and/or illegal applications can not be distinguishable during checking. Electricity theft can be defined as a dishonest or illegal use of electricity equipment or service with the intention to avoid billing charge. In fact, electric distribution companies will never be able to eliminate electricity theft. But it is possible to take measure to detect, prevent and reduce it. In this study, electricity theft detection techniques and reduction methods have been explained in the energy distribution system. In addition, suggestions have been made regarding the use of this method.

Keywords Detection, distribution lines, electricity theft, non technical losses

1. Introduction

Electricity which is a energy is the most main necessity to everyone. It has become a required fact in our daily lives. Electricity generation is both difficult and expensive. In addition electricity reaches to the consumer after it has to undergo generation, transmission and distribution stage. As a result of the incorrect and inefficient use of this energy, technical and non technical losses (NTLs) occur in the phases from the power plants where energy is generated to the point of consumption. Reducing these losses makes more efficient use of existing energy systems [1]. In studies done it has been found out that the rate of energy loss leakage in Turkey is around 14%. This value is much higher than the loss leakage rates in developed countries. In European countries, this rate is 6% [2]. Countries' electricity consumption is considered as one of the factors that determine their economic growth. However, the high loss rates in the electricity transmission and distribution network indicate that there are some technical and non-technical problems in the grids. Technical and non-technical losses determine the energy efficiency of the electricity transmission and distribution network [3]. Distribution system losses have been reported to be over 30% in several countries [4].

NTLs also known electricity theft, is a big problem in energy distribution systems all worldwide. It is proportional to political, social, economic, law, literacy, managerial, infrastructural, and economical conditions of the consumer [4]. A main challenge for utilities is electricity theft. Malignant actors steal electricity for financial gain. Energy losses in energy distribution systems are divided into two parts as technical and non technical losses. Technical losses are losses in technical materials and equipment used in electrical energy systems [5]. They continue until they reach the consumer through transmission and distribution lines starting from the power plants. Technical losses can be calculated easily.

Electricity theft is a big problem faced by all energy distribution services and continues to rising. It results in the loss of large amounts of revenue due the energy distribution company, part of passed on to consumers in the form of higher tariffs. It is hard to notice between honest and dishonest customers.

As a result of the use of illegal electricity, overload and voltage surges can be seen in the distribution lines and interruptions may occur during peak times. Increased voltage level may cause damage to sensitive equipment such as electrical appliances for all consumers connected to the distribution system [3]. Electricity theft can be defined as a dishonest or unmethodical utilization of electricity furnishing or service with the intention to avoid billing charge [6]. Electricity which is generated through many technique is distributed for using to the customers. This energy requirement to be billed as well. Generally two kind of devices are principally used for billing procedure. These are electromechanical and smart meters [7].

Everything happens for a reason, so the reason for this replacement is losses in energy distribution system. Power grids are crucial infrastructure assets that face NTLs such as electricity theft or faulty meters. NTLs may range up to 40% of the total electricity distributed in emerging countries. The basic cause behind electricity theft are lack of literacy rate and low awareness. If costumers are not paying the utility back, then occurs energy. So this is the issue which is called as general debt. General debt is one of the critical results of electric theft [8].

When we look at the non-technical losses in the electricity network, it is seen that the use of illegal electricity in developed and developing countries is based on different reasons [9].

Electricity theft is a eventful guilt, creating short fall, rise of load, decline of frequency, which is not suitable and causing load shedding, rise of tariff on the lawful customers. In addition, it is estimated that worldwide utility companies lose more than $ 25 billion annually due to electricity theft [10]. It is estimated that lose between 5.8 and 8.5 billion TL every year due to electricity theft in Turkey[3]. The electricity theft cause to loss of revenue. When it is reduced there will be rise revenue by which power quality of the developing countries can be improved [11].

As a result of electricity theft, overload and voltage increases can be seen in the distribution lines, electrical outage may occur in peak times. Because of the increase in the voltage level, it can cause damage to sensitive equipment such as electrical appliances for all consumers connected to the distribution system. Therefore, electricity theft detection techniques should be determined and some reduction methods should be applied. Prevention of electricity theft or reduction of energy losses will benefit more from existing electrical systems. For this reason, study focus on electricity theft detection techniques and reduction methods in energy distribution system.

2. Electricity Theft Detection Techniques and Reduction Methods

An energy distribution system can never be 100% secure from theft. In many systems the amount of theft is small (1–2%) in terms of the electricity generated [12]. Incorrect calibration of energy meters during production can cause NTL. In most of the positions changed on the meter, damaged meter terminals and / or illegal applications may not appear during the inspection[13]. Summary of types of non-technical losses given in fig. 1.

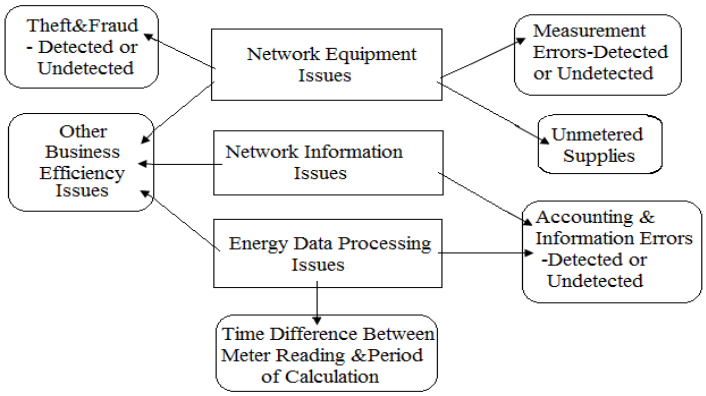

Figure 1: Summary of types of non-technical losses [14]

Generally, NTLs occurs on the distribution network. Therefore, this study focus on distribution system. There are 21 Electricity Distribution Company in Turkey. These are Başkent, Sakarya, Meram, Aras, Çoruh, Fırat, Trakya, Osmangazi, Yeşilırmak, Çamlıbel, Uludağ, Gediz, Boğaziçi, Akedaş, Akdeniz, ADM, Kayseri ve Civarı, İstanbul Anadolu Yakası, Dicle, Vangölü and Toroslar. If we want to calculate non technical losses (NTL) simply one way of calculating it is to calculate technical losses (TL). We can evaluate it as follows;

Total Energy Losses = Energy Supplied - Bills Paid (1)

Total Energy Losses = NTL+TL (2)

Combining equation 1 and 2 we get

NTL= Energy Supplied - Bills Paid –TL (3)

Percentage losses are calculated as

$$\text{Percentage Loss} = \left(\frac{\text{Received Value} - \text{Sold Value}}{\text{Received Value}}\right) x100 \quad (4)$$

According to Republic of Turkey Energy Market Regulatory Authority's Electricity Market Development Reports, the distribution network loss rates between 2014 and 2018 are given in Table 1.

Table 1: Distribution network loss rates

Year	Highest / Lowest Loss Rates	Distribution Company	Loss Rates (%)
By the end of 2014	Highest Loss Rates	Dicle	74,00
		Vangölü	61,00
		Aras	26,00
	Lowest Loss Rates	Trakya	6,33
		Sakarya	6,76
By the end of 2015	Highest Loss Rates	Dicle	72,12
		Vangölü	59,70
		Aras	26,60
	Lowest Loss Rates	Akedaş	4,98
		Kayseri ve Civ.	5,25
By the end of 2016	Highest Loss Rates	Dicle	67,63
		Vangölü	56,42
		Aras	25,68
	Lowest Loss Rates	Trakya	5,46
		Uludağ	5,57
By the end of 2017	Highest Loss Rates	Dicle	64,82
		Vangölü	53,30
		Aras	24,55
	Lowest Loss Rates	Uludağ	4,14
		Trakya	5,09
		ADM	5,26
By the end of 2018	Highest Loss Rates	Dicle	54,94
		Vangölü	49,16
		Aras	23,55
	Lowest Loss Rates	Uludağ	4,20
		Trakya	4,37
		ADM	5,53

As shown in Table 1, generally the highest loss rates were seen in Dicle, Vangölü and Aras respectively. The lowest loss rates were seen in the distribution regions of Trakya and Uludağ. For example, by the end of 2018, the highest loss rates were seen in Dicle with 54,94 %, Vangölü with 49,16 % and Aras with 23,55 %. The lowest loss rates were seen in the distribution regions of Uludağ with 4,20 %, Trakya with 4,37% and ADM with 5,53%.

There are many methods of power theft or theft of electricity. Some of them are direct hooking from line, injecting foreign materials into the meter, drilling holes in the electro mechanical energy meter, inserting film. Electromagnetic meters are tempered by depositing a highly viscous fluid, by injecting film, by using strong magnets, for the interruption of disc. There are some detection techniques and reduction methods such as electronic tamper detection meters, plastic meter encasements, anti theft cable, using Global System for Mobile Communications (GSM), using Power Line communication (PLC), etc.

2.1. Direct hooking from line

One of electricity theft techniques taking connections directly from distribution lines (figure 2). Insulated cable is used to prevent this technique (figure 3).

Figure 2: Hook/kunda system

Figure 3: Use insulated cable

2.2. Change the direction of meter

If the phase and neutral connections are changed on the mechanical meters, the counter disk is reversed. In this way, the saved meter values are delete. Electronic meter should be used to prevent this. In recent years, all new consumers have the obligation to install electronic meters. Figure 4 illustrated the electricity theft technique done by dishonests internally [12]. It has been shown electronic meter in figure 5. In this method the rotating disk entirely stop its disk actions until meter is translocated to its proper location. Generally electricity meters are installed outside the home in proper position on wall or on electric pole. When the direction of meter changes the rotating disk will be stop automatically [15]. Electricity distribution companies lose a lot of money every year due to dishonest of electricity consumers.

Figure 4: Reverse meter counter

Figure 5: Electronic meter

2.3. Bypassing the electric meter

Generally, the bypass powers large and fixed loads that will not blow the fuses in case of overload. The electricity meter cannot save the consumed energy when the bypass cable is used (figure 6). Power Line communication (PLC) meter should be used on electric pole to prevent this. In other words, the installation of the meters to the poles to prevent the use of illegal electricity. It has been shown PLC meter in figure 7.

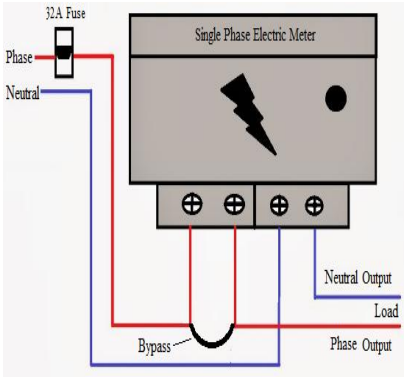

Figure 6: Use of bypass cable

Figure 7: PLC meter

Usually, this danger happens between the distribution grids that links the consumers' ends to the energy grid and could be report of billing anomalies, meter tampering and unpaid bills [16]. PLC meter is a smart electricity meter. Metering with smart meter easily reduces cost of meter reading, billing collection and labor cost to disconnect the faulty consumer. Basic configuration of smart electricity meter is shown below in figure 8.

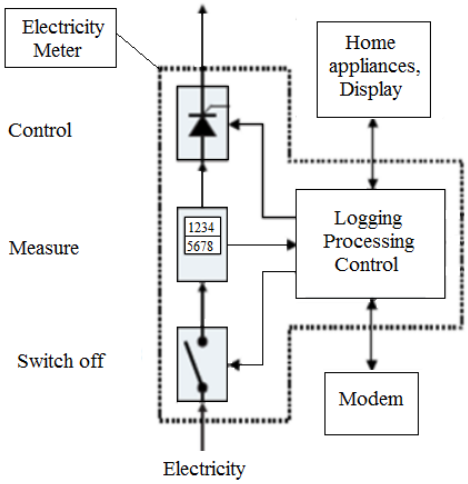

Figure 8: Smart meter basic Configuration [8]

In 2016, PLC meter changes in a certain part of four towns, which are Bulanık 21.71 %, Güroymak 37.61 %, Saray 11.58% and Özalp 29.82 %, by Vangölü Distribution Company. The amount of electrical energy consumed within a settlement remains approximately the same compared to the same periods of the year. For this reason, in order to ensure the comparison before and after the PLC meter is installed, the comparison was made considering the January, February and March months of 2016 before the PLC meter was installed and the January, February and March months of 2017 after the PLC meter was installed.

Table 2: Total loss leakage rates of four towns [2]

Total loss leakage rates of four towns		**2016**	**2017**	**Change (kWh)**	**Change %**
January	Energy received	37.418.024	25.693.956	-11.724.068	-31.33
	Accrue	8.429.090	13.956.865	5.527.775	65,58
	Loss-Leakage	77.47%	45.68%	-31.79%	
February	Energy received	34.918.065	23.746.006	-11.172.059	-32.00
	Accrue	12.642.427	15.302.550	2.660.123	21.04
	Loss-Leakage	63.79%	35,56%	-28.24%	
March	Energy received	33.926.991	19.185.052	-14.741.939	-43.45
	Accrue	12.614.703	13.846.145	1.231.442	9.76
	Loss-Leakage	62.82%	27.83%	-34.99%	
Total 3 Months	Energy received	106.263.080	68.625.014	-37.638.066	-35.42
	Accrue	33.686.220	43.105.560	9.419.340	27.96
	Loss-Leakage	68.30%	37.19%	-31,.11%	

As can be seen in Table 2, the energy received in four towns in January, February and March of 2017 decreased by 37.438.066 kWh with a rate of 35.42% compared to the same months of 2016. In the same period, accrued energy increased by 27.96% to 9,419,340 kWh. Similarly, the rate of loss and leakage decreased by 31.11%. If this method is applied to more regions the NTL can be further reduced.

2.4. Meter exposing meters to strong magnetic fields to wipe out the memory

Due to the physical structure of electromechanical meters, it is prevented that the consumption is measured correctly and recorded correctly by making illegal transactions easily on these meters. In this technique the consumers utilization the magnet material for slow the rotated disk of electromechanical meter. It is also a general technique for electricity theft. The use of a magnet on the meter is shown in figure 9. In this electricity theft technique, the consumers open the electromechanical meter and places the magnetic material on the top surface of the rotating disk. It interferences the easy action of disk and a slower turning disk signals less electricity consumption [15]. Electronic meter can be used to prevent this electricity theft technique. Because there is not rotating disk in electronic meter/ smart meter.

Figure 9: Placing magnets in meter

2.5. Inserting a film disturb the rotation of disc

A part of the photo or x-ray film is inserted through the back of the counter to prevent the numerator from progressing. Some citizens who drill the upper part of the meter with the rope tied with the rope, they put the pin in the counter, disabling the clip in the counter. Therefore stops the operation of the meters.

2.6. Measurement errors

It is a fact that the contribution of measurement errors to non-technical losses cannot be neglected. Due to the lack of periodic maintenance and calibration procedures and the lack of healthy consumption monitoring systems, faulty or even non-functioning meters cannot be detected. However, when there is a case against the subscriber and when the subscriber applies, the counters are checked at the setting and test stations.

2.7. Errors during meter reading

In rare cases, whether or not the meter readers are ignorant or ill-intentioned prevents the meters from being recorded and invoiced correctly, even though the meters have the right metering and recording.

2.8. Use of external neutral

The meter is deactivated by cutting the " neutral line " which must be connected to the meter at the same time as the phase from the energy distribution system. The connection for the use of external neutral is given in figure 10.

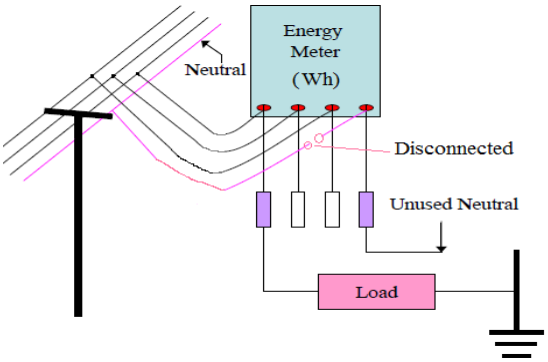

Figure 10: Use of external neutral

In this case, the consumed energy cannot be saved by the meter. In order to prevent this, the line between the meter and the distribution network must be insulated and the meters should be placed in the sealed panel.

2.9. Tampering with meters and seals

Electricity meter tampering is a type of NTL where individuals hack meters to slow or stop the accumulation of energy usage statistics. Increased requirement for enhancing the protection designed into new smart meters. Electricity tampering is a technique of tampering the measuring instrument by removing the seal. In this case a lower reading of electricity energy use is shown. Thus electricity meter can also be tampered and used by some other person. However the prevention of electricity theft of this technique can be detected by placing a light dependent resistor (LDR) circuit inside the electricity meter. For this reason, this type of electricity theft is not a big problem. But the direct rigging of the distribution line is a big problem [17].

3. Conclusions

As a result of unconscious use of electrical energy, a number of losses occur in the processes starting from the power plant to the consumer. Energy theft is known non-technical losses. It is a huge problem in energy distribution systems all over the world. Therefore this paper focuses on electricity theft detection techniques and reduction methods were explained in the energy distribution system. There are many type electricity theft. These are 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. Because of our increasing energy needs, it is important to reduce the losses caused by using existing energy systems more efficiently. Electricity theft can be reduced with technical and non- technical solutions. Technical solutions are electronic tamper detection meter, pre payment meters, plastic meter encasements, anti theft cable using GSM, using PLCs. Non technical solutions are management, public outreach, legal and regulatory. Electricity theft will be prevented by detection techniques and applying reduction methods or reduce energy losses will be provided in energy distribution system. Thus, existing electricity systems will be utilized more.

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