Review on Design and Simulation of Electricity Theft Detection and Protection System with their techno-economic Study

Moitreyo L. Handique[1], Queen Kalita[2], Gitu Das[3]

[1,2,3] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA
[1]*moitreyolakhyahandique@gmail.com*, [2]*kim.kalita.1@gmail.com**, [3]*gitu.das@dbuniversity.ac.in*

Abstract: ***Theft of electricity is a major problem faced by both developed as well as developing countries. It affects both the power as well as economic situation. It also at times is the root cause of blackouts. The objective of this paper is to design and simulate a system that can detect, which in turn, will help in protection from electricity theft.***

Keywords: Electricity theft; Electricity protection; Smart meter, MATLAB Simulink; Smart-grid.

 Article history: Received: 1 Feb 2019 and Accepted: 1 April 2019.

1. Introduction

Modern life cannot be possibly imagined without electricity. From a simple light to computers to even vehicles, now it has grown into such a necessity that it has been declared as a fundamental right. Such is the importance of electricity in modern life. The value of electricity cannot be undermined in the technology-driven world where our daily lives are dominated by appliances and gadgets. Yet there are still places where electricity is not available yet, and their people are still who do not enjoy this fundamental right as we do. There are various reasons for this, such as the insufficient power generation, losses, various geographical terrains etc. But, among these, one of the major reasons is electricity theft. With the advent of automobiles that run on electricity and needs charging, the electricity theft situation is expected to worsen further. This is a huge challenge faced by the whole world, where one side we are talking about carbon emission and need to use renewable clean energy for sustainable growth, we are not being able to manage the situation in an efficient manner.

The motivation of this study is to come up with a measure to detect, prevent and counter the problem of electricity theft in an efficient and robust manner such that it can be tackled and therefore, help the power as well as economic situation.

1.1 Literature Survey

In the research work done by P. Jokar *et al.* [1], the authors presented a consumption pattern-based energy theft detector, find suspicious usage pattern. Areas with a high probability of malicious usage pattern are marked, and by monitoring abnormalities in consumption patterns, suspicious customers are identified. Classification and clustering techniques are used. Also, the use of transformers and anomaly detectors, make the algorithm robust against no malicious changes in usage pattern and provide a high and adjustable performance with a low sampling rate.

In the research work done by M. Tariq *et al.* [2], a stochastic Petri net formalism is used in this paper to detect and localize the occurrence of theft in grid-tied MGs. The disturbance in any of time in the form of resistance above a threshold in the accumulated data of a smart meter, irrespective of the mode of operation, initiates a transition assigned to the arc, which notifies the transmission module. The affected transition and suspected user information are sent to the Meter Data Management System (MDMS) for localization of the theft. In experiments, it calculates the technical and non-technical losses with absolute accuracy without having the knowledge of the exact topology of the power distribution network.

In the research work done by A. J. Dick [3], the researcher looks at revenue protection activities within the UK to combat the problem of theft of electricity, which is estimated to cost the electricity industry (EI) some #50 m per annum. The nature and scale of the problem are first analyzed, with comments on the relative incidence of the various types of theft and interference, and the legal framework is indicated. A report is then made with the mentioned procedure.

In the research done by N. Mohammad *et al.* [4], the researchers proposed a prepaid energy metering system to control electricity theft. Smart meters are used and installed at every customer unit and server is maintained. Both the meter and the server are equipped with GSM module, which allows bidirectional communication. A few techniques to counter malpractices related to electricity are stated. Electricity theft can be reduced using these methods.

In the research work done by A. Jindal *et al.* [9], the authors concentrated on Nontechnical losses, particularly due to electrical theft, have been a major concern in power system industries for a long time. There is a gap between demand and supply and therefore creates energy constraints. Thus, there arises the need to develop a scheme that can detect these thefts precisely in the complex power networks. So, keeping focus on these points, this paper proposes a comprehensive top-down scheme based on a decision tree (DT) and support vector machine (SVM). This system is unique as it can detect theft in both transmission and distribution. The proposed scheme is based on the combination of DT and SVM classifiers for rigorous analysis of gathered electricity consumption data. In other words, the proposed scheme can be viewed as a two-level data processing and analysis approach, since the data processed by DT are fed as an input to the SVM classifier. Furthermore, the obtained results indicate that the proposed scheme reduces false positives to a great extent and is practical enough to be implemented in real-time scenarios.

In the research work done by J. Nagi *et al.* [10], the authors worked on finding efficient measurements for detecting fraudulent electricity consumption has been an active research area in recent years. This paper presents a technique to deal with non-technical losses using a novel intelligence-based technique, Support Vector Machine (SVM). The main motivation of this study is to assist Tenaga Nasional Berhad (TNB) in Malaysia to reduce its NTLs in the distribution sector due to electricity theft. The proposed model preselects suspected customers to be inspected onsite for fraud based on irregularities and abnormal consumption behavior. Here customer consumption patterns are recorded. It detects using abnormal usage pattern. Suspicious users are shortlisted. This method is proved better when simulated in comparison to existing techniques,

In the research work done by J. Nagi *et al*. [11], the authors worked on finding efficient methods for detecting electricity fraud that has been an active research area in recent years. This paper presents a hybrid approach towards non-technical loss (NTL) analysis for electric utilities using genetic algorithm (GA) and support vector machine (SVM). The main motivation of this study is to assist Tenaga Nasional Berhad (TNB) in Malaysia to reduce its NTLs in the distribution sector. This hybrid GA-SVM model preselects suspected customers to be inspected onsite for fraud based on abnormal consumption behavior. The proposed approach uses customer load profile information to expose abnormal behavior that is known to be highly correlated with NTL activities. GA provides an increased convergence and globally optimized SVM hyper-parameters using a combination of random and repopulated genomes. The result of the fraud detection model yields classified classes that are used to shortlist potential fraud suspects for onsite inspection. Simulation results prove the proposed method is more effective compared to the current actions taken by TNB in order to reduce NTL activities.

In the research work done by T. B. Smith [12], he worked on the aspect that electricity theft can be in the form of fraud (meter tampering), stealing (illegal connections), billing irregularities, and unpaid bills. Statistics of electricity theft in 102 countries were collected. Electricity theft and various ways to counter are discussed.

In the research work done by R. F. Ghajar *et al.* [13], the authors worked on the aspect that one of the largest pitfalls for any distribution network is the level of energy losses suffered by the system. Two types of losses being technical and non-technical, technical losses depend largely on the physical properties of the network, while non-technical losses (sometimes a more significant form of losses) are the result of theft or fraud caused by meter tampering, false reading, illegal connections or unpaid bills. The results of this study and a cost/benefit analysis of the proposed system are summarized in this paper.

In the research work done by K. L. Joseph *et al.* [14], the authors worked on the aspect that ongoing theft, corruption, and an artificially decreased pricing structure have made it nearly impossible for the state utilities in India to improve power service. As a result, industrial consumers across India exit the state-run system and rely on their own on-site power generation in order to ensure a consistent and reliable source of electricity. The 2003 Electricity Act encourages further power production from these captive plants through its open access clause. By encouraging the growth of these captive power plants, politicians in India set up a dual-track economy, whereby state-run and market-run production exist side-by-side. This strategy allows politicians to encourage private sector involvement in the electricity market, without jeopardizing the support of key political constituencies at the state level.

2. Theoretical Background

2.1 Indian Scenario

Power theft in India is a critical issue that the country has been trying to deal with for years. The problem is found not simply within the rural areas; however, it's conjointly rampant within the cities likewise. Even though the government has claimed to achieve village electrification in all the villages in India [16], power theft is something that the Indian Govt. has failed to address properly.

As per the Central Electricity Authority, over 27 pc of all power produced in India is either lost due to dissipation from wires or theft. That's about 261,130 GW/HR of power annually- enough to light up New York for nearly two years. It is valued nearly bureau one trillion at a median electricity rate of bureau four per unit.

2.2 World Scenario of power theft

When we hear the phrase "electricity theft," we may automatically picture places like India or Brazil where the number of power outages is astounding. However, unfortunately electricity thieves can be found in nearly every country across the globe, including the U.S. Whether it's performing illegal hookups, tampering with meters, or stealing copper wire from substations, over $200 billion in electricity is lost each year due to equipment failure or electricity thieves. In the U.S. alone, this crime costs roughly $6 billion annually, which makes it the third most stolen commodity following credit card information and vehicles [15].

2.3 Micro Grid

Micro grid technology is especially good at managing and storing natural resources at the point of consumption, meaning they can incorporate clean renewable energy from the sun, wind, waves etc. On Robben Island, the former apartheid prison and now a world heritage site, diesel use have been cut by 75%; while Kodiak Island gets 99% of its power from renewable sources. The ability to be self-sufficient means micro grids can be vital even where larger grids already exist. That is why Red Cross installed a solar micro grid at their Logistics Center in Nairobi to make sure they are covered even during national power outages. Cities at risk from extreme weather conditions can also benefit from having these islanded grids. Micro grids have emerged as one of the key technologies in the ongoing energy revolution helping to make power cleaner and available to more people than ever before.

2.4 Smart Grid

A grid is a network of power lines and substations, which carry electricity from the power station to homes and businesses. Today the grid is in problem, it needs updating and is running at capacity. When power lines break, our power stations cannot generate enough power, blackouts can occur, which is a problem that can cause fatalities. Grids often rely on a single power source and do not provide detailed information on the utilization or consumption, making electricity difficult to manage. To address these problems in the past, simply new power plants were built, but now we need to work towards sustainability and reduce our dependency on fossil fuels by using a smarter grid.

A smart grid suggests that adding sensors and package to the present grid that may offer utility people new info that may facilitate them to perceive and react to changes quickly. For example, if a tree falls on a power line, 1000 homes loose power supply. With the current grid system, .utility employees often physically reroute power, which takes time. With the smart grid, sensors and software would identify and immediately rout the power around the problem, limiting the issue to fewer homes. And there is more, the price of electricity changes throughout the day, but we cannot see it with the current meters in our homes. It may be expensive at peak hours and cheap at nights, with new smart meters we could set heavy power appliances such as dishwasher to run when power is cheap. This provides individuals with more control over their power bills and helps prevent blackout during peak hours. The smart grid also means new ways to use renewable energy. Power generation can now be distributed among multiple sources, so the system is more stable and efficient. This provides the ability to communicate and manage electricity that helps the grid in a smarter way and helps us avoid burning more fossils fuels in the future. The smart grid will help us manage our power bill, help the environment and also help the economy by making a more informed decision about how we use electricity.

3. System Design

3.1 Power Summation Method

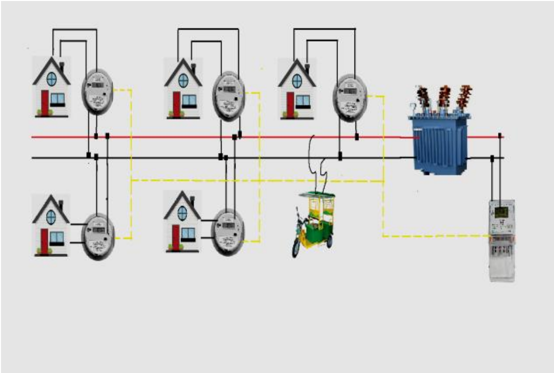

Figure 1: Power Summation Method

The block diagram is one of the two methods intended to work on in this study. One of the two methods is being discussed here.

In this method, the concept of micro grid as well as smart grid is considered along with smart meters. The whole concept of the method is based on the smart meters and the two-way communication they are capable of. The concept is that a micro grid is connected to say a power supply source, which will have a transformer with its own smart meter, connected between it and the loads. Each of the load or houses will have their own smart meters, which will both communicate among themselves as well with the transformer. The whole concept is built on the idea that if the summation of all the power received by individual smart meters considering the possible losses is less than the power supplied by the transformer, there must be electricity theft somewhere in the grid.

This method though on the surface, may seem a very simple one, yet the main and big challenge is that of distinguishing between the losses and the electricity theft. It is basically the main hurdle in the method. Another hurdle in this method has been to come out with ways to localize the theft; we're still studying and trying to come up with ways, which can localize and give us a location regarding the theft.

4. System Implementation (Simulation)

The concept was implemented in MATLAB Simulink. A radial system of transmission is designed showing a 3-phase power Source. A 3-phase transformer was connected to this source while attaching a power measuring unit to it. Then, with a transmission line having inductance and resistance. Power is supplied to three load units, each with its own current measuring unit. The idea is to compare the real power quantities of the supply transformer and the summation of the loads. We have given power measuring units to two of the three loads to consider the one without theft. If the comparison of the real power between the transformer and summation of loads comes off equal, there is no theft and vice versa.

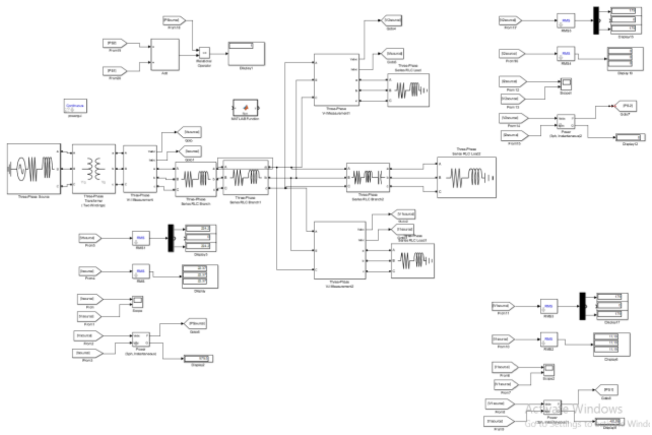

Figure 2: Matlab Simulation

5. Results

The comparator compares the real power of the supply transformer and the real power summation of the loads. If the result of the comparison is equal, then there is no theft and vice versa. Then the result is shown on a display block.

Table 1: Results on the Display Block

Output	Result
1	Theft
0	No Theft

6. Conclusion & Future Scope

The expected outcome of this study is to have various methods to counter the huge problem of electricity theft and to provide a comprehensive and comparative study between these methods based on the economic as well as various aspects. The expected end product of the study is to design and simulate these methods and therefore come up with practical solutions to help the power and economic situation of our country as well as the world.

We managed to detect electricity theft successfully. Localization is the prospect that can be worked on to make the method more robust.

References

[1] P. Jokar, N. Arianpoo and V. C. M. Leung, “Electricity Theft Detection in AMI Using Customers’ Consumption Patterns”, *IEEE Transactions on Smart Grid*, Vol. 7, Issue 1, Jan. 2016, pp. 216-226. Doi: 10.1109/TSG.2015.2425222

[2] M. Tariq and H. V. Poor, “Electricity Theft Detection and Localization in Grid-Tied Microgrids”, *IEEE Transactions on Smart Grid*, Vol. 9, Issue 3, May 2018, pp. 1920-1929. Doi: 10.1109/TSG.2016.2602660

[3] A. J. Dick, “Theft of electricity-how UK electricity companies detect and deter”, *Proc. of European Convention on Security and Detection, 1995*, Brighton, UK, 16-18 May 1995, pp. 90-95. Doi: 10.1049/cp:19950476

[4] N. Mohammad, A. Barua and Muhammad A. Arafat, “A smart prepaid Energy metering system to control electricity theft”, *Proc. of 2013 International Conference on Power, Energy and Control (ICPEC)*, Sri Rangalatchum Dindigul, India, 6-8 Feb. 2013, pp. 562-565. Doi: 10.1109/ICPEC.2013.6527721

[5] S. Kumar, *Electricity Theft: Empowering People and Reforming Power Sector*, Manohar Publications, New Delhi, 2004

[6] “Indian Power Sector Loses $16.2b To Theft Every Year”, *ASIANPOWER*, 21 January, 2015. [Online]. Available: https://Asian-Power.Com/Ipp/In-Focus/Indian-Power-Sector-Loses-162b-Theft-Every-Year (Accessed: 21 July, 2018)

[7] A. Agarwal, “Power Theft in India**”, *PROJECT GURU*,** 10 December, 2012**.** [Online]. Available**:** https://www.projectguru.in/publications/power-theft-india/ (Accessed: 21 July, 2018)

[8] P. Kelly-Detwiler, “Energy Theft: A Bigger Issue Than You Think”, *Forbes*, 23 April, 2013. [Online]. Available**:** https://www.forbes.com/sites/peterdetwiler/2013/04/23/electricity-theft-a-bigger-issue-than-you-think/#693d7aa75ed7 (Accessed: 21 July, 2018)

[9] A. Jindal, A. Dua, K. Kaur, M. Singh, N. Kumar and S. Mishra, “Decision Tree and SVM-Based Data Analytics for Theft Detection in Smart Grid”, *IEEE Transactions on Industrial Informatics*, Vol. 12, Issue 3, June 2016, pp. 1005-1016. Doi: 10.1109/TII.2016.2543145

[10] J. Nagi, A. M. Mohammad , K. S. Yap , S. K. Tiong and S. K. Ahmed, “Non-Technical Loss analysis for detection of electricity theft using support vector machines”, *Proc. of 2008 IEEE 2nd International Power and Energy Conference*, Johor Bahru, 1-3 Dec. 2008, pp. 907-912. Doi: 10.1109/PECON.2008.4762604

[11] J. Nagi, K. S. Yap, S. K. Tiong, S. K. Ahmed and A. M. Mohammad, “Detection of abnormalities and electricity theft using genetic Support Vector Machines”, *Proc. of TENCON 2008 - 2008 IEEE Region 10 Conference*, Hyderabad, India, 19-21 Nov. 2008, pp. 1-6. Doi: 10.1109/TENCON.2008.4766403

[12] T. B. Smith “Electricity Theft: a comparative analysis”, *Energy Policy*, Vol. 32, Issue 18, December 2004, pp. 2067-2076. Doi: https://doi.org/10.1016/S0301-4215(03)00182-4

[13] R. F. Ghajar and J. Khalife, “Cost/benefit analysis of an AMR system to reduce electricity theft and maximize revenues for Électricité du Liban”, *Applied Energy*, Vol. 76, Issues 1-3, September-November 2003, pp. 25-37. Doi: https://doi.org/10.1016/S0306-2619(03)00044-8

[14] K. L. Joseph, “The politics of power: Electricity reform in India”, *Energy Policy*, Vol. 38, Issue 1, January 2010, pp. 503-511. Doi: https://doi.org/10.1016/j.enpol.2009.09.041

[15] Sarah Battaglia, “ENERGY THEFT GOES GLOBAL”, *Your energy blog*, February 11, 2013. [Online]. Available : http://www.yourenergyblog.com/energy-theft-goes-global/ (Accessed: 12 Jan. 2019)

[16] “India says all villages have electricity”, *BBC News*, 30 April 2018. [Online]. Available:

https://www.bbc.com/news/world-asia-india-43946049 (Accessed: 12 Jan. 2019)

Authors' Profiles

Gitu Das, M.Tech., is working as an assistant professor in Assam Don Bosco University, India. He has 1.5 years of industrial experience (in Philips health care as service engineer & T&T Projects Ltd. as site engineer for various substation, overhead lines, electrical wiring etc. His areas of research interest are Renewable Energy, Embedded Systems.

Moitreyo L. Handique, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University (India). His areas of interest are Power Plants Engineering, Renewable Energy.

Queen Kalita, is currently pursuing Bachelor degree in Electrical and Electronics Engineering (final semester), Assam Don Bosco University (India).Her areas of interests are Renewable Energy, Power Systems.