CHAPTER-5

MANAGEMENT OF LOSSES OF INDUSTRIAL LOADS USING WIRELESS COMMUNICATION

5.1 INTRODUCTION

Non-Technical Losses (NTLs) originating from electricity theft and other customer malfeasances are a problem in the electricity supply industry. Electricity theft is the centre of focus all over the world but electricity theft in India is having significant effect on the Indian economy. Such losses occur due to meter tampering, meter malfunction, illegal connections, billing irregularities and unpaid bills [79]. Theft may be industrial, domestic or agriculture. Even though the percentage of theft in industries is low, the energy and financial loss is high due to large amount of electricity distributed, shown in Fig.5.1. One of the real examples of industrial theft is, on 17th July 2008, in Mumbai, there was a power pilferage involving multinational companies. They were stealing power from high tension power supply; it leads to huge amount of energy loss and voltage disturbances to other consumers. Fig.5.1 also gives sources of power, capacity of each source of generation, transmission utilities and percentage distribution of power to each sector. The above losses can be reduced by efficient management, i.e. by adopting best operation and maintenance practices in the transmission and distribution. Developed a real time test model to analyze the above said problems using computers and Embedded Controllers with the help of proper electrical input circuits and wireless communication.

In the present scenario, the Indian electrical distribution can be categorized into domestic and industrial (all non domestics are industrial), where it can be observed that 76% of major consumption is by industrial loads, and only 24% by the domestic
loads. So, ultimately concentrating on the industrial segment may yield a good revenue to the generating companies (Industrial verses domestic is 1:1000 in India). Due to large amount of energy consumption, the energy and financial loss is high, even though the percentage of theft in industries is low.

**Fig.5.1.Working of power sector flow chart**

### 5.2. METHODS OF STEALING

The most common form of electricity stealing is tapping directly from the distribution feeder by tampering the energy meter. During low maximum demand offering to the company, whose insufficient energy makes the company unable to run the entire machinery so they are forced to steal the electricity during peak hours [80]. By-passing the meter and tapping electricity directly from the distribution feeder at desired hours of the day is illustrated in the photograph shown in Fig.5.2. [81]. It is a common practice that people steal electricity during night times when the probability
of inspection for illegal consumption is comparatively low. Such consumers use
a genuine form of electricity during the daytime as their consumption will be low. Such
kind of theft is very difficult to quantize, as the energy consumption pattern is uneven
over a period of time. Another common practice is that people tap a part of electricity
illegally during event gatherings and public functions. Secondary side wires of CTs
are called breaking control wires which are generally insulated, but this insulation can
be damaged such that electricity from one or both the wires may be tapped. Tapping
electricity from these wires causes the meter to read less current or even zero current
based on the number of the tampered wires.

![Image of power line](image)

Fig. 5.2 Illegally tapping the power line

Tampering of the energy meter is done to stop the rotation of the meter or to
give lower reading. Other methods of tampering the meter include, inter-changing the
incoming and outgoing terminals of the meter, damaging the pressure coil of the
meter, modifying the readings [82]. Other methods to tamper the meter are inserting a
film or depositing a highly viscous fluid, and using strong magnets to interrupt the
rotation of disc. Radio frequency devices can be employed to tamper the electronic energy meters. In addition to this corrupt staff of the utility companies might take bribes from illegal consumers and allow such practices. The corrupt employees are responsible for billing irregularities by recording the amount lower than the original consumption.

Sudden inspection of overhead distribution feeders and consumers might yield good results in detecting illegal tapping and meter tampering but it is very difficult to cover all HT and LT consumers. Government of India takes several steps to modernize the metering system based on advanced technology using microprocessors and LCD displays even then the above things are continuing. To overcome this, a real time, on-line, automatic theft detecting and robust communication system is proposed.

The increase in these losses automatically affects the increase in generation leads to high generation cost and environmental pollution. Therefore, minimization of these losses is very crucial in power sector. In the following section, several methods to overcome pilferage and to minimize the NT losses in power systems are discussed.

5.3. EFFECTS OF PILFERAGE

Primarily, electricity theft affects the utility company and then its customers. It will overload the generating unit and quality of supply is also adversely affected [80]. This overload might result in over voltages that can affect the performance and even damage appliances of genuine customers and also it may lead to brownouts and blackouts during the peak load. This huge amount of NTL might trip the generating unit, which lead to the interruption of power supply to all customers. Load shedding should also be required to compensate the voltage collapse during the peak load period. Maintenance of power factor is very difficult without complete information about the total load flow because of the theft. Fixing of tariff and billing is also very
difficult to the power company. It may lead to force the excessive tariff on genuine customers and utility companies also face huge economic losses.

Also, illegal tapping of electricity raises safety concerns like electric shocks and even the death of a person. Improper handling of the distribution feeder might pose danger to the whole community during extreme weather conditions. These wires might start sparking and may give rise to fire.

5.4 PRESENT PILFERAGE SOLUTIONS

Several data mining and research studies on fraud identification are proposed. Statistical-based Outlier detection [83] preselects suspected customers to be inspected onsite for fraud based on irregularities and abnormal comparison behavior. Soft computing methods like Wavelet-based feature extraction with multiple classifiers [84], Artificial Neural Networks (ANNs) [85] and Support Vector Machine (SVM) & fuzzy systems [86] are proposed to detect the theft and reduce the non-technical losses.

The most common method in use is, installing high quality electronic meters [87]. This method is beneficial, despite their high cost and necessary network infrastructure extensions. In addition, Automatic Meter Reading (AMR) proposed in [88, 89] has been used as an intelligent filter, to provide an effective method for measuring losses and electricity theft in the LV transmission and distribution networks. The current methods of minimizing NTLs impose high operational costs and require extensive use of human resources. Several methods have been developed in other countries to minimize NTL problems [90, 91]. Most electricity supply utilities concentrate on onsite technical inspection of customers, which has high operational costs and occupy much human resources and time.
Most of the studies cited above used data mining techniques by directly applying them to customer databases as inputs.

5.5. PROPOSED METHOD

According to Govt. release, in India, power theft is amounting to more than Rs.75, 000 Crores per year. In Maharashtra state out of 35% loss, theft is 29%. In the proposed design it is easy to identify the industrial power theft systematically.

Apart from the non-technical losses, technical losses plays major setback to the power system network by creating losses with improper maintenance of conductors, transformers and switch gears. Resulting into unaccounted losses and the entire network will get damaged. An effective system to be introduced to identify the above said losses to save power and provide uninterrupted supply to the consumers. Proposed an advanced technique to reduce losses and keep power system alive using wireless based relays with effective communication technologies.

Non-technical losses creates slow interruption on power quality resulting recovery of cost but technical losses creates fast interruption with poor power quality resulting non recoverable losses.

The method monitors the power dispatched at the substation and total power consumption by the all users. Once if the above things are equal with little proportional losses, the system keeps excellent utility factor. If not, it tries to find out where it is loss or theft. By using efficient and real time system, it can easily identify the difference as “loss or theft”.

In nature, losses are the prime factors which disturb the utility factor. Possibility of loss is by means of trees, high wind, tiny shorts, etc.

In case of loss, the particular power flow route alone will be disabled and others will be enabled using perfect relay logic. It also locates fault area and will be
displayed on the computer screen as well as if necessary it can be spelled out through voice using multimedia. Nowadays all the electrical distribution is carried out using SCADA for making global power management system. Using SCADA distribution is perfectly possible, but this work supports the SCADA for utility factor. To prove this concept, an experimental model is developed. Block diagram for the experimental model is shown in Fig.5.3. It consists of a sensing system, signal conditioning electronic circuits, advanced embedded hardware for middle level computing, a powerful computer network for further transmission of data to various places and wireless network to communicate with related control centre. Each one can be explained as follows.

![System Block Diagram]

Fig.5.3 Proposed system block diagram

In sensing system instrument transformers are used for the measurement and control of voltages and currents. Direct measurement of high voltage or heavy currents involves large and expensive instruments, relays, and other circuit components of many designs. The use of instrument transformers, however, makes it possible to use relatively small and inexpensive instruments and control devices of standardized designs. Instrument transformers also protect the operator, the measuring devices and the control equipments from the dangers of high voltage. The use of instrument transformers results in increased safety, accuracy and convenience.
Current transformer sense the change in current converted in to corresponding voltage and given to embedded microcontroller [EMC].

Signal conditioners are more reliable. The output of secondary isolation system will be AC in nature, must be rectified, conditioned and calibrated as per the requirement of conversion circuits. These circuits are op-Amp based full wave precision rectifiers (or) absolute rectifiers. These circuits meet overall standards of measurements. The prime objective of these devices are to rectify, filter, setting up the calibration limits, protecting the high voltage hazards, protecting the inputs and outputs. Output of these circuits will be pure DC in nature with respects to the inputs referred to it.

To perform the various operations and conversions required to control and monitor the devices, a processor is needed. The processor may be a microprocessor, micro controller or embedded controller. In this work, an embedded controller has been preferred because of its advantages like built in ADC, RAM, ROM, ports, USART, DAC, etc. This leads to lesser space occupation by the circuit and also the speed of embedded controllers is more compared to other processors. The embedded controller selected for this work is PIC16F877A due to its various features. The Hardware of the proposed experimental system is shown in Fig.5.4. Working of the circuit is explained in the following sections.

At consumer premises, in control cubical one potential transformer, two current transformers, signal conditioner, embedded controller, wireless transmitter and two relays are placed. Transformer senses the change in current at user and the voltage corresponding to this current is given to signal conditioner. Rectified and amplified output of the signal conditioner is given to embedded microcontroller. Output of embedded microcontroller given to the wireless modem through RS-
232. The wireless modem encoded the collected data and sent to the control center. In the control center one Potential transformer, one current transformer, wireless receiver, signal conditioner, embedded controller and one relay are present. Wireless modem received the transmitted data, decoded and given to computer for further processing.

Fig. 5.4 Experimental model of the proposed system

1. Power supply Transformer
2. Potential Transformer
3. Current Transformer (1, 2, 3, 4, 5)
4. Relay Driver
5. Signal Conditioning Circuit
6. Power supply for Signal conditioner
7. Embedded Circuit
8. Power Supply Circuit
5.5.1 Specifications of developed prototype model

Potential Transformer: 250/5V, 50mA
Current Transformer: 5/0.05A with shunting of 10Ω and burden of 1VA
Operational Amplifier: LM1458
Embedded Microcontroller: PIC 16F877A
Relays: 12V, SPDT
Load: Resistive loads

5.5.2 Logic Diagram

To find out theft and loss is very critical in hardware and software. The proposed technology utilizes wireless sensing system as well as computerized comparison systems to analyze theft from actual usage and loss. The logic diagram is shown in Fig.5.5. It consists of 5 CT’s and 5 relays used to simulate the real conditions. The CT-1 and relay-1 will considered as power delivered from the substation and in case if there is a fault immediately after the substation, relay-1 can be tripped to save energy (This could be the technical loss and eliminated because this cannot be recovered).

CT-2 and CT-3 are employed to find out loss, theft and kVA consumed by user-1. CT-4 and CT-5 are employed to find out loss, theft and kVA consumed by user-2. The apparent power passed through CT-2, CT-3 will be compared by software and if both are equal there cannot be loss or theft on that particular line. Similarly CT-4 and CT-5 will be compared; if both are equal there cannot be loss or theft on that particular line. If main power calculated by CT-1 and PT is not equal to the data collected by the user CT’s (CT-3, CT-5) there may be a possibility of theft or loss in user-1 or user-2 lines. There is a possibility that the users can connect load before the meters. Even now CT-2 is not equal to CT-3 and CT-4 is not equal to CT-5 then there
may be a possibility of theft or loss in user-1 or user-2 lines. Now we need to develop an algorithm to check the above cases.

The algorithm is simple in nature using relay logic. The kVA power through CT-2 and CT-3 may be different, that time software will provide alert message on the computer screen as theft/loss. The engineer available at the substation can trip off the relay so that the user power will be disabled for shorter duration. The mathematical calculations to be carried out to indicate loss or theft are considered in section 5.5.4 and algorithm is shown in Fig.5.6.

![Fig.5.5 Logic diagram](image)

Where,

- R1 to R5 ➔ Relays
- C1 to C5 ➔ Current transformers
- LP ➔ Loss points
- TP ➔ Theft points
- U1, U2 ➔ Users

**5.5.3 Mathematical analysis**

<table>
<thead>
<tr>
<th>Common Bus Voltage</th>
<th>Ch₀</th>
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</thead>
<tbody>
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<td>Current CT₁</td>
<td>Ch₁</td>
</tr>
<tr>
<td>Current CT₂</td>
<td>Ch₂</td>
</tr>
</tbody>
</table>
Current CT \(3 \, \rightarrow \) Ch\(3\)

Current CT \(4 \rightarrow \) Ch\(4\)

Current CT \(5 \, \rightarrow \) Ch\(5\)

Where Ch\(0\) to Ch\(5\) are ADC channels

Total Apparent Power delivered = \((\text{Ch}_0 \times \text{Ch}_1) / 1000\) = kVA \(1\)

User-1 Sending kVA = \((\text{Ch}_0 \times \text{Ch}_3) / 1000\) = kVA \(2\)

User-2 Sending kVA = \((\text{Ch}_0 \times \text{Ch}_5) / 1000\) = kVA \(3\)

User-1 Load kVA = \((\text{Ch}_0 \times \text{Ch}_2) / 1000\) = kVA

User-2 Load kVA = \((\text{Ch}_0 \times \text{Ch}_4) / 1000\) = kVA \(5\)

If kVA \(2 + kVA \, 3 \, + \, 10\% \, \text{PL (Proportional Cable Loss)}\) = kVA \(1\)

If kVA \(2 = kVA \, 4\) \(\rightarrow\) No loss or theft on user-1 area.

If kVA \(3 = kVA \, 5\) \(\rightarrow\) No loss or theft on user-2 area.

5.5.4 Sample calculations

Consider,

\[
\begin{align*}
\text{MAIN (kVA1)} &= 1000 \\
\text{USER-1 (kVA2)} &= 400 \\
\text{USER-2 (kVA3)} &= 500
\end{align*}
\]

Proportional losses (PL) = 10\% of consumption

If USER1 + USER2 + 10\% PL = kVA1 no need of execution of program.

This shows that NO LOSS / THEFT

\[
\begin{align*}
\text{If kVA1} &= 1000 \\
\text{kVA2} &= 400 \\
\text{kVA3} &= 200 \\
\text{PL} &= 60
\end{align*}
\]

According to consumption by users = 660 kVA
Difference between main and users is 340 kVA

To find out theft / loss, Trip, Relay-3(Theft check relay) then if main kVA value reduces to 600, then NO THEFT by USER-1. In case of loss relay-2 to be tripped to save energy from short circuits and other users will get quality power.

If main kVA value less than 220, then THEFT by USER-1. No tripping to be further executed. Once if the theft is found, we need to permit the theft until it is proved (Physical verification).

Similarly, if we trip Relay-5 then if main kVA value reduces to 800, then NO THEFT by USER-2. In case of loss relay-4 to be tripped to save energy from short circuits and other users will get quality power.

If main kVA value less than 440, then THEFT by USER-2. No tripping to be further executed. Once if the theft is found, we need to permit the theft until it is proved (Physical verification).
5.5.5 Flowchart

Flowchart to find out loss or theft using relay logic is shown in Fig. 5.6.

Fig. 5.6 Flowchart for loss analysis
5.6 Result Analysis

Based on the mathematical analysis and flowchart given in Fig.5.6, program is developed using VB6.0 software. Different analyses of theft/loss carried out are shown below.

![Fig. 5.7 Normal condition](image)

Fig. 5.7 Normal condition

Fig.5.7 shows Technical and Non-technical losses in transmission line at normal condition. At this condition, it is considered that No loss due to fault in lines and no theft by users.

![Fig.5.8 loss in line 1](image)

Fig.5.8 loss in line 1
Fig. 5.8 shows there is a theft check in line 1 (by indicating red light). After checking the logic, there found a loss in line 1 and this cannot be theft. Immediately trip-1 to be enabled to trip the power to the concerned user.

Fig. 5.9 Theft by user 1

Fig. 5.9 shows there is a theft check in line 1 (by indicating red light). There found a theft by user 1 and this cannot be loss because line 1 loss value is very low. Hence, the user to be permitted to consume power until it is physically verified.

Fig. 5.10 loss in line 2
Fig. 5.10 shows there is a theft check in line 2 (by indicating red light). After checking the logic, there found a loss in line 2 and this cannot be theft. Immediately trip-2 to be enabled to trip the power to the concerned user.

![Image of a graphical user interface showing technical and non-technical losses in TX line]

**Fig. 5.11 Theft by user 2**

Fig. 5.11 shows there is a theft check in line 2 (by indicating red light). There found a theft by user 2 and this cannot be loss because line 2 loss value is very low. Hence, the user to be permitted to consume power until it is physically verified.
5.7 CASE STUDY OF INDUSTRIAL FEEDER

Line diagram of 11kV PR Rolling Mill Industrial feeder is shown in Fig.5.12.

It shows different industries connected at different distances.

Fig.5.12  Line diagram of industrial feeder
The total energy loss due to pilferage is calculated and tabulated in tables 5.1 & 5.2 for two HT numbers.

Table 5.1 HTSCNO: XXXXXX

<table>
<thead>
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<th>S.No.</th>
<th>Month of the year</th>
<th>Productive load(kW)</th>
<th>Anticipated Pilferage(kW)</th>
<th>%Pilferage loss</th>
<th>Energy loss(kWh)</th>
<th>Cost of Pilferage(Rs)</th>
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The above values are calculated by considering 50% of load is being theft by two industries whose HT numbers are XXXXXX and XXXXXX. These calculations are performed treating 25 working days per month and 6 hrs theft duration per day. The percentage losses are clearly observed from the graphical representation shown in Fig.5.13. The total energy loss is found to be 2,17,1700 kWh and it costs Rs.1,32,67800 only for two industries. By considering whole country the combined Figure would be very huge which definitely find place in our economy. So, implementation of advanced technologies is very much essential for reduction of unrecorded energy loss.
Pilferage Sample calculations of industrial feeder:

Input to the feeder = 195677kWh.

Let, Number of working of days of industry in a month = 25

Number of working hours in a day = 10

Power factor = 0.9

Number of theft hours in day = 6

\[
\text{Connected load} = \frac{195677}{0.9 \times 25 \times 10} = 869.67\text{kW} \\
\approx 870\text{kW}
\]

Productive load = 90% of connected load

\[= 0.9 \times 870 = 783\text{kW}\]

Anticipated pilferage = 50% of productive load

\[= 0.5 \times 783 = 391.5\text{kW}\]

Energy loss due to pilferage = Pilferage*No of days*No of theft hours

\[= 391.5 \times 25 \times 6 = 58725\text{kWh}\]

Percentage of Energy loss due to pilferage/Input

\[= \frac{58725}{195677} \times 100 = 30.111919\%\]

Financial loss due to pilferage = Energy loss due to pilferage*cost per kwh

\[= 58725 \times Rs 8 = Rs 469800\]
5.8 CONCLUSIONS

This chapter concentrates on the effect of theft on Indian economy. The relays are enabled and/or disabled to find out pilferage. A quantitative analysis of overall power flow is evaluated and automated energy usage, theft or loss are displayed for effective energy management on online. Based on the present energy scenario in our country and T&D losses, it is aimed for reducing the pilferage and energy losses that occur due to HT customers. The proposed design is well evaluated using real time hardware. The method employed is very unique and cost effective for implementation. By this design it can be concluded that power theft can be effectively curbed by detecting where the power theft occurs and informing the authorities by using wireless communication. Besides, the proposed method may serve as a useful input to the upcoming deregulated electricity market and smart grid applications.

A case study is performed on 11kV Industrial feeder for approximate evaluation of huge non-technical losses by the proposed smart management system to curb the pilferage.