ELECTRIC POWER THEFT DETECTION USING TIME DOMAIN REFLECTOMETER

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ABSTRACT

Non-technical losses and electricity theft in particular is a widespread problem in the electricity distribution networks. In recent years due to economic recession and changes in energy prices in Iran, this problem also experiences a growing trend. In this paper, a novel method using a Time Domain Reflectometer (TDR) is used to diagnose and determine the power theft. The proposed method do not requires any additional equipment and can be used in different situations. This method is a complementary approach for data analysis and statistical methods to detect electric power theft.

INTRODUCTION

Transmission and distribution of electrical energy from the point of production to the final consumption is accompanied with numerous losses. Transmission and distribution losses in particular can be generally divided into two categories: technical losses and non-technical losses [1]. Meanwhile, non-technical losses in the distribution sector are major problems in determining losses. Non-technical losses cannot be accurately calculated, but can be estimated. In many developing countries, Non-technical losses account for up to 40% of their total generation capacity [2].

Electric power theft constitutes the important and major part of non-technical losses and consists of various methods and tricks that have been adopted and implemented by some subscribers to use electrical energy without paying the fees at the same time.

Many different methods of electric power theft have been identified including illegal tapping of electricity directly from the low voltage feeder, bypassing the revenue meter, tampering with the energy meter in order to manipulate the meter reading, using strong magnets to affect the rotating disc, using electricity from utility company without a contract or valid obligation to alter its measurement and several physical methods to evade payment to the utility [1,3]. The most common form of stealing electricity is tapping electricity directly from the distribution feeder known as unauthorized loads.

Electricity theft may lead to trip the generation units and cause interruptions to customers. This unpredictable amount of energy can result in poor quality of electricity supply as well as over voltages. Moreover, electric power theft increases safety concerns like electric shocks and even the death of a person who operates it [4].

From a business perspective, illegal tapping of electricity can lead to lose a considerable amount of total revenue by utility companies [5].

Numerous technical and non-technical techniques for estimation and control of electric power theft have been reported [1,6]. A methodology to identify energy theft and tampered meters as well as meters that are not working properly was proposed by Bandim et al. based on a central observer meter that is responsible for metering the overall energy of a group of consumers under investigation [7].

Nagi et al. presented a hybrid approach towards non-technical loss analysis using genetic algorithm (GA) and support vector machine (SVM). This model uses customer load profile information to expose abnormal behavior that is highly correlated with non-technical loss activities. [8,9]

Anand and Naveen developed a novel solution to the revenue crisis and energy thefts prevalent in Indian power sector known as vigilant energy metering system (VEMS) [10].

In this paper, a novel method using a Time Domain Reflectometer (TDR) is used to diagnose and determine the illegal tapping. Time Domain Reflectometer (TDR) is an advanced instrument capable of identifying a wide range of cable faults using a technique called Pulse Echo (also known as Time Domain Reflectometry). In this method, a pulse is transmitted into a cable from one end. Any changes in cable impedance will cause a proportion of the pulse to be reflected. These reflections are displayed as a trace on the instrument. The instrument can be used on any cable consisting of at least two insulated metallic elements, one of which may be the armoring or screen of the cable.

METHODOLOGY

Narrow pulses of electrical energy are transmitted along a pair of conductors in a cable. The pulse travels through the cable at a velocity determined by the insulation between the conductors and the resistance to the flow of the pulse is characterized as impedance for the cable. Changes in cable impedance will cause a proportion of the pulse to be reflected. The pulse velocity is normally described as a fraction of the speed of light and is called the Velocity Factor.

The instrument converts the measured time for a pulse to be reflected into a distance by velocity factor. It can be displayed as a ratio of the speed of light or as a distance per microsecond in ft./us or m/us. Measuring the time between the transmitted pulse and the reception of the reflected pulse, and multiplying this by the speed of light and the velocity factor, results the actual distance to the reflection point.

The ability of the instrument to accurately measure the distance to a cable feature relies on the velocity factor being correct, any errors in the velocity factor are directly proportional to distance measurement errors. Hence, the instrument uses the velocity factor to three decimal places to reduce any errors.

If a cable is metal and it has at least two conductors, it can be tested by a TDR. TDRs will troubleshoot and measure all types of twisted pair and coaxial cables, both aerial and underground.

TDRs require 2 conductors running in parallel to operate and identify the change in impedance. Any connection, change of cable type, break in the cable, or fault will cause a change of impedance. Each type of change has a different effect on the display of the TDR; a positive reflection shows higher impedance, while lower reflection shows lower impedance.

As was mentioned earlier the main problem is the issue of determining presence or absence of unauthorized tapping directly from the distribution feeder. It becomes more important given that major power thefts are covered somehow to remain hidden from public view.

EXPERIMENTAL TESTS AND RESULTS

Experiments performed in this study utilize some cables with different lengths, a conventional meter, and the TDR manufactured by Megger.

Fig. 1: TDR2000/2P by Megger.

Figure 2 shows result of test on a 40m cable when there is not any illegal tapping in the case of open circuit termination. The remarkable point in this case is that tapping at the distance of approximately one meter of the meter is not observable in waveforms due to a larger fault (open circuit) at the termination of the cable, which prevents observation of faults near it.

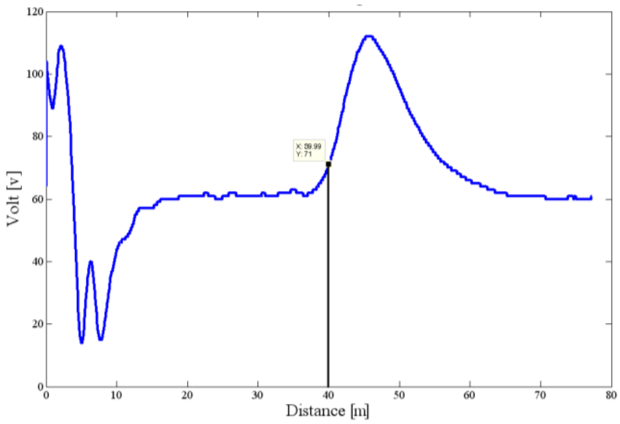

Fig. 2: TDR waveform in the first examination

The other situation examined in this paper is connecting TDR terminals to the cable right before the metering device. This scheme is implemented in two different conditions: when the metering device is switched on or off.

Figure 3 shows the experiment result when the metering device is switched on, without any illegal tapping. However, if an unauthorized branch is tapped in distance of approximately one meter of the meter, the result is the same as shown in figure 4.

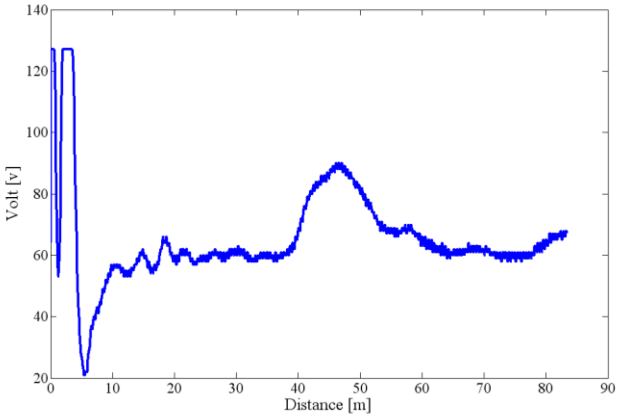

Fig. 3: TDR waveform in the second examination when the metering device is switched on without illegal tapping.

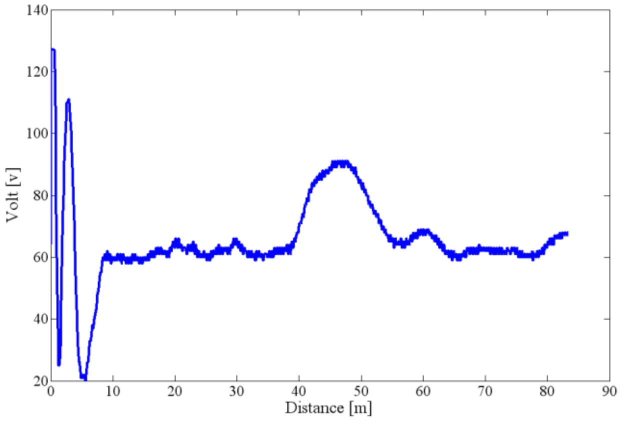

Fig. 4: TDR waveform in the second examination when

the metering device is switched on with an illegal tapping.

The third examination is performed the same as the second on with the exception that the metering device is switched off. Figure 5 shows the experiment result without any illegal tapping, while figure 6 reveals result of an unauthorized tapping in distance of approximately one meter of the meter.

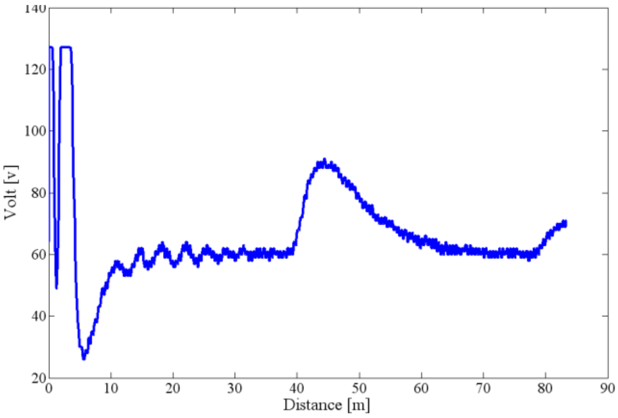

Fig. 5: TDR waveform in the third examination when the metering device is switched off without illegal tapping.

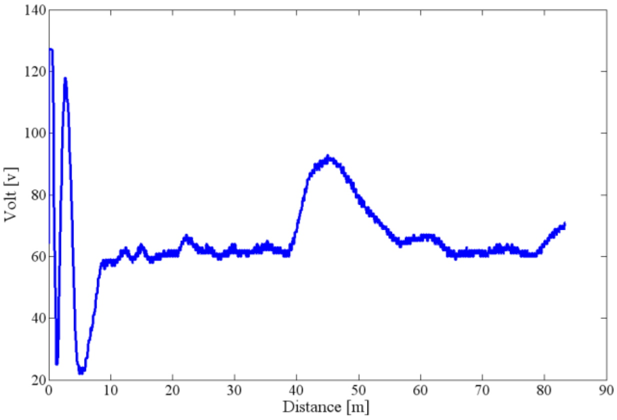

Fig. 6: TDR waveform in the third examination when the metering device is switched off with an illegal tapping.

As it can be seen, either in switched on or off situations of the metering device, waveforms are not significantly different when there is an unauthorized tapping.
Indeed, since the illegal tapping is a T-joint connection, it is expected to have a negative trace followed by long positive. In order to overcome this obstacle, an auxiliary cable is employed. The length of this cable is 14m.
Figure 7 shows TDR waveform when the auxiliary cable is utilized and the metering device is switched on, without any tapping along with the cable while in figure 8, TDR waveform is presented with an unknown load. As the figures reveal, there is not any significant difference between the two waveforms that is due to metering device where another path for the reflected pulse is emerged. This leads to a disrupted waveform and made the accurate diagnosis more difficult.

The test is performed when the metering device is switched off and the results are shown in figure 9 and 10. As it can be seen, waveforms are quite different.

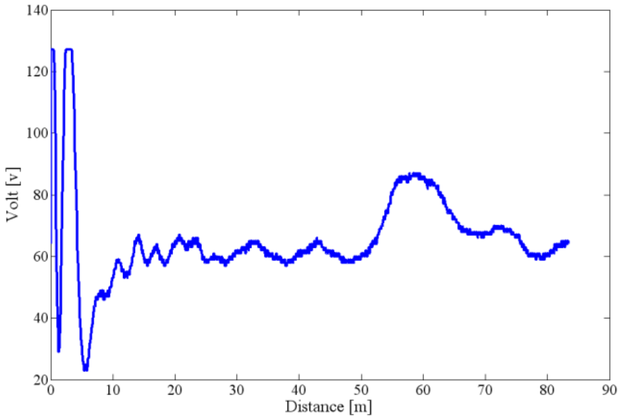

Fig. 7: TDR waveform using an auxiliary cable when the metering device is switched on without illegal tapping.

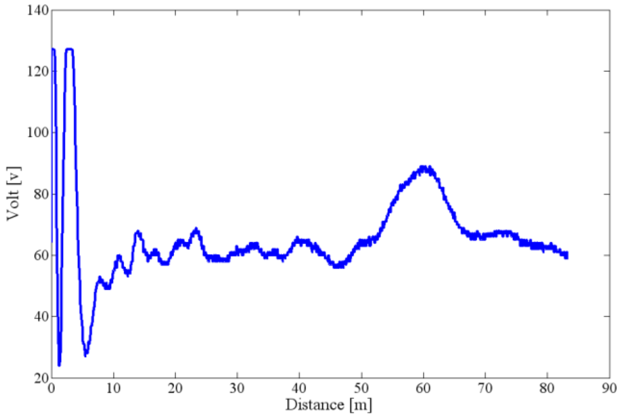

Fig. 8: TDR waveform using an auxiliary cable when the metering device is switched on with an illegal tapping.

As shown in figure 10, TDR waveform in the situation that the metering device is switched on and illegal tapping exist, is quite different from that of revealed in figure 9. There is also expected negative trace followed by long positive in figure 10.
In order to verify the performance of the proposed method, experiments have also been performed in an energized circuit. Figure 11 and 12 represent TDR waveforms in the case normal operation and illegal tapping respectively.
Therefore it can be concluded that using this method, unauthorized tapping can be determined carefully. It should be noted that in all tests, the length of the feeder is considered around 40 m and tapping is located around one meter from the metering device. However, if either of these two parameters is changed (particularly reduced), there might be some errors in electric power theft detection.

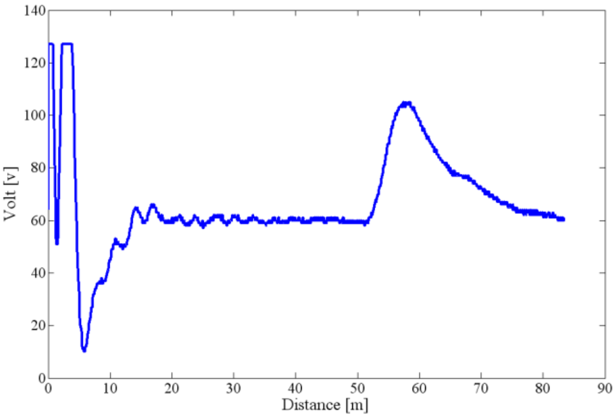

Fig. 9: TDR waveform using an auxiliary cable when the metering device is switched off without illegal tapping.

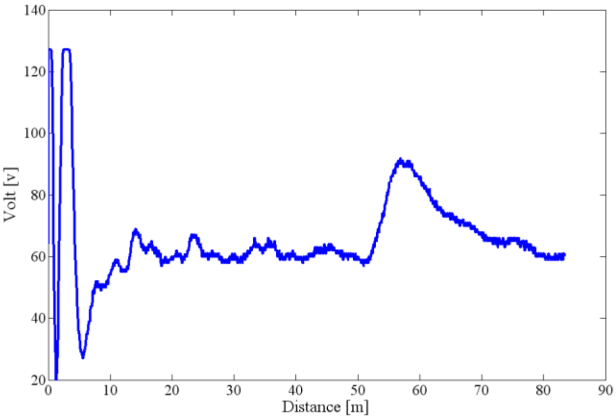

Fig. 10: TDR waveform using an auxiliary cable when the metering device is switched off with an illegal tapping.

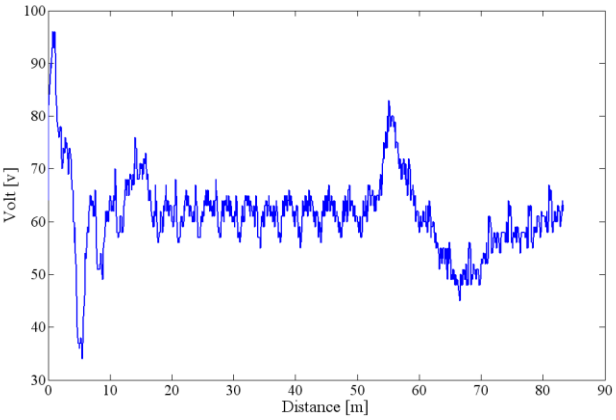

Fig. 11: TDR waveform in normal operation.

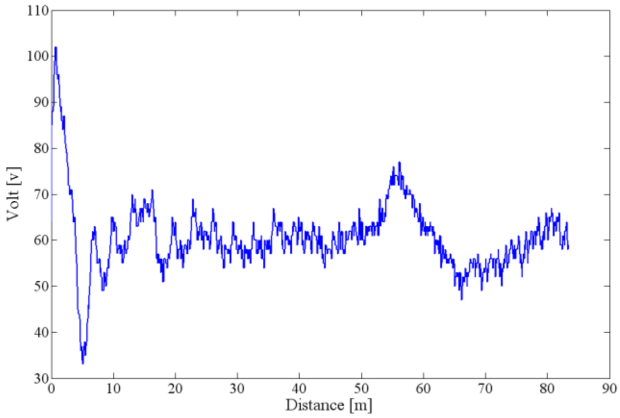

Fig. 12: TDR waveform with an illegal tapping.

CONCLUSION

This paper tries to investigate a new method of electric power theft detection using time domain reflectometer. Illegal tapping of electricity directly from the distribution feeder is the most common form of electricity theft that is considered in this method. Several examinations have been carried out to verify the performance of TDR in detecting unauthorized tapping. Results show that unauthorized tapping can be determined accurately by connecting TDR to the cable right before the metering device using an auxiliary cable. This methodology is a complementary approach for data analysis and statistical methods to detect electric power theft.

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