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Energy Theft Detection with Energy Privacy Preservation in the Smart Grid: A Review

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Abstract— Faults Energy is primary resources for running modern industries & households, & electrical energy has become the predominant part of total energy requirement of mankind. Most of the industrial household equipment run of electrical energy, even automobiles are moving towards electrical energy. Electrical energy is transferred directly to consumers over wire, thus energy metering & billing is an indispensable part of electrical energy distribution system. Conventionally, an employee/ contractor of electrical energy distribution company used to visit consumer premises to take reading from energy meter (electromechanical or electronic type) installed at consumer premises, for billing of energy consumed.

With the advent of IOT & smart grids, a new type of metering has evolved, viz AMI (advanced metering infrastructure) AMI eliminates the need of manual meter reading & sends continuous energy usage data over network (GSM /Optical Fiber/RF) or internet . Deployment of AMI is highly beneficial to energy companies to reduce manpower costs, but usage of AMI also increases the risk of energy theft as consumer premises is rarely visited for maintenance or surprise inspection. This document gives the detail information about the energy theft methodology based on AMI (advanced metering infrastructure).

Keywords—*AMI (Advanced Metering Infrastructure), Distributed Totalization Metering, Artificial Intelligence, Cryptography.*

I. INTRODUCTION

Energy is the quantitative property in physics which must be transmitted to an object in order to operate on or to heat the object. The law on energy preservation states that energy may be transformed, but that it cannot be produced or destroyed. Energy is the quantity

preserved. The SI energy unit is the joule that, by moving it 1 meter against 1 Newton force, is the energy transmitted to an object.

Common types of energy include the kinetic energy of the moving object, the potential energies stored in the position of the object in a power field (gravitational, power, etc.). The energy of elasticity stored on solid objects stretching is the chemical energy that is released when a fuel burns.

Near connection is between mass and energy. Because of mass-energy equivalence, any mass object (called rest mass) also has an equal amount of energy in the form known as rest energy and any additional (of any form) energy obtained by the object above that remaining energy, will increase the total mass of an object as its total energy increases. After heating an object for example, its energy growth could be calculated as a small mass increase with a sufficiently sensitive scale.

Living organisms use the energy they receive from food to remain alive. The energy it obtains from power sources such as fossil fuels, nuclear energy and renewable energy is needed for human society. The atmosphere and ecosystem processes of Earth are powered by the Earth's radiant energy from the sun and its geothermal energy.

II. Energy Metering, Its Evolution, & Classification

1. The Watt-Hour or Energy Meter is an electrical tool that calculates the amount of power used by customers. Services are one of the divisions that implement these instruments in every location, such as households, businesses, business buildings, for the energy use, for loads like lamps, fans, fridges, and other home appliances. These devices are mounted.

2. Classification of Energy Meter

Electronic energy meters

Electronics energy meter classified into two parts;

- Analog energy meter
- Digital energy meter

(a) Analog energy meters

The voltage and current produced by the potential transformer and current transformer in analogue energy meter respectively. With the aid of analogue to digital converters these

analogue values are converted into digital samples (ADC). These samples were transformed by a frequency converter to frequency signals. It was used to monitor the counter device that combines these samples over time and reads the electricity usage. Comparing electromechanic energy meter, the analogue energy meter is more reliable but less accurate than the optical power meter.

Figure: 1Analog Energy Meter

(b) Digital energy meters

A microprocessor or optical signal processor is used in the digital power meter. Similar to a microprocessor analogue energy meter, transducer of voltage and current connected to an analogue to a digital converter. The microprocessor multiplied its voltage and current samples. The phase angle of tension and current calculated by a microprocessor for reactivity and power factor calculation. It can measure parameters such as electricity consumption, power factor, reactive power, voltage, current, date and time and charges according to the tariff to perform these tasks in a microprocessor. The LCD or LED monitor for the digital energy meter has parameters for display.

In comparison with analogue and electronic meters, the digital energy meter is more reliable and the risks of being manipulated and thefted in a digital energy meter are lower. However, digital energy meter costs in comparison with electromechanic and analogue energy meter. Installations are high. Digital power meter accuracy depends on the microprocessor.

Figure: 2 Digital Energy Meter

III. LITERATURE REVIEW

The Advanced Metering Infrastructure (AMI) is a major component of the smart grid that collects, measures and analyses energy consumption data from customers. The establishment of this network was possible thanks to the advent of new information and communication technology. However, the introduction of these technologies created new problems at the AMI. One is electric robbery, which has become a major concern in conventional energy systems throughout the world. In response to these challenges, data sets on the use of electricity are evaluated for intruders. Traditional techniques to identify intruders are the use of machine learning and data mining methods. This paper analyses the feasibility of using outliers to enhance AMI protection through electricity theft detection. We examine the output of different external detection algorithms on true data (consumer energy usage). The results show how feasible the use of outliers algorithms in the defence of AMI is and how efficient it is to apply these techniques in robbery data sets.[1]

This letter provides a predictor of the Smart Grids energy theft based on the three newest GBCs: extreme grade boosts, categorical boosts (CatBoost), and light gradient boosts. The following gradient is used for the smart grid energy theft recognition (LightGBM). Most current ML algorithms concentrate on the finest tuning of the hyper parameters in the classification system. Our ML algorithm, GBTD, is designed to improve detection efficiency and time complexity through the use of feature engineering preprocessing. By generating storage features such as standard deviation, mean, minimal, and maximum value of daily electricity use, the GBTD increases both the detection rate (DR) and false positive rate (FPR). GBTD also reduces the complexity of the classifier using weighted feature-import extraction

techniques (WFI). The realistic implementation of the proposed ML for robbery detection was emphasized by reducing FPRs and data storage and improving the complexity of GBTD classification times. This letter also proposes the imitation of the real world theft patterns and to use the dataset for an assessment of the number of the algorithm proposed to update the current robbery in six cases. [2]

The worldwide focus of smart city implementation and deployment is obviously energy efficiencies but the preparation of smart grid vulnerability threatens to undermine smart grids (SGs). Adversaries launch attacks for different reasons; however, SG installations and thus energy conservation are seriously concerned with the rising threat of electricity theft. Intelligent electricity meter installations across advanced electricity metering infrastructure provide exciting solutions and greater potential as they provide sufficient data for analytical lessons to achieve constructive action against different cyber-attacks. The first phase in such preventive steps to curb electrical stealing, this study indicates the origins of risks. It offers a mechanism to track, recognise and curb risks based on electricity theft factors in a clever utilities network. These symptoms are mainly concentrated in the proposed system on the risks listed that indicate the potential incidence of electric theft to prevent robbery. This study offers smart city planners a useful background in developing a more dependable, robust and safe energy management system that a sustainable city needs.[3]

Advanced measuring networks (AMI) are vulnerable to energy theft cyber-attacks. This article proposes a customer-specific detector based on a profound neural network (DNN) that effectively prevents such cyber stakes, as opposed to existing research using low-tech electricity detection architectures. In the proposed learning stage of the DNN-based detector, a sequential grid-search analysis is carried out to adapt the hyper parameters properly so as to improve the detection efficiency. Exhaustive research studies are carried out on the basis of 5,000 customers with publicly available current energy data. A perforated detector examines a mix of various types of electricity theft cyber-attacks. The findings from the simulation show significant efficiency gains compared to state-of-the-art shallow detectors. [4]

Advanced AMI networks are used to track and account for pure positions in modern intelligent grids. However, cyber-assault power theft suffers from this strategy. This document proposes a broad and recurrent electrical power detector based on the deep neural network (RNN) that uses flawless, static and custom power detectors to effectively prevent these cyber assaults. The proposed model uses a time series of electricity utilization for the installation of a GRU-RNN, which improves the detection efficiency of its clients. Furthermore a random search study to adjust its hyper parameters accordingly is performed in the learning stage of the proposed RNN detector. A thorough detector efficiency study with public real data is being conducted from 200 clients on 107,200 days of energy use. The

simulation results show the superior performance of the proposed detector compared to state-of-the-art electrical theft detectors.[5]

We propose a predictive remote detection method to mitigate attacks on Advanced Measurement Infrastructure (AMI). The proposed method is calculated using historical measurement differences between the next time stages to calculate various statistical distance indicators (Jensen-Shannone distance, Hellinger distance and Cusped distribution function dependent distances). The range collapses when the opponent starts an AMI energy robbery. A threshold is established to detect malignant samples. We checked the performance of the proposed method with true intelligent meter data in a different attack scenario. The results of the test show that the proposed approach reduces energy robbery attacks effectively.[6]

Theft of energy is one of the main concerns for advanced metering infrastructure (AMI). Financial losses resulting from energy theft are trillions of dollars per year in developed and developing countries. In this paper, we proposed a theft detection scheme focused on the principal component for AMI energy theft detection. Main components were discovered using customer data. The distance between transformed tests and historical consumption data is determined between Mahalanobis samples. The test sample is considered to be malicious if the Mahalanobis distance is below the predetermined threshold. The method proposed is evaluated using real smart meter data in various attack scenarios. The experimental results demonstrate that the proposed scheme detects high detection rate energy robbery attacks.[7]

We use the main component analysis (PCA) detection approach to detect advanced metering energy theft attacks (AMI). The PCA approximation is introduced by a dimensional reduction of the high-dimensional AMI data and the author extracts the consumer underlying patterns which are repeated every day, or each week. AMI data is reconstructed using key components and is used to compute relative entropy. The similarity of two probability distributions from reworked consumption datasets to relative entropy is measured during the proposed procedure. When the energy volume attacks are injected into AMI, the probability distribution of energy is different from the historical consumption leading to a higher relative entropy. In various attack scenarios, the proposed detection method is evaluated using real-smart meter data. The results show that high-detection robbery attacks can be identified by the system proposed.[8]

IV. The Energy Theft & Its Method & Implication

With more energy theft, attempts are being made to prevent criminals from tampering with meters and distributing energy from the grid. Stealing energy is not only a question of currency theft, but it can be harmful to the inhabitants of the house, raising the risk of electric fires, gas leaks, and explosions.

We look closely at energy theft, how it is to be detected and recorded if you believe it takes place in your building in an attempt to raise awareness about the risks raised by robbery.

How do the energy theft by 'meter cheaters. ‘When a meter is manipulated, the easiest method of energy theft is to stop recording real usage to try to reduce the energy bills. This typically requires the meter to be changed so that energy can be used without proper logging. Growing numbers of commercial and domestic energy consumers lose considerable as their gas and electricity meters are being manipulated to ultimately minimize their annual energy bill.

Safety implications:

• The exposed wiring on the meter itself will cause serious electrical shocks and burns if an electrical meter is tampered with. Not only that, but bypassing the meter could lead to "live" of electrical interrupters and equipment, which could increase the risk of shock and fire in other parts of the premises. Exposed cables and weak links can become extremely hot to the extent that they ignite and burn. This compromise the security of the whole building and jeopardizes both you and your colleagues.

• The supply can get damaged when gas meters have been messed with, leading to potentially fatal gas leaks.

• Gas is also highly inflammable and can combust into a fireball when 5 percent of the gas is mixed up in the air. As the smoke grows in a space, it can cause headaches and even loss of awareness. Such small things as a flicker can ignite gas and possibly cause a devastating fireball or a catastrophic explosion.

1.5.2Financial and criminal implications:

• You face a substantial fine and a criminal record if you are charged with energy theft. You could also be in prison for up to five years in certain cases.

• It is estimated that with each case of energy theft, about £20 would apply to each energy bill in the UK.

• If you believe your electricity source is stolen from energy, your supply will be shut down before a thorough examination is undertaken.

• If your insurance company has found that your meter has been tampered by a fire or property damage caused by energy theft, you will not pay.

Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure

AMI is a collective term for describing the entire infrastructure from two routes to the control systems of centers to all software capable in the near real time of collecting and transmitting energy consumption information. AMI is a collective term (advanced metering infrastructure). AMI allows two-way consumer contact and is the smart grid's backbone. The AMI objectives are to remotely measure data that are error-free, identify network problems, profile loads, audit energy and cut part loads rather than release them.

Building Blocks of AMI

AMI is composed of a variety of hardware and software components that are both involved in energy consumption measures and in the transmission to utilities and consumers of information on energy, water and gas use. AMI includes the overall technical components:

• Smart meters - Advanced meters that can collection information at diverse intervals about electricity, water and gas consumption and send data to the utility through fixed communication systems and receive information such as service utility pricing signals for customer transmission. • Advanced metering devices

• Communication Network: Advanced two-way networks that provide information between smart meters and utilities, and vice versa. Network of communication. Networks like PowerLine Broadband, PowerLine Communications, Fiber Optic communication, Radio Frequency Fixed (Festival, Mobile Communications and SPS) or public networks are used for these applications.

• Data Acquisition Device Meter Software programme on Control Center hardware and DCUs, used for collecting data from meters via the communication network and sending to the MDMS. • Data Acquisition System

• Data Management System (DMS) metering system: host system that gets, stores and analyses the data metering.

Home area Network (HAN) - The AMI expansion will promote contact with AMI by home appliances on customer premises such that loads can be controlled more effectively both by the utilities and the users.

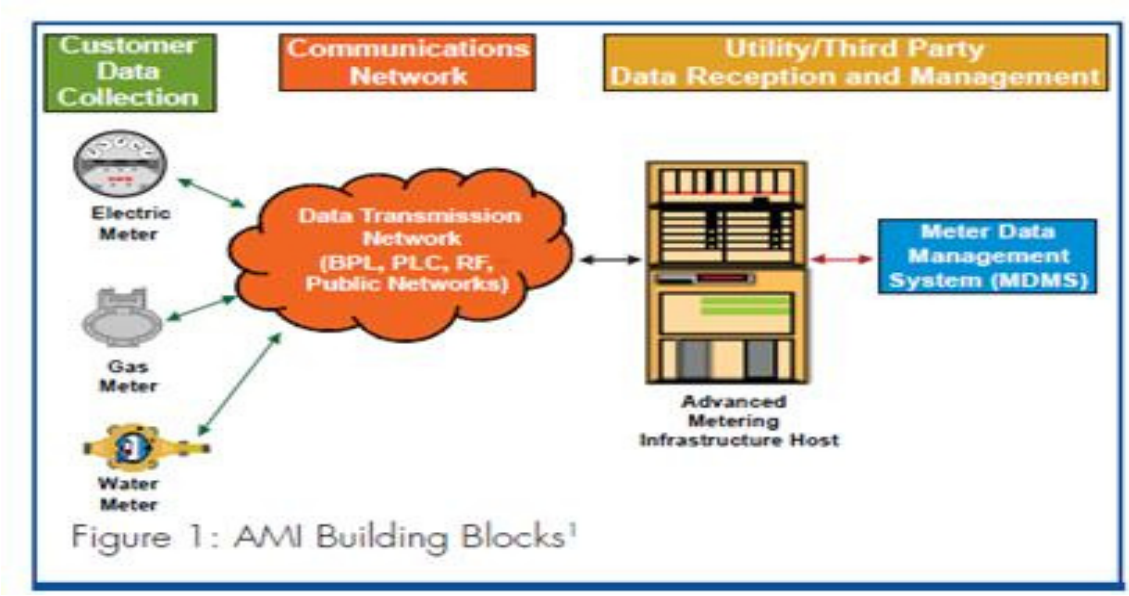

Figure: 3 Illustrates the components that make up AMI, including advanced electric, gas and water meters a data transmission network and a data management system

V. CONCLUSIONS

The work that has been undertaken by the author has been able to demonstrate a novel technique of energy theft detection & prevention in AMI (Advanced Metering Infrastructure) setup. To prevent advanced data manipulator or hacking type of attacks a highly advanced cryptography technique. Using centralized key generation server of TCP/IP protocol, MAC (Machine Address) based key regeneration, controlled node count & variable length random key cryptography is employed.

To detect any kind of theft whether conventional or data attack, distributed totalization metering is employed in conjunction with artificial intelligence. In distributed totalization metering is employed in conjunction with Artificial Intelligence. After this detailed study of energy theft we have concluded that artificial neural network is one of the best techniques to stop the energy theft in AMI (Advanced Metering Infrastructure) setup.

VI. FUTURE WORK

Energy is the life line of modern world, no industries or household is independent of electrical energy. This work has successfully demonstrated a novel technique for prevention & detection of energy theft in AMI (Advanced Metering Infrastructure) or smart meters. As usage penetration of smart grids & AMI / smart metering devices is set to rise with IOT revolution, there is a need for constant evolvement & up-gradation to counter present & future energy theft threats.

One of the desired evolutions can be employment of self-learning neural networks, so they can automatically adapt to changing consumption & load patterns & reduce false alarms. Also AMI/ smart meters may be incorporated with GPS to enhance cryptographic security by employing satellite time stamp or auto activation of high surveillance metering in case of geographic location marked for previous energy theft history. Also, the system can employ to disconnect power to a section of consumers in case of large differential theft detected.

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