ElectroSave/TransfoSave – Efficient Electrical Distribution System

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ABSTRACT

Keywords: Electricity Theft, Transformers, Energy Crisis, Internet of Things (IoT), Peshawar Electric Supply Company (PESCO), Power Distribution, Jazz, Key Point Indicators (KPIs)

Considering the fast growth of technologies across the globe, energy consumption has exponentially risen up, leaving far behind the generation and availability due to irregularities. The biggest threat to energy industry mainly depends on the transmission losses and theft, which is causing billions of dollars annual deficit. In order to overcome energy crises in Pakistan, a modern yet effective system is required to regularize the energy consumption by taking drastic measures. Jazz and Company of Intelligent Systems & Network Research (CISNR) has joined hands to develop a smart and efficient system named as ElectroCure/TransfoCure. It is a system designed to cater not only electricity theft; it also provides a platform to reduce transmission losses. As sample area has identified for experimentation purpose, targeting more than a hundred thousand beneficiaries.

With the passing time, energy crises in Pakistan are getting worse. Annual losses are crossing billions of dollars, including theft and line losses. Per initial working, Pakistan has areas where these losses are approaching 20-30% approximately. of the total generation capacity. If timely measures are not taken, situation will get worse. As energy drives everything, from households to official matters, development projects to recreational activities, everything is dependent on electricity. Since we do not have a substantial energy alternative for electricity, we need to regularize the consumption to meet the basic requirements of the people.

- A smart, efficient yet comprehensive solution to monitor, manage and control electricity distribution system
- Cost reduction for both consumer and provider by introducing meter-less billing system
- Minimize the annual deficit of billions of dollars in country's circular debt

Chapter 1
Introduction

1.1. Problem Statement

Pakistan has been facing a major problem of electricity theft and distribution losses, and it is responsible for major economic problems in our society. The biggest threat to the energy industry mainly depends on transmission losses and theft, which is causing billions of dollars in annual deficit. In order to cater to the problem of electrical power loss in Pakistan, we need to come up with a product that not only monitors electricity theft and transmission losses but also reports them.

1.2. Background Information

Electricity theft is on the rise globally, and deception can be done through illegitimate provisioning (bypassing meter connections), stopping the revolving disk of energy meters, meter meddling, physical demolition of energy meters, and fake billing. Energy theft is a common occurrence in most regions of the world. Energy theft is a growing problem and struggles for utilities all over the world; it is estimated that each year, theft costs the global economy between $80 and $100 billion (Aggarwal, 2022). This is a global problem that not only raises prices for paying customers and requires expensive government subsidies, but it also poses a threat to public safety in several nations due to risky illegal power connections. High non-technical losses are a challenge to the financial viability of energy utilities in many nations. In India, 7169 power theft cases were detected from 2020-21 resulting in a loss of Rs 87 crore, this number increased to 13,370 cases from 2021-22 which caused a total of Rs 264 crore worth of electricity (Sen, 2022) Pakistan falls among nearly 102 countries that face the impacts of electricity theft concern due to the political situations, advanced corruption, weak infrastructure, appointments of non-technical staff, low-level government proficiency, and deficiency of accountability, law and order situations (Hussain, Memon & Shah, et al., 2016).

A significant worldwide challenge today is climate change. Attaining global decarbonization calls for an improvement in the global energy system. However, energy theft in developing countries like Pakistan, India, and South Africa limits the progress of global efforts in the reduction of greenhouse gas emissions (Gupta, 2022).

As per the report of Northeast Group (Scott, 2014). it was reported $89.3 billion in losses occurred during the year 2015 annually. In India, it was stated that the economic losses are $16.2 billion from its income due to electricity theft, Brazil lost $10.5 Billion, USA lost $6 billion, Russia $5.1 billion, and Pakistan $0.89 billion respectively. Figure 1 summarizes all the mentioned country's economic losses due to theft.

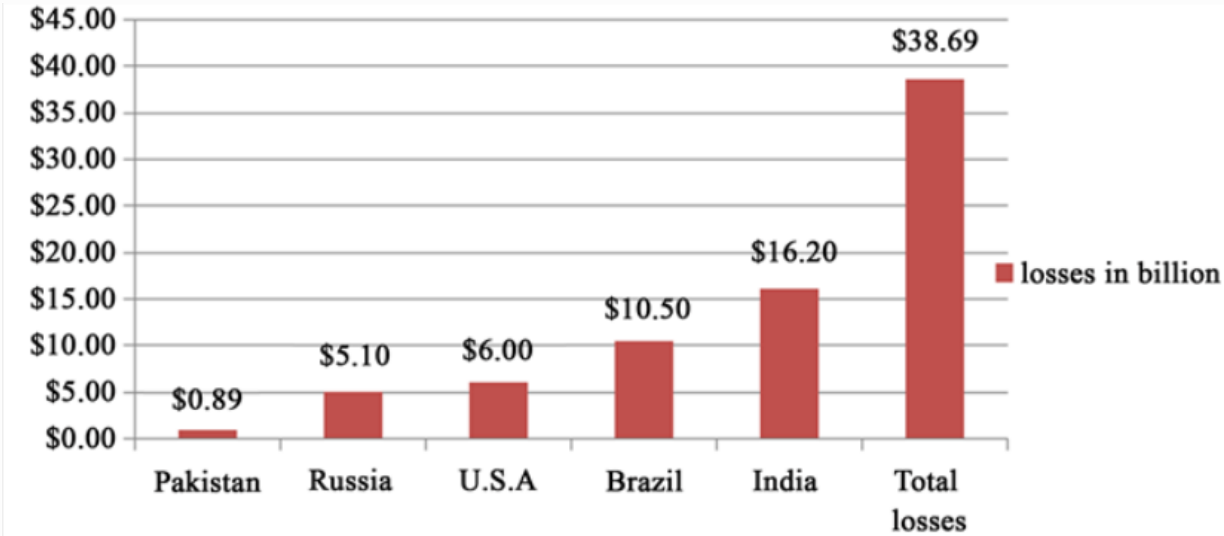


Figure 1: **World economies lose billions of dollars per year by electricity theft**

There are essentially two types of losses, namely, technical losses and non-technical losses during the transmission of electricity. These issues are faced not only by under-developed countries but also by developed countries and it is affecting the economies of these countries tremendously. The majority of electricity theft happens due to non-technical losses area of the power sector. Non-technical losses are relatively hard to account for as these losses occur more frequently and power companies do not have an effective mechanism in place to control these losses. Consequently, these losses disrupt the power supply chain, rise the power load on grid stations, and increase bills imposed on customers. Technical losses are ordinary losses occurred regularly in the power sector and these losses are produced by the physical organizational properties of the power system. Technical losses largely contain within a lossy transmission line, substation transformers, and electrical network losses (Hussain, Memon & Shah, et al., 2016).

The problem of electricity theft has socioeconomic, political, environmental, and technical origins, but the solution is commonly pursued exclusively through technical measures. We need to come up with a solution for energy theft and line losses faced in Pakistan to prevent revenue leakages.

The impact of electricity theft is not only left to the institutional organizations of the particular segment but globally upon countries as well. As a consequence of electricity theft, it averts countries from:

a) Lessening tariffs paid by customers
b) Subsidizing electricity utilization of complex users
c) Broadening access to electricity to the unserved population (the poverty-stricken and socially challenged)

Consequently, electricity loss abolishment becomes the top vital task for any country for bringing comfort and welfare to its citizens and increasing the standard of living of its citizens. Determined by the scale of the problem, countries look for cost-effective and efficient solutions in advanced technologies such as smart metering. Even though, with the availability of advance technological systems, theft and losses are increasing by the day, suggesting that technology on its own is not adequate to cater to this threat (Sharmaa, Pandey & Punia, , et al., 2016).

1.3. Types of Energy Theft

There are majorly two types of energy losses, namely, technical losses and non-technical losses. Technical energy losses happen infrequently to all utilities and are generally easily resolved by refining infrastructure, but non-technical losses are more problematic as they are the units of energy left unaccounted for (and unpaid for) and thus considered energy theft. The NEPRA's State of Industry Report, 2022 said that during the year, the permissible transmission and distribution (T&D) losses for the DISCOs were 13.41% whereas actual losses were 17.13% (Ahmadani, 2022). Energy theft transpires in three main ways:

a) ***Direct theft*** – The phenomenon when a customer partially or totally bypasses the meter using an unlawful connection mechanism so actual utilization is not recorded and reported. This is a common occurrence in developing countries like Pakistan where low-income people rely heavily on electricity theft to reduce their bills.
b) ***Tariff misuse*** – This is the case when a customer's electricity use type is misinterpreted, and an imprecise lower tariff is applied (i.e., energy use may be depicted as a residential property while in reality it is used for commercial purposes). This mainly happens in places like India and some Middle Eastern countries, where the government provides partial subsidiary on residential energy and the common people take advantage of tariff misuse in their favour.
c) ***Meter tampering*** – This occurs when the meter itself is tampered with to prevent consumption from registering. Most typically, a diversion is installed within the meter to

"jump" the connection between grid supply and premises wiring, either bypassing energy or causing the meter to run slowly (Gupta, 2022).

1.4. Broad Problem Area

With the modernization and advancement of technologies across the globe, energy demand is on the rise exponentially, with energy theft following the trend. Electricity theft is getting worse day by day and threatening the energy industry at large. As a consequence of electricity theft, the country's public sector distributors (DISCOs) lost more than Rs. 2.8 billion in the fiscal year 2021-2022. Furthermore, the collective economic losses annually as a result of electrical power theft at the commercial, domestic, and industrial level are Rs 90 billion in totality.

The National Electric Power Regulatory Authority (NEPRA) has communicated that high Transmission and Distribution (T&D) losses united with low recoveries are the main grounds for the accrual of circular debt, which has now approached Rs 2,252,750 million as of June 2022. As per NEPRA's report on the State of Industry 2022, DISCOs recoveries during FY 2021-22 were 90.51% as compared to 97.30% during FY 2020-21, i.e. almost 7% less than the previous financial year.

It has become vital for the Pakistani government to take the necessary steps required for corrective measures and improvement in the distribution system companies. The main reasons for the accumulation of circular debt are high transmission and distribution losses and low recoveries, which are now at Rs. 2,252,750 million as of July 2022. The losses and recoveries of DISCOs, particularly Tribal Areas Electric Supply Company (TESCO), Hyderabad Electric Supply Company (HESCO), Sukkur Electric Supply Company (SEPCO), Peshawar Electric Supply Company (PESCO), and Quetta Electric Supply Company (QESCO) need to be improved.

1.5. Existing Gap in the Market

According to official reports, Pakistani electricity supply companies have accumulated annual losses of 27%. Internationally accepted transmission and distribution losses are at 6%, however, they are experiencing unaccounted electricity losses of 21% (Yasin, 2018), worth Rs. 473 Billion. Major contributing anomalies for electricity theft are meter tampering, theft from transmission and distribution lines, billing irregularities, and unpaid bills. The Senate Public Accounts Committee (PAC) for power reported that the country sustained a Rs. 473 billion line losses annually and Peshawar Electric Supply Company (PESCO) is at the top of the list on the line losses which are up to 37.2% while District Bannu tops the electricity theft (Yousafzai, 2022).

The above has serious consequences for the electricity user. Either a premium is charged to ensure the uptime of electricity or significant electricity rationing (load-shedding) happens across Pakistan. Power theft continues to torment the country as increasing load shedding brings suffering to the citizens especially the ones belonging from low income areas. By bringing ground visibility to electricity grid distribution and usage patterns, electricity companies can reduce the risk of line loss and theft. Therefore, they can improve the accessibility of electricity significantly.

Jazz, a leading mobile operator in Pakistan, was awarded a grant from the GSMA Mobile for Development utility program to demonstrate how mobile technology can support electricity network monitoring and household cluster metering, reduce electricity theft and feeder loss for grid distributors, and to enhance service and billing efficiency for end consumers.

Considering the fast growth of technologies across the globe, energy consumption has exponentially risen up, leaving far behind the generation and availability due to irregularities. In order to overcome energy crises in Pakistan, a modern yet effective system is required to regularize energy consumption by taking drastic measures. Jazz and Company of Intelligent Systems & Network Research (CISNR) has joined hands to develop a smart and efficient system named as ElectroSave/TransfoSave. It is an automated meter reading system designed to cater not only to electricity theft; it also provides a platform to reduce transmission losses. As a sample area, Peshawar has been identified for experimentation purposes, targeting more than a hundred thousand beneficiaries.

Peshawar Electric Supply Company (PESCO) is the only electricity company responsible for electricity distribution across the whole province of Khyber Pakhtunkhwa (KP). That is why the organization’s size and network are vast and distributed across various districts of Khyber Pakhtunkhwa (KP). While it covers most of the developed cities and towns, it also covers the rural areas of the province and villages where the literacy rate is very low. Apart from these rural areas, the newly merged Federally Administered Tribal Areas (FATA) region into the province has increased PESCO’s responsibility. Since FATA has suffered over the years due to its hostile situation, the electricity was distributed over the region free of cost. While after the merger with Khyber Pakhtunkhwa (KP), the consumers were introduced to electricity bills that were not conventional to the consumers, and therefore, the recovery was low from the region. Moreover, in some regions of the province in addition to technical/line losses, there was electricity theft as well. That is why PESCO had been losing billions of revenues due to electricity losses.

With the passing of time, energy crises in Pakistan are getting worse. Annual losses are crossing billions of dollars, including theft and line losses. Per initial work, Pakistan has areas where these losses are approaching 20-30% approximately. of the total generation capacity. If timely measures are not taken, the situation will get worse. As energy drives everything, from households to official matters, development projects to recreational activities, everything is dependent on electricity. Since we do not have a substantial energy alternative for electricity, we need to regularize the consumption to meet the basic requirements of the people.

The whole model of the proposed solution of ElectroSave and TransfoSave is inspired by the smart metering solution, however without the presence of any smart meter. Metering without the meter is a rather unique idea. In this solution, a single module can be shared by multi-consumers, thus reducing the cost per consumer for smart metering implementation. This solution can be easily integrated with the current electricity infrastructure, without completely revamping the whole setup. It can be an ideal solution for third-world countries that are facing huge line loss through electricity theft. This solution provides real-time data acquisition for the electricity distribution network, metering, monitoring, and control.

1.6. Contribution of Research

Conventionally, the detection of electricity theft has widely depended on meter readers and service staff for keeping an eye on the meter and reporting it in case they feel any discrepancies. However, this method is not very efficient as service staff cannot be available on sites 24/7 for data analysis. At most, meter readers may visit each meter on monthly basis to collect data, which may not be a very efficient way to analyze and report electricity theft and it's a highly unreliable line of defense. There comes a need for an Automatic Meter Reading (AMR) system that is an efficient solution for automating the manual task of meter reading so human dependency can be removed from this significant function. With the solution that is being documented, no one needs to keep an eye on the utility's cash register and updates will be shared with the monitoring party on a need basis.

Additionally, Automated Meter Reading (AMR) systems are a solution to provide interference flags that are intended to categorize energy theft when tampering occurs at the meter, along with warning the utility tampering to the monitoring side by making use IoT-based smart metering solution. This device provides real-time data to its consumers. AMR may not be a flawless solution for detecting theft and losses as many consumers may find ways around it to bypass the solution wholly or to tamper with it without triggering any alarms (Madrazo, 2009).

A prototype of the gadget (ElectroSave / TransfoSave) has been manufactured but test run trials are yet to be practiced. This project deals with the test run - trial results of the gadget. The observations collected from the test run will be analyzed and the recommendations will be proposed to the company for the effective functioning of the product before its official launch in the market.

1.6.1. ElectroSave

ElectroSave is a low-cost smart IoT-based metering solution with a unique meter-less architecture. The device is installed on the consumer level for the real-time metering, monitoring, and control of electricity distribution. It's an efficient solution to cater to line losses detection and electricity theft. The ElectroSave solution features remote power on/off control, demand response, and an interactive interface. This prototype ensures secure billing that will allow automatic billing, calculate line loss, and use wireless sensor networks to find electricity theft at the source. Additionally, this secure surveillance system will prove to be efficient in tackling power theft issues as the data directly taken from the grid to a centrally controlled database in the electricity supply company leaves room for no end-user involvement. Consumers would be unable to tamper with meters or wires at their end. Similarly, the product also aims to address the problem of billing irregularities. A Smart High Voltage Distribution System (HVDS) is introduced by ElectroSave's advanced feature for dependable and secure electricity distribution.

ElectroSave has many benefits to Pakistan's growing energy crisis and electricity losses. Firstly, it proves to be useful in the reduction of not only electricity theft but also technical losses and administrative losses. Since the product uses remote technology to automatically send alerts and data to the central billing system, it reduces HR costs. Moreover, the system would eradicate the necessity for meter readers in Pakistan, ending the practice of bribery and other illegal human intervention-based actions. The innovation of ElectroSave is the key factor in a technology and knowledge-based economy that may yield the greatest benefits across a range of sectors including agriculture, energy, resources, water, and IT.

1.6.2. TranfoSave

TransfoSave is another IoT-based device installed on Transformers for the real-time metering, monitoring and control of electricity distribution on transformer level. It provides numerous run-time parameters such as, voltage level, power factor, link status, short-circuits, load-balancing & phase shifts to the user. It protects the transformer from hefty damages due to overloading & unbalanced load connectivity .

TransfoSave is a load-balancing transformer device that includes an automated system for monitoring and regulating transformers, data collection and control, and an effective and intelligent approach for eliminating any inappropriate, ineffective, or error-prone tasks. It is an efficient device that enhances the equipment’s lifetime by load-balancing, monitoring and reporting. The product offers plenty of features like monitoring of voltage, remote current, KVA, KVAR, PF, graphs showing trends for KVA, KVAR, power factor, and voltage, peak/Off-peak time adjustment, and real-time consumption, a summary of Transformers and boxes (Description & location etc.), detection and reporting of transformer faults, logs and graphs of consumption, specific information of users, link failure detection, load imbalance detection, and meter programming. Lastly, the product will also calculate power factor for real, apparent, and reactive power.

TranfoSave will be developed according to international standards and needs to make the best possible solution for Pakistan. It provides run-time characteristics, including phase shifts, link downs, short circuits, and power factors as well as voltages, currents, and power factors. By shielding the transformer from overloaded and unbalanced loads, it prevents damage. TransfoSave will also help in reducing costs by decreasing technical and administrative losses.

A smart, efficient yet comprehensive solution to monitor, manage and control the electricity distribution system and account for the losses that are happening due to electricity theft. Not only does it monitor and report line losses and electricity theft, but it also provides a cost reduction model for both consumer and provider by introducing a meter-less billing system. Both of these products can be considered as a solution to deal with meter tampering and bypassing to reduce electricity theft. It can also minimize the annual deficit of billions of dollars in the country’s circular debt.

Chapter 2

Literature Review

In this comprehensive literature review, we will delve into multiple papers that focus on the critical issue of electricity theft and its detection and prevention. Electricity theft poses significant challenges for utility companies worldwide, resulting in substantial financial losses and compromising the integrity and safety of power systems. The selected papers shed light on various approaches, methodologies, and technologies that have been proposed and implemented to address this pervasive problem in diverse contexts. From advanced metering infrastructure systems to Internet of Things (IoT)-enabled solutions and machine learning algorithms, these papers provide valuable insights into the strategies used to detect, prevent, and mitigate the impact of electricity theft. Furthermore, the review includes studies that investigate consumer perception towards electricity theft, analyze relationships between variables using path analysis, and evaluate the effectiveness of different models and systems in specific regions, such as Pakistan and India. By examining and synthesizing these research works, we aim to develop a comprehensive understanding of the existing methodologies, innovative techniques, and emerging trends in electricity theft detection and prevention. This knowledge will not only contribute to the academic discourse but also provide practical insights for policymakers, utility companies, and stakeholders seeking effective strategies to combat electricity theft and safeguard the reliability and sustainability of power systems in the face of this persistent challenge.

2.1 Advanced Metering Infrastructure Systems

In their paper on power theft detection and automatic elimination, Sourav Tarafder and Kamalika Banerjee discuss several approaches that have been proposed for detecting and preventing power theft. Power theft is a serious problem in many parts of the world, as it can lead to significant financial losses for utilities and can also be dangerous due to the potential for electrical accidents. There are several approaches that can be taken to detect and eliminate power theft.

One approach is to use monitoring equipment to detect unusual patterns of power usage that may indicate theft. This can involve installing meters or sensors at key points in the power distribution system, such as at transformers or at the point of service for individual customers. The data collected by these sensors can then be analyzed using machine learning algorithms or other techniques to identify unusual patterns that may indicate power theft (Tarafder & Banerjee, 2019).

Another approach is to use advanced metering infrastructure (AMI) systems, which can provide more detailed and accurate information about power usage at the customer level. AMI systems typically include smart meters that can be installed at individual customer premises, as well as communication infrastructure and software for collecting and analyzing data from the meters. By using AMI systems, utilities can more accurately detect and track power theft, and can also identify other issues such as energy waste or inefficiencies in the power distribution system.

There are also several technologies that can be used to automatically eliminate power theft, such as automated disconnection systems and smart switches that can be remotely controlled to cut off power to specific customers or areas. These systems can be triggered by alarms or other alerts indicating potential power theft, and can help to prevent further losses and protect the integrity of the power distribution system.

Overall, the use of advanced monitoring and control technologies can be an effective way to detect and eliminate power theft, helping utilities to improve their financial performance and ensure the safety and reliability of their power systems.

The data set for this paper has been taken from India, which will facilitate predicting cultural and social trends in Pakistan as well. The several approaches mentioned in this paper help understand the existing methodologies that are being used to detect and prevent electricity theft in our neighbouring country India and a similar used case will be applicable in Pakistan as well.

2.2 Power Theft in Pakistan

This paper discusses the problem of power theft in Pakistan and the challenges faced by the power distribution companies in detecting and preventing it. The authors present a new and improved model for power theft detection that is more efficient and effective than previous models. It discusses the various components of the model and explains how it works, including the use of advanced technologies such as data analysis, artificial intelligence, and machine learning.

Data and statistics is presented to support the effectiveness of the proposed model and compared the results of the new model with those of previous models and demonstrate how it can help reduce the occurrence of power theft in Pakistan. It further discusses the implementation process of the proposed model and the steps required for its successful deployment. Furthermore, any potential challenges or limitations are discussed in the paper and multiple recommendations are mentioned for overcoming them (Afridi & Wahab, et al., 2021).

The proposed model is likely more efficient and effective than previous models and has the potential to reduce the occurrence of power theft in Pakistan. The paper may provide valuable information for policy-makers, power distribution companies, and other stakeholders interested in finding solutions to the problem of power theft in Pakistan.

In this paper, new and advanced techniques like data analysis, artificial intelligence, and machine learning are used to develop a model that helps analyze and eliminate power theft in Pakistan. It is crucial to understand the existing techniques already developed using new methodologies and it with further facilitate us in developing our IoT-based product to deal with electricity theft.

2.3 Adaptive Neuro-Fuzzy Inference System

This paper discusses several approaches that have been proposed for detecting and preventing electricity theft. Electricity theft is a significant problem in many power distribution grids, as it can lead to financial losses for utilities and can also compromise the reliability and safety of the power system. One approach that has been proposed for detecting electricity theft is the use of an adaptive neuro-fuzzy inference system (ANFIS).

ANFIS is a type of machine learning algorithm that combines elements of both fuzzy logic and artificial neural networks. It is designed to be able to learn from data and adapt to changing conditions, making it well-suited for use in power systems where conditions can vary widely over time (Blazakis, Kapetanakis, & Stavrakakis, 2020).

To use ANFIS for electricity theft detection, data on power usage and other relevant variables would be collected from sensors or meters installed at key points in the power distribution system. This data would then be fed into the ANFIS algorithm, which would use it to build a model of normal power usage patterns. Any deviations from these normal patterns could then be flagged as potential instances of electricity theft.

One potential advantage of using ANFIS for electricity theft detection is that it can handle complex and non-linear relationships between variables, which may be present in power systems. It can also adapt to changing conditions over time, allowing it to maintain accuracy even as power usage patterns or other variables change.

Overall, the use of ANFIS and other machine learning algorithms may be a promising approach for detecting electricity theft in power distribution grids, helping utilities to reduce financial losses and improve the reliability and safety of their power systems. By using machine learning and IoT, utilities can improve the efficiency of their operations and reduce the financial losses incurred due to electricity theft. This can lead to improved energy efficiency and cost savings, which can be passed on to customers in the form of lower bills, which is the major reason for developing our device.

2.4 Smart Energy Theft System

In this paper the author has proposed the smart energy theft system (SETS) for detecting and preventing energy theft in smart homes that use the Internet of Things (IoT). Energy theft is a serious problem in many parts of the world, as it can lead to significant financial losses for utilities and can also be dangerous due to the potential for electrical accidents.

The SETS system is based on the use of smart meters and other IoT devices to monitor and control energy usage in smart homes. The system includes a central controller that receives data from the smart meters and other devices, and uses machine learning algorithms to analyze the data and detect any unusual patterns that may indicate energy theft (Li, Logenthiran, Phan & Woo, 2019).

If energy theft is detected, the SETS system can take a variety of actions to prevent it. For example, it could remotely disconnect the power to the home, alert the utility or other authorities, or trigger an alarm to alert the homeowner. The system can also be configured to allow the homeowner to override any actions taken by the system, if desired.

Overall, the SETS system represents a promising approach for detecting and preventing energy theft in smart homes, helping to reduce financial losses for utilities and improve the safety and reliability of the power system. By using IoT technologies and machine learning algorithms, the SETS system can provide a highly effective and efficient way to monitor and control energy usage in smart homes. This is an existing IoT-based housing system used to monitor and prevent electricity theft and referring to this model, we can develop our product as well.

2.5 Use of IoT for Electricity Theft Detection

This paper discusses that the Internet of Things (IoT) can be used to help detect and prevent electricity theft, which is a significant problem in many parts of the world. Electricity theft can lead to financial losses for utilities and can also compromise the reliability and safety of the power system.

One approach to using the IoT for electricity theft detection is to install smart meters or other sensors at key points in the power distribution system. These devices can collect data on power usage and other relevant variables, and transmit the data to a central controller using wireless communication technologies (Khairnar & Khairnar, 2018).

The central controller can then use machine learning algorithms or other techniques to analyze the data and identify any unusual patterns that may indicate electricity theft. If electricity theft is detected, the controller can take a variety of actions to prevent it, such as remotely disconnecting the power to the affected customer or alerting the utility or other authorities.

Overall, the use of the IoT and machine learning algorithms can be an effective way to detect and prevent electricity theft in power distribution grids. By providing real-time monitoring and control capabilities, the IoT can help utilities to reduce financial losses and improve the reliability and safety of their power systems. The findings in this paper are closely linked with our product as it is also a smart metering device deployed on commercial level.

2.6 IoT-enabled Mobile Devices

Real-time energy monitoring in Internet of Things (IoT)-enabled mobile devices refers to the ability to collect and analyze data on energy usage in real-time, using sensors and other IoT technologies. This can be useful for a variety of applications, including energy management, energy conservation, and detecting and preventing energy theft.

One approach to real-time energy monitoring in IoT-enabled mobile devices is to use sensors and other devices to collect data on energy usage, such as the amount of electricity being consumed or the power draw of specific appliances or devices. This data can then be transmitted to a central controller using wireless communication technologies, such as Wi-Fi or Bluetooth (Shivaraman, Saki, Liu &Ramanathan, 2020).

The central controller can then use machine learning algorithms or other techniques to analyze the data in real-time, providing insights into energy usage patterns and identifying any unusual or anomalous behavior that may indicate energy theft or other issues.

Real-time energy monitoring in IoT-enabled mobile devices can be useful for a variety of applications, such as helping homeowners to manage their energy usage and save money on their utility bills, or helping utilities to detect and prevent energy theft. By providing real-time insights into energy usage patterns, this technology can help to improve the efficiency and reliability of energy systems. This research was done in India and it helps us understand that IoT based devices are an efficient way to deal with power theft and how mobile devices are reliable for IoT-based power theft solutions.

2.7 IoT & Machine learning Algorithms for Energy Theft Prevention

IoT-based energy metering and theft detection is a system that uses the Internet of Things (IoT) to monitor and control energy usage, with the goal of detecting and preventing energy theft. Energy theft is a serious problem in many parts of the world, as it can lead to significant financial losses for utilities and can also compromise the reliability and safety of the power system.

One approach to using the IoT for energy metering and theft detection is to install smart meters or other sensors at key points in the power distribution system. These devices can collect data on energy usage and other relevant variables, and transmit the data to a central controller using wireless communication technologies.

The central controller can then use machine learning algorithms or other techniques to analyze the data and identify any unusual patterns that may indicate energy theft. If energy theft is detected, the controller can take a variety of actions to prevent it, such as remotely disconnecting the power to the affected customer or alerting the utility or other authorities.

Overall, the use of the IoT and machine learning algorithms can be an effective way to detect and prevent energy theft in power distribution grids. By providing real-time monitoring and control capabilities, the IoT can help utilities to reduce financial losses and improve the reliability and safety of their power systems.

2.8 IoT-based Power Theft Detection in India

In their paper on IoT-based power theft detection and tracking, Dr. A. Rajasekaran, P. Ajay Sai, P. Bhanu Teja, P.G.S. Swetha Priya discuss the use of the Internet of Things (IoT) to detect and prevent power theft in power distribution grids.

Power theft is a significant problem in many parts of the world, as it can lead to financial losses for utilities and can also compromise the reliability and safety of the power system. One approach to detecting and preventing power theft is to use the IoT to monitor and control power usage in real-time (Uddanti, Joseph, & Kishoreraja, 2017).

The authors propose a system that uses smart meters or other sensors to collect data on power usage and other relevant variables, and transmit the data to a central controller using wireless communication technologies. The central controller can then use machine learning algorithms or other techniques to analyze the data and identify any unusual patterns that may indicate power theft. If power theft is detected, the controller can take a variety of actions to prevent it, such as remotely disconnecting the power to the affected customer or alerting the utility or other authorities.

Overall, the use of the IoT and machine learning algorithms can be an effective way to detect and prevent power theft in power distribution grids. By providing real-time monitoring and control capabilities, the IoT can help utilities to reduce financial losses and improve the reliability and safety of their power systems.

2.9 Potential of IoT in Reducing Electricity Theft

The issue of electricity theft poses significant challenges for utility companies, resulting in financial losses and compromised system integrity. Maninderpal Singh and Er. Varun Sanduja propose utilizing the Internet of Things (IoT) to minimize electricity theft. Their work emphasizes the potential of IoT-based monitoring and detection systems in identifying abnormal usage patterns and detecting theft incidents in real-time.

IoT enables the integration of smart meters, sensors, and communication networks to collect and analyze power consumption data. By employing data analytics and machine learning techniques, patterns and anomalies can be identified, enhancing the accuracy of theft detection systems. Furthermore, automated response mechanisms triggered by IoT systems, such as remote disconnection or notification alerts, offer proactive measures to deter and minimize theft occurrences.

Privacy and security considerations are paramount in IoT-based theft prevention systems. Protecting sensitive customer data through secure communication protocols, encryption techniques, and access control mechanisms is essential. Singh and Sanduja also highlight the cost-effectiveness and scalability of IoT solutions. Despite initial investments, the long-term benefits of reduced theft losses outweigh the costs, while scalability allows for broader coverage and future technological advancements.

In summary, Singh and Sanduja's research underscores the potential of IoT in mitigating electricity theft. Through IoT-based monitoring, data analytics, and automated response mechanisms, utilities can enhance their ability to detect and prevent theft, leading to improved financial performance and system integrity. Addressing privacy and security concerns and considering the cost-effectiveness and scalability aspects are crucial for successful implementation. Further exploration and implementation of IoT-based approaches are needed to assess their real-world effectiveness and address practical challenges.

2.10 Development of Electricity Theft Detection System in Pakistan

The development of an electricity theft detection system involves designing and implementing a system that can detect and prevent unauthorized use of electricity, which is a significant problem in many parts of the world. Electricity theft can lead to financial losses for utilities and can also compromise the reliability and safety of the power system (Singh & Sanduja, 2015).

In this paper, there are several approaches that can be taken to develop an electricity theft detection system, depending on the specific requirements and constraints of the system. Some common elements of such a system might include:

Monitoring equipment: This could include sensors, meters, or other devices that collect data on electricity usage and other relevant variables. These devices would typically be installed at key points in the power distribution system, such as at transformers or at the point of service for individual customers.

Communication infrastructure: This would typically include wireless or wired communication technologies that allow the monitoring equipment to transmit data to a central controller.

Central controller: This would be a central hub or server that receives data from the monitoring equipment and processes it using machine learning algorithms or other techniques. The central controller would be responsible for identifying any unusual patterns that may indicate electricity theft and taking appropriate actions to prevent it.

Control systems: This could include automated disconnection systems or smart switches that can be remotely controlled to cut off power to specific customers or areas in the event of electricity theft.

Overall, the development of an electricity theft detection system requires a combination of hardware and software components, as well as careful planning and design to ensure that the system is effective and efficient at detecting and preventing electricity theft. This particular research has been done in Pakistan, making it more relevant to our paper. [

2.11 Data-Driven Strategies for Energy Theft Detection in Smart Grids

In their survey on energy theft in smart grids, Ahlam Althobaiti, Anish Jindal, Angelos K. Marnerides, and Utz Roedig discuss the various data-driven attack strategies and detection methods that have been proposed for detecting and preventing energy theft.

Energy theft in smart grids refers to the unauthorized use of electricity in a manner that bypasses or circumvents the normal billing and payment processes. This can lead to significant financial losses for utilities, as well as compromising the reliability and safety of the power system (Althobaiti, Jindal, Marnerides & Roedig, 2021)

One approach to detecting and preventing energy theft in smart grids is to use data analytics and machine learning techniques to analyze data collected from smart meters and other monitoring equipment. By identifying unusual patterns or anomalies in the data, it may be possible to detect instances of energy theft and take appropriate actions to prevent it.

The survey discusses several data-driven attack strategies that have been proposed for detecting energy theft in smart grids, including the use of pattern recognition algorithms, anomaly detection algorithms, and data mining techniques. It also discusses various detection methods that have been proposed, including the use of smart meters, advanced metering infrastructure (AMI) systems, and automated disconnection systems.

Overall, the survey suggests that a combination of data analytics and machine learning techniques, along with monitoring equipment and automated control systems, may be effective approaches for detecting and preventing energy theft in smart grids. By providing real-time monitoring and control capabilities, these approaches can help utilities.

2.12 Perception of Electricity Theft: Path Analysis Study in Twin Cities

This paper evaluates consumer’s perception towards electricity theft and research was done in Islamabad and Rawalpindi. Path analysis is a statistical technique that is used to evaluate the relationships between variables and to understand the nature of the relationships between them. It is a form of structural equation modeling, which is used to test theoretical models that describe relationships between variables.

In this paper, path analysis has been used to evaluate the relationship between consumers' perceptions of electricity theft and other variables, such as their attitudes towards electricity theft, their willingness to report electricity theft, and any other factors that may be related to their perceptions (Babar, Jami & Haq, 2022).

It is not uncommon for researchers to use path analysis to examine the relationships between variables in a variety of contexts, including social, economic, and psychological research. The technique is useful because it allows researchers to examine the strength and direction of relationships between variables and to identify any possible causal relationships between them.

Chapter 3

Impact Analysis & Discussion

3.1. About PESCO

Peshawar Electric Supply Company (PESCO) is a power distribution company in Pakistan that is responsible for distributing electricity to the Khyber Pakhtunkhwa province and its surrounding areas. PESCO's primary role is to ensure the reliable and efficient supply of electricity to its customers, which includes households, businesses, and industries. This involves the management and maintenance of the electrical infrastructure, such as power lines, substations, transformers, and meters, as well as the implementation of measures to reduce electricity losses and improve the quality of the electricity supply. PESCO also plays a key role in promoting energy conservation and encouraging the adoption of renewable energy sources in its service area.

To address the issue of electricity theft, PESCO has taken several measures, including increasing the number of surveillance teams, conducting regular inspections of high-loss feeders, installing tamper-proof meters, and imposing penalties on those caught stealing electricity. PESCO has also implemented a program to raise awareness among the public about the negative impacts of electricity theft and to encourage people to report incidents of theft.

In addition to these measures, PESCO has also implemented various technological solutions to reduce electricity losses, including the installation of high-tech meters and transformers, the deployment of automated systems for monitoring and controlling the distribution network, and the implementation of smart grid technologies. PESCO has also collaborated with law enforcement agencies to take legal action against electricity thieves and to promote a culture of compliance with the law.

3.2. Pre-implementation State of PESCO

Prior to the implementation of the ElectroSave and TransfoSave solutions, PESCO was experiencing substantial technical and line losses, which accounted for 32.6% of the overall infrastructure. Additionally, theft and administrative losses amounted to 11.65% of the infrastructure. In recognition of the urgent need to address these losses, PESCO designated two feeders within the border region of Peshawar for the implementation of the ElectroSave and

TransfoSave solutions. These feeders were chosen specifically due to their reputation as areas where line losses and power theft were particularly prevalent. One of the designated feeders was located in the Karkhano Market region, while the other was located in the Ring Road region. To establish a baseline for future analysis, pre-implementation statistics were collected and recorded. These statistics provide valuable insights into the state of PESCO's infrastructure prior to the implementation of the new solutions and serve as a reference point for evaluating the effectiveness of these solutions in reducing losses and improving efficiency. Pre-implementation statistics are as follows:

S/No.	Feeder Location	Average Load	No. of Transformers	Type of Consumers	% Losses (Monthly)	No. of Units Lost (Monthly)
1	Karkhano	6000KW	59	Domestic & Commercial	38.30%	187,945
2	Ring Road	6000KW	195	Domestic & Commercial	41.07%	88,371

Source: PESCO MIS

Table 1: Pre-Implementation Statistics of PESCO

As listed in the table above, the Karkhano feeder has 59 transformers while Ring Road 195 with a total load of 6000KW. TransfoSave units have been installed on 59 transformers in Karkhano feeder and 195 transformers in Ring Road feeder accounting for a total of 250 TransfoSave units installed.

The proposed solution, known as TransfoSave, is expected to effectively address technical and administrative losses, resulting in a significant reduction in the percentage of losses and leading to substantial savings in revenue for utility companies. TransfoSave is a system that can be installed on transformers and provides real-time monitoring of the distribution process. This monitoring system is capable of detecting any irregularities or anomalies that may occur during the distribution process and immediately alerting the relevant parties. By implementing TransfoSave, utility companies can optimize their operational efficiency, minimize revenue losses due to technical and administrative issues, and ultimately provide a more reliable and consistent electricity supply to their customers.

Based on the statistics provided, it is evident that there are significant infrastructure losses in PESCO. In an effort to address this issue, a pilot implementation of a new solution has been undertaken. This implementation has been carried out on two separate feeders in both the Karkhano and Ring Road regions. The objective of this pilot implementation is to measure the effectiveness of the proposed solution in reducing losses and improving the efficiency of the infrastructure. The results of this implementation will be detailed in the subsequent sections of this document, providing a comprehensive analysis of the impact that this new solution has on PESCO's infrastructure. By closely examining the results of this pilot implementation, PESCO can gain valuable insights into how to optimize their infrastructure and minimize losses in the future.

3.3. Project Beneficiaries

Initially, ElectroSave and TransfoSave solutions were deployed in Peshawar in three solutions. The solution types were deployed, TransfoSave transformer controlled for residential customers, ElectroSave transformer controlled for residential customers and ElectroSave user controlled for domestic customers. With the help of this project both commercial and residential consumers will have access to improved and increased access to electricity supply. In the table no. 2, solution details are mentioned.

3.3.1. Total Number of Beneficiaries:

Solution Type	No of Units Installed	No. Beneficiaries per unit	Avg. People per Household	No. of In-direct Beneficiaries	Female Beneficiaries	Formula (Calculation)
TransfoSave	250	150	7	262,500	131,250[a]	(250 X 150 = 37,500 households) Avg. 7 people per household (37,500 X 7= 262,500 people)
ElectroSave-Transformer Controlled	5	50	7	1,750	875[b]	(5 X 50= 250 households) Avg. of 7 people per household

						(250 X 7 = 1750 people)
ElectroSave-User Controlled	5	250	1	1,250	125[c]	(5 X 250=1,250) Domestic Market
				Total:	**265,500**	**132,250**	

a – 1:1 (Female : Male)

b – 1:1 (Female : Male)

c – 1:10 (Female: Male)

Table 2: Total Number of Beneficiaries

3.4. Business Intelligence KPIs

3.4.1. Rollout of ElectroSave (May – August 2022)

ElectroSave is the device installed on the consumer level for the real-time metering, monitoring and control of electricity distribution. The number of ElectroSave units installed on the Karkhano feeder are 10, distributed over the transformers and subsequent consumers. Each ElectroSave device is catering to an average of 50 transformer-controlled consumers and 250 user-controlled consumers. Below are the post-implementation statistics of ElectroSave Aug 22 to Oct 22:

ElectroSave – Administrative (Theft) Losses (10 Transformers) Recovery					
S/No.	**Transformer #**	**Electricity-Units lost in 10 days (kWH)**	**Per month electricity-units lost (kWH)**	**Quarterly electricity-units lost (kWH)**	**Amount lost (PKR)**
1	TR 05	455	1,365	5,460	81,900
2	TR 139	3,167	9,501	38,004	570,060
3	TR 31	512	1,536	6,144	92,160
4	TR 160	7,040	21,120	84,480	1,267,200
5	TR 16	3,085	9,255	37,020	555,300

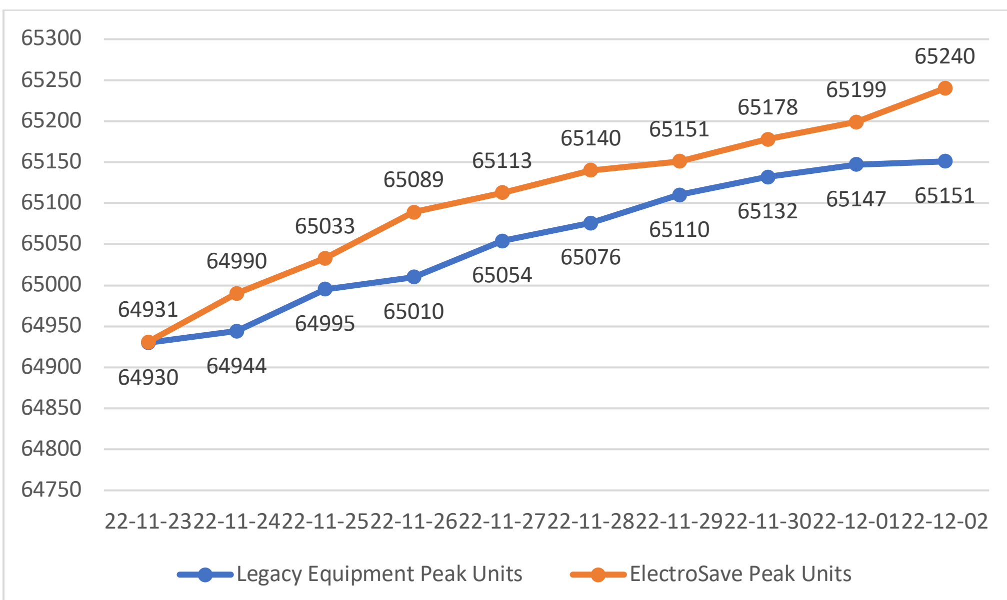
6	TR 89	2	6	24	360
7	TR 136	1,098	3,294	13,176	197,640
8	TR 83	3,010	9,030	36,120	541,800
9	TR 145	10	30	120	1,800
10	TR 122	284	852	3,408	51,120
Total		18,663	55,989	2,23,956	3,359,340

Table 3: Post-Implementation Statistics of ElectroSave

As seen from the table above, the corresponding data for Administrative Losses have been shown for a period of 4 months and the amount of revenue lost due to administrative losses in the infrastructure. The transformers running on high administrative losses e.g. TR#139, TR#160, TR#136, TR#83 etc., are losing a substantial number of electricity-units (kWh) on a monthly basis. If managed effectively, 3.35 Million PKR can be saved on just the listed 10 transformers. If scaled up, the savings would automatically cross billions of revenues.

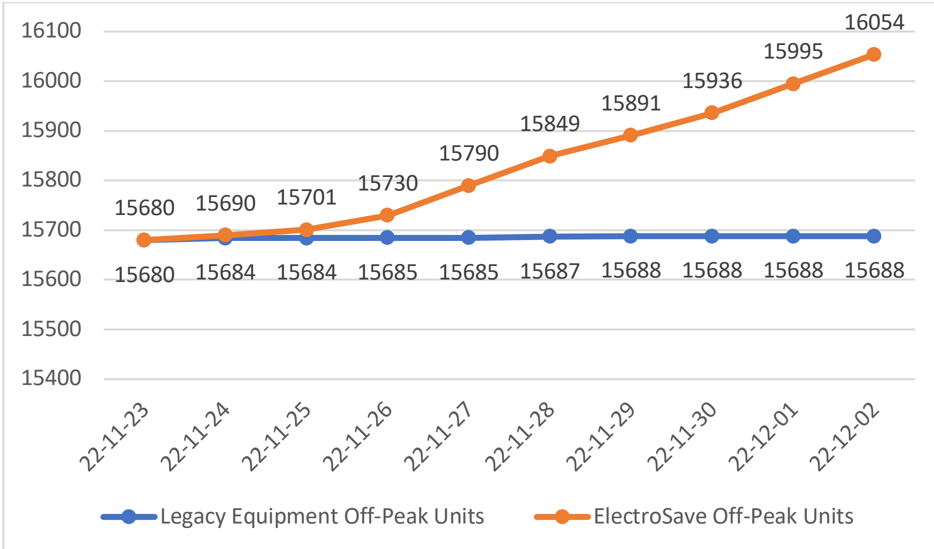
Legacy equipment is old tempered meters. A comparison between ElectroSave and legacy equipment (old meters) is shown as below for 4 sample transformers:

Figure 2: TR#5 Peak Units (kWh)



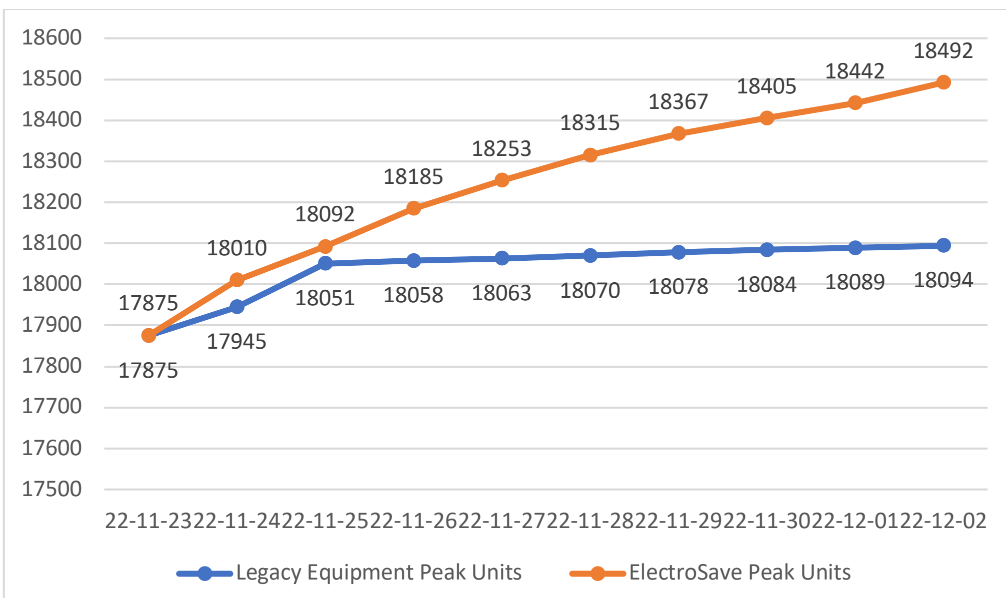
As per figure 2, after deploying ElectroSave on TR#5, the increasing trend of peak units remain similar to the legacy equipment. However, the trend line has moved upward, which confirms that there was an issue of electricity theft previously being faced in the area.

Figure 3: TR#5 Off-Peak Units (kWh)



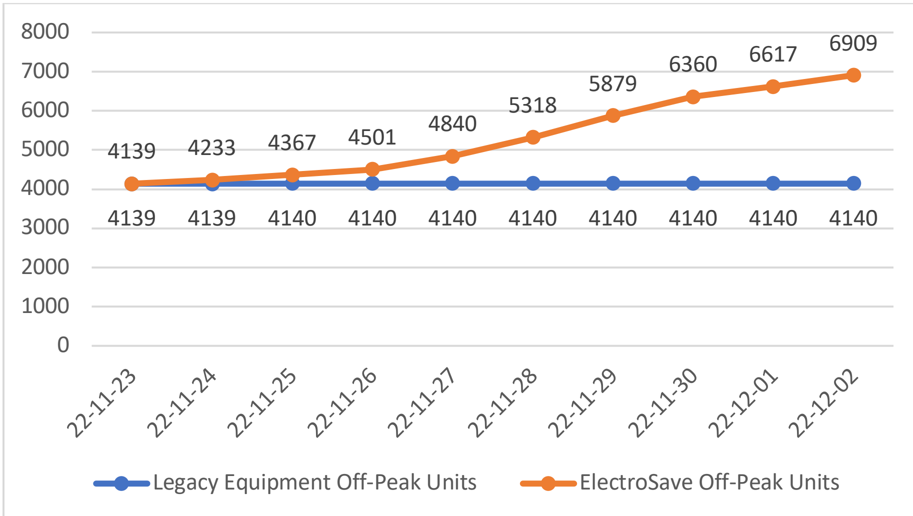
Referring to figure 3 we can see that after installation of ElectroSave on TR#5, the trend line of off-peak units has changed. While the trend line was constant prior to the deployment of ElectroSave, it can be noted that after deployment, it has an increasing trend.

Figure 3: TR#139 Peak Units (kWh)



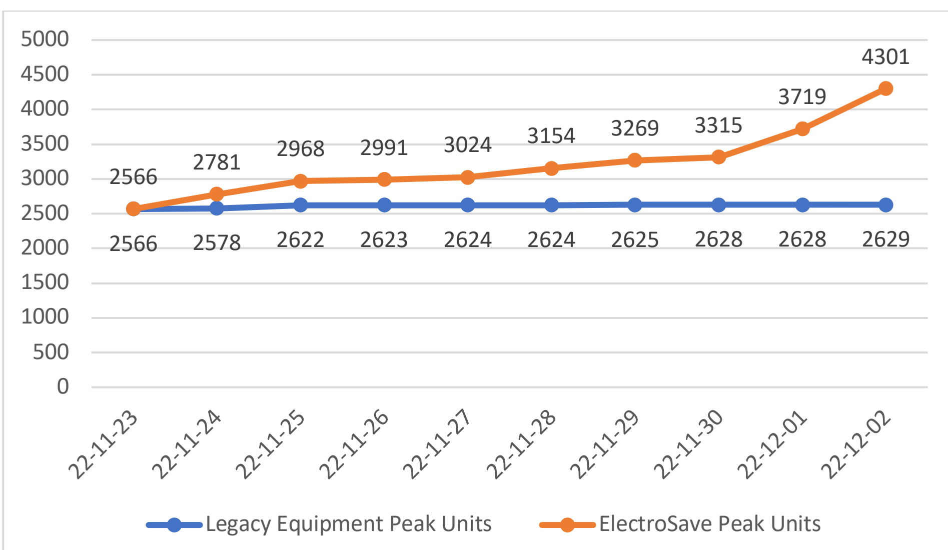
According to figure 4, for TR#139 during peak hours, trend line of legacy equipment is increasing initially and then becomes relatively constant. However, after deployment of ElectroSave, the peak units has a relatively linear increase

Figure 4: TR#139 Off-Peak Units (kWh)



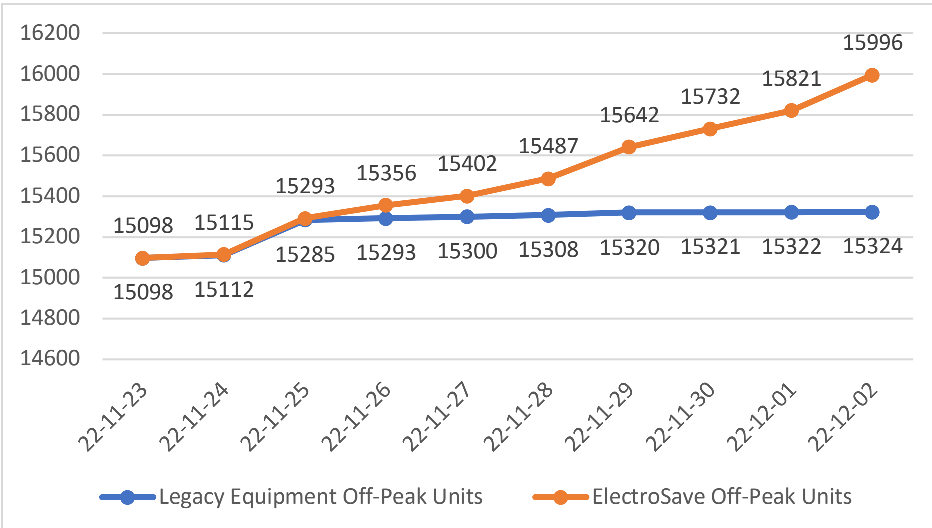
As per figure 5, with the legacy equipment, the trend line remains constant during the off-peak hours for TR#139. Although with the help of ElectroSave, it can be seen that the trend is increasing.

Figure 5: TR#136 Peak Units (kWh)



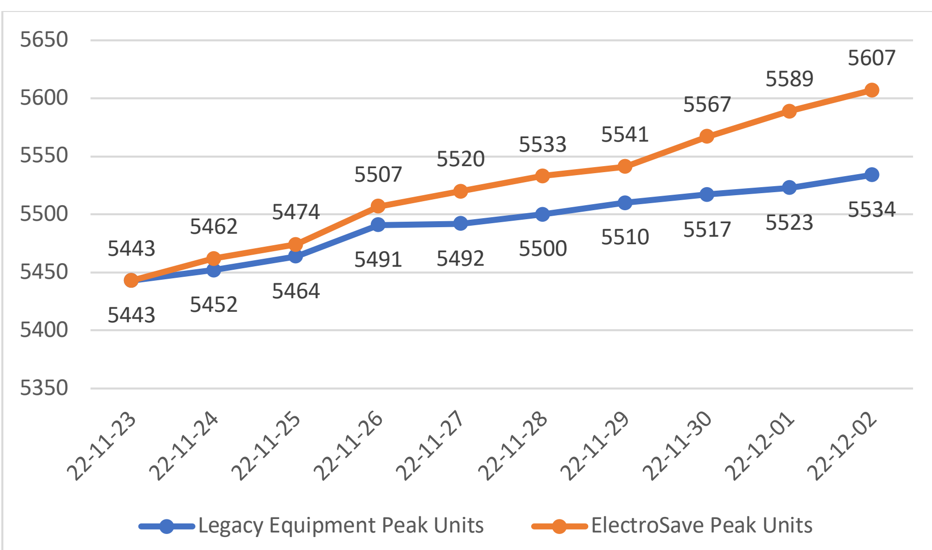
Referring to figure 6, it can be noted that trend line of TR#136 legacy equipment remains relatively constant. However, with the use of ElectroSave, trend line has moved upawards and depicts an increasing trend.

Figure 6: TR#136 Off-Peak Units (kWh)



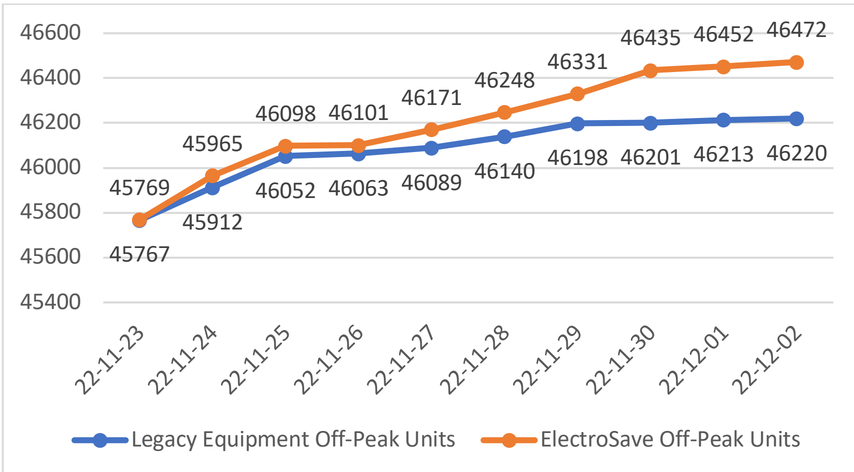
As per figure 7, the off-peak units of TR#136 have an increasing trend initially and then becomes nearly constant using the legacy equipment. It can be noted that using ElectroSave, the off-peak units are increasing linearly.

Figure 7: TR#122 Peak Units (kWh)



If we note figure 8, the trend line of both legacy equipment and ElectroSave peak units for TR#122 is depicting a linear increase. But the trend line of ElectroSave peak unit trend line has moved upward

Figure 8: TR#122 Off-Peak Units (kWh)



If we note figure 8, the trend line of both legacy equipment and ElectroSave off-peak units for TR#122 is depicting a linear increase. But the trend line of ElectroSave peak unit trend line has moved upward

3.4.2. Rollout of TransfoSave (May – August 2022)

TransfoSave is the device installed on Transformers for the real-time metering, monitoring and control of electricity distribution on transformer level. The total number of TransfoSave devices installed are 250, among which the number of TransfoSave units installed on the Karkhano feeder are 59, and the number of TransfoSave units installed on Ring Road feeder are 191.

Below are the post implementation statistics of TransfoSave:

S/No.	Particulars	Values
1.	Electricity-Units lost on 250 Transformers during Month-1	43,665
2.	Electricity-Units lost on 250 Transformers during Month-2	49,157
3.	Electricity-Units lost on 250 Transformers during Month-3	47,167
4.	Quarterly Electricity-Units lost	139,990
5.	Estimated Yearly Electricity-Units lost	559,961

6.	Estimated Yearly Revenue lost (PKR)	8,399,414
7.	Electricity-Units recoverable via 250 TransfoSaves per month	46,663

Table 4: Post Implementation Statistics of TransfoSave

As seen from the table above, the transformers with TransfoSave system deployed are losing significant units per month and thus losing ample revenue of worth 8.3 Million PKR annually due to technical losses and unbalance load (unmanaged electricity distribution).

Unbalanced load refers to unmanaged electricity distribution. Unbalanced load causes more losses, which are reduced significantly after TransfoSave implementation and it is evident in the graphs shown below. Following are graphs of some transformers to show the comparison week-wise:

Figure 9: Week-wise Comparison Transformer#1

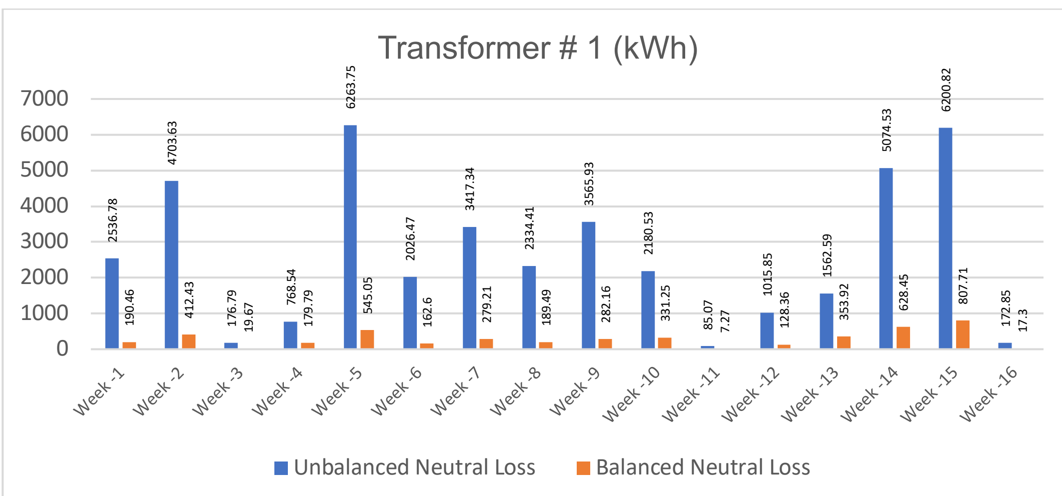
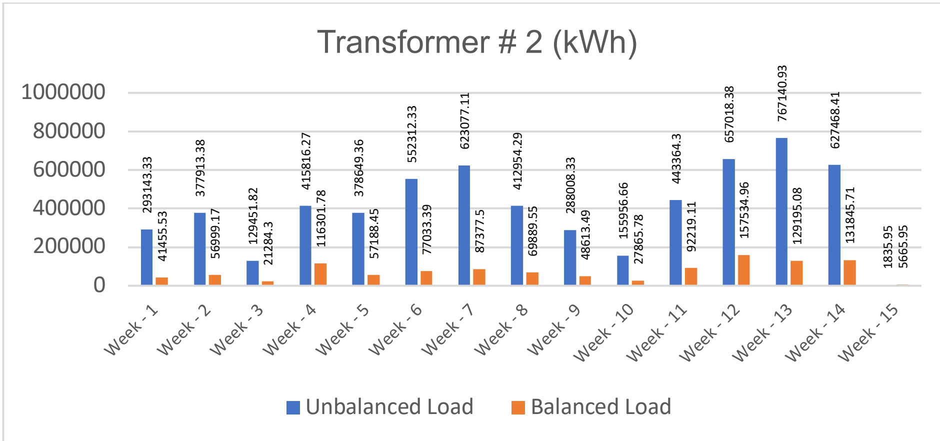
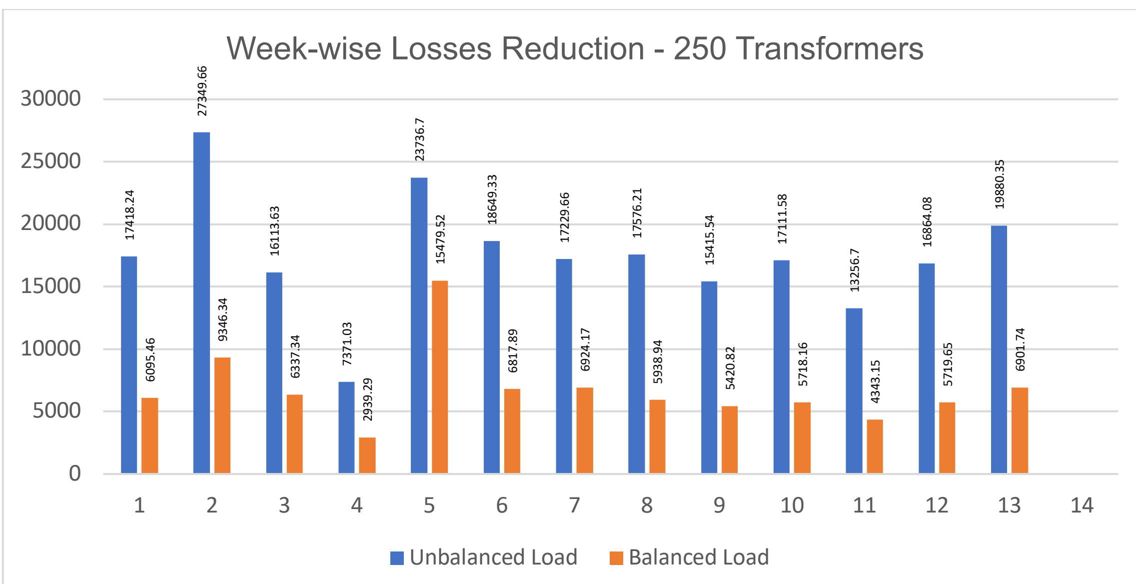


Figure 10: Week-wise Comparison Transformer#2



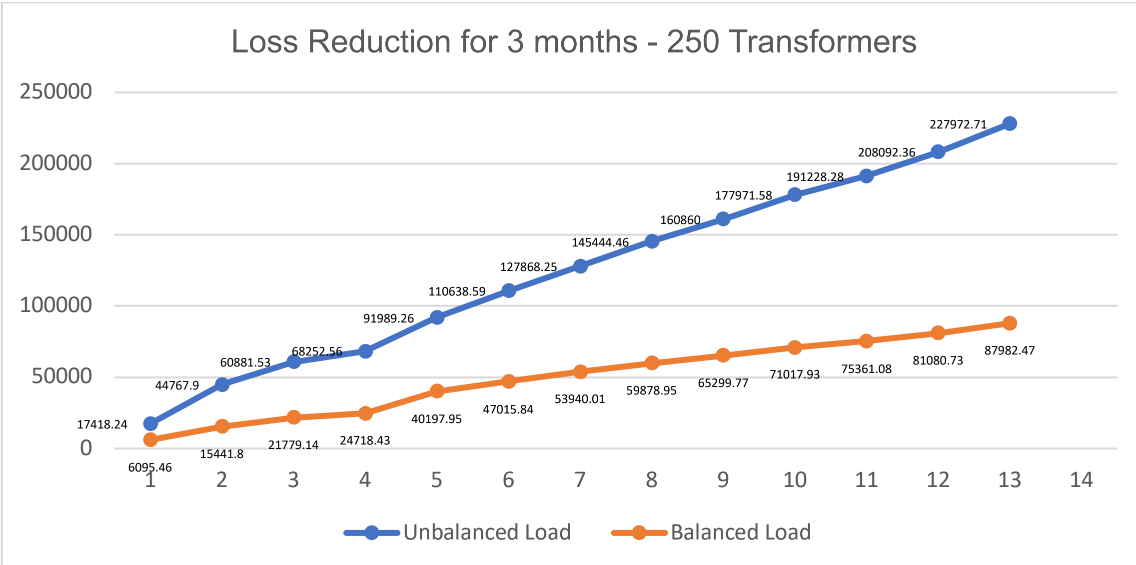
Following is the week-wise statistics for comparison between Unbalanced Load (Legacy Equipment) and Balanced Load (TransfoSave) the total 250 transformers on both the feeders:

Figure 11: Week-wise Loss Reduction



Following is the graph showing the comparison data for 3 months:

Figure 12: Three Months Loss Reduction



3.5. Financial Sustainability

According to the statistics received from PESCO officials, there is a loss of 187,845 units per month on Karkhano feeder, which means that the losses reported on these 10 transformers accounts for 29.8% of the total loss on Karkhano feeder. The table below provides a brief snapshot of the benefits of implementation of this system.

S/No.	Particulars	Value
1.	Ratio (Losses on 10 Transformers vs Total Losses on the Feeder)	0.298
2.	% Losses on the Feeder	38.3
3.	% Losses on Feeder after implementation with only 10 ElectroSave Units	27.2
4.	% Losses reduced after implementation of 10 ElectroSave Units	11.1
5.	Total Consumers on the Karkhano Feeder	2,826
6.	No. of Consumers under the implemented area	500
7.	% implementation on the feeder customers	17.7

Table 5: % Change in Loss against ElectroSave

Since the total losses on the Karkhano feeder are 187,845 units per month, the losses on the selected 10 transformers accounts for 29.8% of the total losses as illustrated in the table above. The percentage losses on Karkhano feeder are 38.3%, and the percentage losses reduced after implementation on the mentioned 10 transformers is 11.10%. This means that the percentage losses on the whole feeder after the implementation of ElectroSave on 10 transformers is reduced from 38.3% to 27.2%. Total number of consumers on the Karkhano feeder are 2,826 while the implementation is done over 500 consumers. The revenue saving on these 10 transformers i.e. 3.35 Million PKR is achieved with only 17.7% implementation of ElectroSave. Thus, if scaled up, it will result in more saving and improved access to energy across the distribution infrastructure.

With the implementation of TransfoSave units and balancing of the load, total 46,663 units can be recovered per month. Benefits of TransfoSave are listed below:

S/No.	Particulars	Value
1.	Total units lost on both feeders per month (combined)	276,316
2.	% Losses on the Feeders	39.5
3.	% Losses after implementation of TransfoSave	32.82
4.	% Losses reduced after implementation of TransfoSave (in total loss)	6.67

Table 6: % Change in Loss Against TransfoSave

It can be seen from the table above that the combined losses on both Karkhano and Ring Road feeder are 276,316 units per month and the combined percentage loss is 39.5%. With implementation of TransfoSave the combined technical loss on both the feeders is reduced to 32.82%.

Chapter 4

Findings & Lessons

1.1. Project Milestones

1.1.1. Number of instances using real-time information depicting theft / resolution of theft consumption / underbilling / overbilling / loss etc.

ElectroSave:

- Sample of 20 Commercial consumers for ElectroSave implementation and 9 of them were facing theft issue, and the statistic reported are for those 9.

TransfoSave:

- The technical losses are reported for 250 transformers due to unbalance load.

1.1.2. Estimated Monthly revenue recovered (PKR) for PESCO

Solution	No. of Units Recovered per Month	Tariff	Est. Monthly Revenue Collection
ElectroSave	55,989	20	1,119,556
TransfoSave	46,663	20	933,260

Table 7: Estimated Monthly Revenue for PESCO

1.1.3. Percentage change between average monthly revenue collected before and average monthly revenue collected after project implementation. This percentage is same as the percentage reduction in overall losses through TransfoSave and ElectroSave

Description	Karkhano Feeder		Ring Road Feeder	% Change after solution implementation
	ElectroSave	TransfoSave	TransfoSave	
Number of units installed	10	59	191	-
% reduction in losses post implementation	11.1	6.67	6.67	12.22

Table 8: % Change of Monthly Revenue Before & After Implemenation

1.1.4. Electricity downtime (minutes) (average per household per month). Percentage reduction in losses is reflected as Percentage reduction in load shedding, thus improving by 17.77%, eventually results in increased and improved energy access by the same factor. Earlier approximately 40% load shedding, after proactive actions and reduction in losses will eventually come down to 22%, means reduction in down time by almost 50% [10hrs to 5 hrs (300mins.)]

1.1.5. Percentage change in loss against TransfoSave and ElectroSave is mentioned in table no. 5 and table no. 6

4.2. Mobile KPIs

4.2.1. Revenue and Overall Use

Jazz has enabled distribution company PESCO with remote monitoring, automated metering and control on individual consumer line. In-case of non-payment or theft, PESCO can control the individual transformer.

Following are the perceived benefits for MNOs:

- Revenue from data transfer (M2M Connectivity, cloud hosting and A2P SMS), since the system comprises of IoT sensors that send data to cloud and inform consumers on their utilization patterns

- Access and handling of imperative energy related data to help Utility companies in short-term and long-term planning and make proactive measures against misuse in the infrastructure
- Avenues for enhanced revenue streams by reducing losses making utility companies profitable through a transparent data acquisition system
- Extended consumer outreach and access by deploying IoT sensors
- Aligned with the GoP (Government of Pakistan) objectives of contribution in the digital economy

Mobile services include:

- Mobile Apps (Real-time usage stats)
- Cloud hosting
- Application-to-Person (A2P) SMS
- Machine-to-Machine (M2M) Connectivity
- Mobile Financial Services
- USSD

4.2.2. Revenue Monetization & Share Model:

Proposed revenue sharing model has been discussed with PESCO and CISNR

Entity	Tariff
Loss Reduction of PESCO	x% (x= Revenue saved due to loss reduction)
Percentage Shares of Jazz & CISNR	50% of x%
Jazz Share (%) out of the 50%	70% out of the 50%
CISNR Share (%) out of the 50%	30% out of the 50%

Table 9: Proposed Revenue Sharing Model

4.3. Key Overall Learnings

4.3.1. Key Challenges

- Since the deployment time overlapped the month of Ramadan (the fasting month for Muslims) so we faced the issue of limited working hours and additional human resource were added to meet the defined project timelines.

- Due to the downtime associated with each device installation (the downtime was minimal), CISNR had to move our deployment time to midnight since we couldn't get approvals from the authorities due to Ramadan.

- Due to the server connectivity issue we faced & the time we lost in order to troubleshoot what exactly went wrong and where exactly the issue is, we decided to keep all the information available on a reporting platform where all the involved POCs could check the connectivity details, data usage, location details etc. online. Jazz team took this decision so we could acquire the line losses in a more processed and optimised way once the deployment is done.

- Jazz & CISNR applied for the GSMA grant with Karachi Electric as their utility partner however they couldn't continue due to their internal management issues. In the middle of project documentation, K-electric refused to proceed that caused a two-month delay in the project since on boarding a new customer and getting the agreement signed took some time.

- Jazz managed to get another partner PESCO from North Western side of Pakistan which is better for the research & study purposes of the project.

    - In Pakistan, it is considerably challenging to work with public sector entities due to strong bureaucratic holds and employee unions. The working pace for public sector entities is not as swift as projected timelines. PESCO is a public sector utility company which is running on high losses (32.6 % technical losses and 11.65% administrative losses) having segments of both legitimate and illegitimate consumers. Since the core feature of our solution is to identify and eliminate illegitimate consumers, the devices were physically damaged or stolen to disrupt the metering process. The TransfoSave devices were the target mostly since one unit serving multiple consumers and exposed outside the box. 15% of the devices were damaged, and replaced, since PTA recently changed some policies, we have to remove devices and re-register them individually, thus only 50% are in operation, rest of the process is underway.

- There was slight resistance from the officials due to lack of technical understanding of the device and its capabilities. But the senior management was cooperative and technically sound, which made the project activity accomplishments comparatively easier.

- As mentioned in the Perception Survey report one instance is the response from CEO PESCO where he states that practically two-line men are responsible for reading 1,300 meters in a month while the daily capability comes out to be not more than six meters per day per resource. This means that it is practically impossible for the distribution company to ensure timely collection of accurate data. The human errors and possible corruption may also lead to incorrect data collection. Regarding the advantage of MNO proposed solution over other options, it is not practically possible to replace every installed meter with a digital connected meter in a city as densely populated as Peshawar. A single device can cover multiple households at ten times lesser cost.

4.3.2. Key Lessons

- Deployed solution provides monitoring and metering with real time data acquisition of the whole infrastructure through mobile connectivity thus taking care of complete infrastructure and make the electricity distribution network more efficient and transparent without any human intervention and remotely. Installed devices pro-actively monitor and report technical losses and unbalances load. Every unit lost translates into revenue loss owing to the reason that the produced electricity is not reaching the consumer but going wasted in the supply lines.

- Mobile technology enables real time communication between the installed devices on transformers and distribution poles or boxes, and the central control system. Without the installed solution and control center with real time communication, the electricity distribution company has to identify and resolve all transmission line related faults manually which is near to impossible due to understaffing and at times lack of technical expertise. Feedback from the perception survey suggests PESCO massively understaffed at 13,500 officials against 27,000 requisite personnel. **It is impossible to monitor each and every neighborhood and visit each and every household-level electric meter.**

- Same is reflected in the perception survey conducted in the deployment areas and interviews with the distribution company itself. In summary most of the technical faults and incorrect configurations go unnoticed and unreported due to lack of transparency. The mobile based communication bridges this gap by connecting and monitoring equipment with the control center. In addition, the bill reading is a manual process executed by meter-readers which can have potential human error-factor resulting in overbilling / underbilling.

- Apart from automation of distribution network PESCO needs to reduce communication gap and adopt a consumer-centric approach to operations. A2P SMS has been enabled for PESCO which will provide enhanced and transparent visibility to consumers regarding their usage, consumption pattern, billing alerts, planned outages and awareness campaigns from PESCO.

    - Consumers are increasingly distrustful of PESCO and its officials; however, mobile phones are considered source of information. Robocall campaigns utilizing the credibility of notable personalities such as the Prime Minister will help improve PESCO perception and increased adoption of PESCO initiatives such as the smart-metering solutions. Identification of early adopters such as Shopkeepers will help with community engagement and mobilization.

- This system provides everything that smart metering does, with added ability of real-time monitoring of infrastructure and theft detection and at a much lesser capital and runtime cost. The real-time data helps in making short and long term planning on electricity management and reduce maintenance burden on the Utility companies, reduce uninformed blackouts.

    - In this solution, a single module can be shared by multi-consumers, thus reducing the cost per consumer for the smart metering implementation. This solution can be easily integrated with the current electricity infrastructure, without completely revamping the whole set up. It can be an ideal solution for the third world countries that are facing huge line-loss through electricity theft.

- This solution helps in reduction of load shedding, proactive faults tracing and recovery, transparent billing and increase reliable energy access. Minimizing electricity losses ultimately result in increased access to electricity, since the government’s policy is such that if an area is encountering more line losses or theft, there will be more load shedding in that particular area. Thus, minimising the losses for utility Company would ultimately result in better access of electricity to consumers at reduced prices. Also, the solution provides proper management system to the electricity distribution company, which reduces faults and blackouts, thus benefitting underserved and low-income communities in terms of increased and improved energy access.

- Through the collaboration with PESCO and CISNR, Jazz aspires to present a successful use case to decision-making national level bodies within the utilities space, addressing the immediate issue of inefficient power distribution and theft. If implemented at a national level the solution can potentially revolutionise power distribution by reducing overheads and associated costs, eventually ensuring an uninterrupted and cost-effective power supply across Pakistan.

4.3.3. Key Commercial Learnings

- Local currency (PKR) devaluation during project implementation resulted in increased device procurement budget by almost GBP 14,544/-.

- Since the previous infrastructure lacked transparency, there was slight hindrance in investment involved. The unavailability of the accurate statistics created mistrust among the customers thus resulting in unethical procedures. However, after implementation and receiving of the data/statistics from the field, the utility company realised the potential and capability of the product and proposed a prospective pilot implementation in other regions. PESCO is currently looking forward to business models that can be proposed for such an implementation across various regions under its jurisdiction. The business model needs to be discussed and agreed upon. Moreover; PEPCO (Pakistan electric power company) the holding company which operates as a division of Ministry of Water and Power in Pakistan has sent a team to deployment sites to check the progress of ElectroSave and they were pretty satisfactory with the product and forwarded the case to ministry for further action, so the solution will be pitched at national level to all electricity distribution companies once productization is completed between Jazz and CISNR.

- Bearing in mind the current situation of the electricity infrastructure nationwide the demand is considerably high since billions of dollar revenue is lost on a national level due to electricity distribution technical and administrative losses.

- The prevailing field performance is a vital component in marketing the product, creating a concrete business case depend on the success of the implementation. The implementation from PESCO expounds a success story that is commendable for the rest of the utility companies in the country as PESCO is leading the rest of the utility companies in terms of Administrative & Technical losses. As a result of current implementation, the relevant national level public entities are closely looking into the results to consider this solution for the rest of the utility companies as well.

- Since the customer segment is primarily a public entity, implementation and execution of various project routes were not as tranquil as expected. Moreover, being a public entity, the concerned personnel were disinclined to sharing data that is needed to be integrated into the system. Therefore, taking PESCO into confidence was a challenge that was addressed and resolved via deliberations with the senior management.

- Furthermore, the pace of official activities involved such as mobilization of resources needed from PESCO was not aligned with the core project's anticipated timelines. Thus, with conjoint settlement and senior management involvement the teams were mobilized and implementation was through.

- The conservative distribution system of the utility company is old-fashioned and in order to make it efficient considering the current and prospective load, our system has the ability to be easily integrated thereon adding value to the distribution company infrastructure.

- The deployment of the product in field does not need any extensive after-sales services as the product life is estimated to be 15 years. However, the safety and security of the device is to be ensured after deployment. There were certain incidents where the device was targeted and physically damaged or taken away. Therefore, the safety and security of the device after installation rests on the utility company.

- There is a viable service model and the partnership is exploring turnkey solution and revenue-share business model.

4.3.4. Key Mobile Learnings

- With Jazz providing the data transfer and data storage while CISNR providing the IoT system, there are a number of business opportunities to jointly collaborate.

- Since data collection, transfer and storage is an essential element of IoT and AI based solutions, Jazz plays an important role in handling the data and thus becomes an ideal partner in modern technological solutions. Considering the extensive outreach and market penetration, Jazz can support the implementation and execution of such technological solutions and therefore taking the solution to other distribution companies based on subscription model can be better performed.

- Jazz in addition to mobile connectivity services has extended mobile financial services which are shaping the future for mobile based financial transactions. The use of digital/mobile financial services for billing purposes is increasing, Jazz being a service provider of the mobile financial services across the country will be able to hold the digital money thus resulting in mobile accounts growth. Integration of JazzCash payment gateway and PESCO billing system is under progress and this will enable more than 2.6M PESCO consumers to avail mobile financial services.

- In outskirts of the city, where access to banks is not easy for the consumers, payment of bills becomes a hassle since the consumer has to travel to the nearest bank to make the payment. While mobile financial services are available in almost all areas and small towns/villages of the country, using mobile financial services for bill payment can be the best alternative for far-flung consumers. Furthermore, the integration of mobile financial services in our system enables utility company as well as consumers in adoption of the mobile based financial services which substantially raise the consumer base for Jazz along with the money handling services

4.3.5. Regulatory and Government

- GoP has initiative to reduce reliance on imports, along with increase in taxes for devices particularly, the foreign import process has been made considerably strict. As per the policy, all the IoT devices have to undergo a screening process before being registered in the country for usage. The screening process itself is time consuming and thus resulting in an overall procurement process delay. However, measures have been taken to achieve a lifetime license for our devices in order to streamline and standardize future procurements

- Since PESCO is a public entity, they had to undergo lengthy and time-consuming governance and regulatory issues to share consumer’s data and the misalignment in the timelines, swiftness of performing an activity, and the hurdles faced on field during the implementation was challenging for the team. In the earlier stages of the project, due to strong bureaucracy holds and exploitation the project activities were not effectively entertained. Since the infrastructure is old and lacks innovation, the adoption to IoT based technologies in the public sector of the country is not as easy as it may seem. After completion of deployment and presentation of the data to the senior management of PESCO, the solution was appreciated and believed in. Thus, the results from the implementations convinced the officials about the capabilities and potential of the solution

- GoP is taking a digital Pakistan initiative and the line losses reduction project is aligned with their policy. The initiative “Pakistan’s Digital Ambition” is designed both for the GoP and private sector to work towards a digitally progressive and inclusive Pakistan by enhancing connectivity, improving digital infrastructure, investing in digital skills and literacy, and promoting innovation and entrepreneurship.

4.3.6. GSMA’s Role

- GSMA has played the pivotal role in the execution of this project. GSMA allocated grant helped in funding the project financial aspects and build confidence of public sector entities to venture into this initiative.

- GSMA has provided exposure to both Jazz and CISNR in the international forums for showcasing the solution and also rack opinion from international experts.

- GSMA can leverage this developing business model and productize it for both national and international market.

- GSMA can help in creating business harmony via bringing utility companies and technology providers on same platform to enable development in various sectors. Since GSMA has a global presence, it can mobilize MNOs, utility companies and techpreneurs on same platform that may result in international collaborations and business alliances.

4.3.7. Organizational Growth and Next Steps

- Compiled statistics from this project will serve as a success story for the solution, which will open new avenues for partnerships with other public utility companies as well as corporate sector. The success of this project will give Jazz a competitive edge over the competitors in the market with similar or alternative solutions.

- PESCO is currently analysing other regions affected by administrative & technical losses and has plan to evaluate the proposed solution commercially by Q2, 2020 and in order to scale the solution at national level partnership model between Jazz and CISNR is under review. Once commercialised, solution will be pitched to other utility companies operating in Pakistan.

Chapter 5

Conclusion & Recommendations

5.1. Conclusion

The implementation of TransfoSave and ElectroSave units on the two feeders has proven to be highly effective in reducing both technical and administrative losses. The introduction of these innovative technologies has led to a significant reduction in theft and line losses, thereby yielding substantial benefits for the power distribution company (PESCO). By successfully curbing electricity theft and minimizing losses, the TransfoSave and ElectroSave units have demonstrated their potential to revolutionize PESCO's infrastructure.

Furthermore, the positive outcomes observed in this project indicate that scaling up the implementation of TransfoSave and ElectroSave units across a broader network would result in even greater savings. The reduction in technical and administrative losses achieved through these technologies can be multiplied when applied on a larger scale, leading to improved financial performance for PESCO and creating a more sustainable and efficient power distribution system.

To evaluate the financial viability of the project, the Return on Investment (ROI) for TransfoSave and ElectroSave has been assessed. The ROI analysis demonstrates the economic benefits derived from implementing these units. The results highlight the significant potential for cost savings and financial gains that can be realized over time. The favorable ROI not only justifies the initial investment in TransfoSave and ElectroSave units but also indicates the potential for long-term financial sustainability and profitability.

Item	Revenue Lost Annually (PKR)	Revenue Lost Annually (GBP)	Investment Made (PKR)	Investment Made (GBP)	Return on Investment (months)
ElectroSave	13,434,672	66,839.16	8,381,700	41,700	7.48
TransfoSave	11,199,120	55,717.02	13,567,500	67,500	14.54

Table No. 10: ROI Assessment for TransfoSave and ElectroSave

The scaling up of the implementation of TransfoSave and ElectroSave units across a broader network would result in even greater savings. The reduction in technical and administrative losses achieved through these technologies can be multiplied when applied on a larger scale, leading to improved financial performance for PESCO and creating a more sustainable and efficient power distribution system.

The savings from implementing ElectroSave and TransfoSave can be used to improve the power distribution system in Pakistan in a number of ways. For example, the savings could be used to:

- Increase the capacity of the power grid.
- Improve the reliability of the power supply.
- Reduce the cost of electricity production.
- Create a more sustainable and environmentally friendly power grid.

The remarkable financial performance of the implemented ElectroSave and TransfoSave units further validates their status as a profitable investment in combating technical and administrative losses. The swift recovery of investment in these units highlights their effectiveness in generating substantial savings within a short timeframe. With just 7.5 months required for Ten (10) ElectroSave Units to recoup their initial investment, and 19 months for TransfoSave to achieve the same, it is evident that these technologies offer significant financial benefits.

By considering the recovery period and the estimated total savings, it becomes evident that the implementation of ElectroSave and TransfoSave units leads to substantial cost reductions. The table above demonstrates that the annual savings resulting from this implementation amount to an impressive, estimated sum of 24.6 Million PKR. These substantial savings not only reinforce the profitability of ElectroSave and TransfoSave as investment choices but also emphasize their potential to significantly contribute to PESCO's financial stability and long-term sustainability.

Moreover, the significant annual savings accrued from the implementation of these units can be reinvested in various initiatives aimed at further improving the power distribution system. The funds can be allocated to infrastructure upgrades, technology advancements, and customer-centric improvements, ultimately enhancing the overall efficiency and quality of service provided by PESCO. These reinvestments can create a positive cycle of continual improvement and drive further reductions in technical and administrative losses, thereby optimizing the financial performance of the company.

5.2. Recommendations

Based on the findings and lessons of the project, here are some future recommendations:

- **Expand Implementation:** Based on the success and positive outcomes observed in the project, it is recommended to expand the implementation of TransfoSave and ElectroSave units to other feeders and regions within PESCO's jurisdiction. This will help to further reduce technical and administrative losses and increase overall revenue recovery.

- **Collaborate with Other Utility Companies:** Considering the high losses incurred by utility companies across Pakistan, it is recommended to collaborate with other utility companies and present the success case of this project. By sharing the benefits and potential cost savings, other companies may be encouraged to adopt similar solutions, leading to a significant reduction in losses at a national level.

- **Strengthen Security Measures:** The incidents of device damage and theft highlight the need to strengthen security measures to ensure the safety and longevity of the implemented solutions. Collaborate with PESCO and other stakeholders to develop strategies for securing the devices, such as implementing tamper-proof installations, surveillance systems, and raising awareness among consumers about the consequences of tampering.

- **Improve Consumer Engagement:** Enhance consumer outreach and engagement by leveraging mobile services such as mobile apps, A2P SMS, and USSD. Provide consumers with real-time usage statistics, billing alerts, and outage notifications to increase transparency and build trust. Conduct targeted awareness campaigns to educate consumers about the benefits of the implemented solutions and encourage their active participation in reducing losses.

- **Regulatory Support:** Work closely with the government and regulatory bodies to address the challenges related to data sharing, regulatory approvals, and policy compliance. Advocate for streamlined processes and policies that facilitate the adoption of IoT-based solutions in the energy sector, promoting transparency, and reducing losses.

- **Business Models and Revenue Sharing:** Explore and refine the revenue-sharing model proposed for loss reduction. Collaborate with PESCO, CISNR, and other stakeholders to determine a fair and sustainable revenue-sharing mechanism that incentivizes all parties involved and ensures long-term viability of the project.

- **National-Level Adoption:** With the support of GSMA, promote the adoption of this solution at a national level by showcasing the success story to decision-making bodies within the utilities space. Engage with other distribution companies and government entities to demonstrate the potential of the solution in revolutionizing power distribution and reducing losses on a larger scale.

- **Continuous Monitoring and Evaluation:** Establish a robust monitoring and evaluation framework to continuously assess the performance and impact of the implemented solutions. Regularly analyze data, conduct audits, and gather feedback to identify areas for improvement and make necessary adjustments to maximize the effectiveness of the solution.

- **International Collaboration:** Leverage GSMA's global presence and connections to foster international collaborations and business alliances. Explore opportunities to showcase the solution in international forums and engage with other countries facing similar challenges in the energy sector. This can lead to knowledge sharing, technology transfer, and potential partnerships for expanding the solution globally.

By implementing these recommendations, it is expected that the project's success can be replicated on a larger scale, leading to significant reductions in technical and administrative losses, improved energy access, increased revenue recovery, and a more efficient and transparent energy infrastructure.

References

- Aggarwal, G. (2022) *Leveraging AI to counter energy theft and ntls*, *Bidgely*. Available at: https://www.bidgely.com/blog/ai-combat-energy-theft-non-technical-losses/ (Accessed: February 1, 2023).
- Sen, S. (2022) *2,625 power thefts detected in 3 months across Maharashtra: Mumbai News - Times of India*, *The Times of India*. TOI. Available at: https://timesofindia.indiatimes.com/city/mumbai/2625-power-thefts-detected-in-3-months-across-maharashtra/articleshow/93483183.cms (Accessed: February 1, 2023).
- Hussain, Z. *et al.* (2016) *Methods and techniques of electricity thieving in Pakistan*, *Journal of Power and Energy Engineering*. Scientific Research Publishing. Available at: https://www.scirp.org/journal/paperinformation.aspx?paperid=70365#ref1s (Accessed: January 24, 2023).
- Gupta, A. (2022) *Council post: Why energy theft is preventing global decarbonization*, *Forbes*. Forbes Magazine. Available at: https://www.forbes.com/sites/forbestechcouncil/2022/09/06/why-energy-theft-is-preventing-global-decarbonization/?sh=2ce42354ff4b (Accessed: January 24, 2023).
- Northeast Group, L.L.C. (2018) *World loses $89.3 billion to electricity theft annually, $58.7 billion in emerging markets*, *World Loses $89.3 Billion to Electricity Theft Annually, $58.7 Billion in Emerging Markets*. Available at: https://www.prnewswire.com/news-releases/world-loses-893-billion-to-electricity-theft-annually-587-billion-in-emerging-markets-300006515.html (Accessed: January 24, 2023).
- Hussain, Z. *et al.* (2016) *Methods and techniques of electricity thieving in Pakistan*, *Journal of Power and Energy Engineering*. Scientific Research Publishing. Available at: https://www.scirp.org/journal/paperinformation.aspx?paperid=70365#:~:text=The%20economy%20loss%20is%20Rs,commercial%2C%20domestic%20and%20industrial%20level. (Accessed: February 2, 2023).
- Tanushree Sharmaa, Person Envelope, K. K. Pandeyb, D.K. Puniab, Joji Raob, A.links open overlay *et al.* (2015) *Of pilferers and poachers: Combating Electricity Theft in India*, *Energy Research & Social Science*. Elsevier. Available at: https://www.sciencedirect.com/science/article/abs/pii/S2214629615300293 (Accessed: January 24, 2023).
- Ahmadani, A. (2022) *T&D losses, low recoveries main causes behind swelling circular debt: NEPRA*, *PT*. Available at: https://www.pakistantoday.com.pk/2022/09/30/td-losses-low-recoveries-main-causes-behind-swelling-circular-debt-nepra/#:~:text=The%20NEPRA's%20State%20of%20Industry,actual%20losses%20were%2017.13%20percent. (Accessed: January 24, 2023).

- Gupta, A. (2022) *Council post: Why energy theft is preventing global decarbonization*, *Forbes*. Forbes Magazine. Available at: https://www.forbes.com/sites/forbestechcouncil/2022/09/06/why-energy-theft-is-preventing-global-decarbonization/?sh=4be9467a4ff4 (Accessed: January 24, 2023).
- Yasin, A. (2018) *RS213 billion electricity line losses, theft: Peshawar stands on top of list*, *thenews*. The News International. Available at: https://www.thenews.com.pk/print/275516-rs213-billion-electricity-line-losses-theft-peshawar-stands-on-top-of-list-sukkur-comes-second-hyderabad-third (Accessed: February 1, 2023).
- Yousafzai, F. (2022) *Power Sector's transmission & distribution losses soar to RS473 billion in 2021*, *The Nation*. The Nation. Available at: https://www.nation.com.pk/15-Aug-2022/power-sector-s-transmission-amp-amp-distribution-losses-soar-to-rs473-billion-in-2021#:~:text=Due%20to%20mismanagement%20and%20weak,was%20added%20to%20circular%20debt.x (Accessed: February 1, 2023).
- Madrazo, M. (2009) *Bridging the knowledge gap to identify energy theft*, *Electric Energy Online*. Available at: https://electricenergyonline.com/energy/magazine/456/article/Bridging-the-Knowledge-Gap-to-Identify-Energy-Theft.htm (Accessed: February 1, 2023).
- Tarafder, S. and Banerjee, K. (2022) *Power theft detection and automatic elimination - IJISRT*. Available at: https://ijisrt.com/wp-content/uploads/2019/03/IJISRT19FB319.pdf (Accessed: February 1, 2023).
- Afridi, A. *et al.* (2021) "An efficient and improved model for power theft detection in Pakistan," *Bulletin of Electrical Engineering and Informatics*, 10(4), pp. 1828–1837. Available at: https://doi.org/10.11591/eei.v10i4.3014.
- Blazakis, K.V., Kapetanakis, T.N. and Stavrakakis, G.S. (2020) *Effective electricity theft detection in power distribution grids using an adaptive neuro fuzzy inference system*, *MDPI*. Multidisciplinary Digital Publishing Institute. Available at: https://www.mdpi.com/1996-1073/13/12/3110 (Accessed: February 1, 2023).
- Li, W. *et al.* (2019) *A novel smart energy theft system (sets) for IOT-based Smart Home*, *ResearchGate*. Available at: https://www.researchgate.net/publication/331576621_A_novel_smart_energy_theft_system_SETS_for_IoT-based_smart_home (Accessed: February 1, 2023).
- Khairnar, N.S. and Khairnar, R.S. (2018) *IOT based Electricity Theft Detection* , *Ijream*. Available at: https://www.ijream.org/papers/ICRTET0016.pdf (Accessed: February 1, 2023).
- Shivaraman, N. *et al.* (2020) *Real-time energy monitoring in IOT-enabled mobile devices*, *arXiv.org*. Available at: https://arxiv.org/abs/2004.14804 (Accessed: February 1, 2023).

- Uddanti, S., Joseph, C. and Kishoreraja, P.C. (2017) *IOT based energy metering and theft detection - acadpubl.eu*, *Ijream*. Available at: https://acadpubl.eu/jsi/2017-117-8-10/articles/9/9.pdf (Accessed: February 1, 2023).
- Rajasekaran, A. *et al.* (2020) *IOT Based Power Theft Detection* , *Ijsdr*. Available at: https://www.ijsdr.org/papers/IJSDR2003046.pdf (Accessed: February 2, 2023).
- Singh, M. and Sanduja, E.V. (2015) *Minimizing Electricity Theft by Internet of Things*, *Ijarcce*. Available at: https://www.ijarcce.com/upload/2015/august-15/IJARCCE%2069.pdf (Accessed: February 1, 2023).
- Aaqib, M., Din, I.U. and Ghani, M. (2022) *The development of an electricity theft detection system*, *Pakistan Journal of Engineering and Technology*. Available at: https://hpej.net/journals/pakjet/article/view/2064 (Accessed: February 1, 2023).
- ALTHOBAITI, A.H.L.A.M. et al. (2021) *Energy Theft in Smart Grids: A Survey on Data-Driven Attack Strategies and Detection Methods, IEEE Access*. Available at: https://eprints.lancs.ac.uk/id/eprint/163102/1/ACCESS3131220_2_.pdf (Accessed: February 1, 2023).
- Babar, Z., JamilPerson, F. and Haq, W. (2022) *Consumer's perception towards electricity theft: A case study of islamabad and Rawalpindi using a path analysis*, *Energy Policy*. Elsevier. Available at: https://www.sciencedirect.com/science/article/pii/S0301421522004098 (Accessed: February 1, 2023).