1. INTRODUCTION

1.1 General

In India, average power losses, have been officially indicated as 23 percent of the electricity generated. However, as per sample studies carried out by independent agencies including TERI, these losses have been estimated to be as high as 50 percent in some states. With the setting up of State Regulatory Commissions [1] in the country, accurate estimation of T&D Losses has gained importance as the level of losses directly affects the sales and power purchase requirements and hence has a bearing on the determination of electricity tariff of a utility by the commission [7].

1.2 Factor of power losses

Power losses occur in the process of supplying electricity to consumers because of commercial and technical losses. The commercial losses are due to pilferage, **defective meters**, and **errors in meter reading** and in estimating **unmetered supply** of energy. The technical losses are caused by power dissipated in the conductors and equipment used for transmission, transformation, sub- transmission and distribution of power. These technical losses are inherent in a system and can be reduced to an optimum level. The losses can be further sub grouped depending upon the stage of power transformation & transmission system as Transmission Losses (400kV /220kV /132kV / 66kV), as Sub transmission losses [2] (33kV /11kV) and Distribution losses (11kV /0.4kv).

1.3 Level of power losses

The officially declared transmission and distribution losses in India have gradually risen from about 15 percent up to the year 1966-67 to about 23 percent in 2006-2007. The continued rising trend in the losses is a serious matter concern and all out efforts are required to contain them. According to a study carried out by Electric Power Research Institute (EPRI)S of the USA some time back, the losses in various elements of the T&D system usually are of the order as indicated as shown in table 1.1.

Table 1-1: Various elements of power losses according to EPRI.

System element	Minim	Maximum
Distribution lines and service connections	3.0	7.0
Sub-transmission system & step-down to distribution voltage level	2.0	4.5
Transformation to intermediate voltage level, transmission system & step down to sub-transmission voltage level	1.5	3.0
Step-up transformers & EHV transmission system	0.5	1.0
Total Losses	7.0	15.5

The losses in any system would depend on the pattern of energy use, intensity of load demand, load density, and capability and configuration of the transmission and distribution system that vary for various system elements. According to CEA vide its publication 'Guidelines for Reduction of Transmission and Distribution Losses' it should be reasonable to aim for total energy losses in the range of 10-15% in the different states in India.

1.4 Reasons for high power losses

In many parts of the world experiences demonstrate that it is possible to reduce the losses in a reasonably short period of time and that such investments have a high internal rate of return. A clear understanding on the magnitude of technical and commercial power losses is the first step in the direction of reducing power losses. It can be achieved by putting in place a system for accurate energy accounting. This system is essentially a tool for energy management and helps in breaking down the total energy consumption into all its components [3]. It aims at accounting for energy generated and its consumption by various categories of consumers as well as, for energy required for meeting technical requirement of system elements. It also helps the utility in bringing accountability and efficiency in its working.

1.5 Reasons for high technical losses

The following are the major reasons for high technical losses in our country: -

- Inadequate investment on transmission and distribution, particularly in sub-transmission and distribution. While the desired investment ratio between generation and transmission and distribution should be 1:1, during the period 1956 -97 it decreased to 1:0.45. Low investment has resulted in overloading of the distribution system without commensurate strengthening and augmentation.
- Haphazard growths of sub-transmission and distribution system with the short-term objective of extension of power supply to new areas.
- Large scale rural electrification through long 11kV and LT lines.
- Too many stage of transformations.
- Improper load management.
- Inadequate reactive compensation
- Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

1.6 Reasons for commercial losses

Theft and pilferage account for an important part of the high T&D losses in India. Theft and pilferage of energy is mainly committed by two categories of consumers i.e. non-consumers and bonafide consumers. Antisocial elements avail unauthorized/unrecorded supply by hooking or tapping the bare conductors of L.T. feeder or tampered service wires. Some of the bonafide consumers wilfully commit the pilferage by way of damaging and/or creating disturbances to measuring equipment installed at their premises. Some of the modes for **illegal consumption [5]** of electricity are given below:

- **Stopping the meters by remote control.**
- **Wilful burning of meters.**
- **Improper testing and calibration of meters.**
- **Bypassing the meter.**
- **Making unauthorized extensions of loads, especially those having "H.P." tariff.**
- **Changing C.T. ratio and reducing the recording.**
- **Errors in meter reading and recording.**
- **Tampering the meter readings by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters.**
- **Changing the sequence of terminal wiring.**

1.7 Power losses in restructured SEBs

Some states have embarked on programs of power sector reforms and have taken steps to restructure their SEBs (State Electricity Boards). The reforming states that were reporting T&D losses of around 20% before restructuring process suddenly reported higher losses after carried out detailed studies of their system. For example, before restructuring its power sector, Orissa reported 23% loss, after restructuring, T&D loss were shown to be 51%. In AP where these losses were of the order of about 25% before restructuring, it is now estimated to be around 45% after restructuring. Haryana has now estimated its losses at 40% and Rajasthan at 43% against earlier level of 32% and 26% respectively

1.8 Regulatory concerns

In the absence of a realistic estimate of power losses, it is not possible for the regulatory commissions to correctly estimate the revenue requirements and also avoid the situation where the consumers pay for the inefficiencies of the utilities. In order to determine an appropriate tariff, the first step is to justified cost incurred by the entity. This would provide an indication of the revenue requirement, which in turn is the basis of any tariff design. The regulator must be very careful about how losses are worked out. The aim of the regulator must be to encourage the utility to make every effort to reduce losses while at the same time ensuring that those conditions applied which threaten the viability of the utility are not applied.

1.9 Barriers in private sector participation

The lack of realistic estimates of power losses acts as a disincentive for private sector participation in power distribution as the party can't have an idea of the realistic revenue potential of the area being privatized.

1.10 Unmetered supply

Unmetered supply to agricultural pumps and single point connections to small domestic consumers of weaker sections of the society is one of the major reasons for commercial losses. In most states, the agricultural tariff [2] is based on the unit horsepower (H.P.) of the motors.

Such power loads get sanctioned at the low load declarations. Once the connections are released, the consumers get into the habit of increasing their connected loads, without obtaining necessary sanction, for increased loading, from the utility. Further estimation of the energy consumed in unmetered supply has a great bearing on the estimation of power losses because inherent errors in estimation. Most of the utilities intentionally overestimate the unmetered agricultural consumption to get higher subsidy from the State Government and project reduction in losses. In other words, higher the estimates of the unmetered consumption, lesser the transmission and distribution loss figure and vice versa [6]. Moreover, the correct estimation of unmetered consumption through the agricultural sector greatly de- pends upon the cropping pattern, ground water level, seasonal variation, hours of operation etc.

To increase the food output, almost all the State Governments show benevolence to farmers and arrange supply of electric power for irrigation to the farmers at a nominal rate, and in some States, without charges at all. In view of this, most Electricity Boards supply power to agriculture sector and claim subsidy from the State Govt. based on energy consumption.

Since the energy supplied to the agriculture sector is a generous gesture by the State Govt., all the electricity boards have eliminated energy meters for agriculture sector services. The absence of energy meters provides ample opportunities to SEBs to estimate average consumption in agriculture sector at a much higher value than the actual. In the absence of energy meters, most of the SEBs resort to fudging consumption figures to include not only the under estimated T&D Losses but also energy theft from their system. The extent of fudging is more in the States where agricultural activity is high. The benefit derived by these boards is not only the extent of subsidy from the respective States but also self-praise by showing much less transmission and distribution losses. Further the boards are ignoring the inefficiency in operating the distribution system by blaming the agricultural supply for all ills and raising the tariff of other consumers.

Most of the methods [5] being employed by SEBs for estimating the **unmetered energy consumption** are as follows:

- **Estimation based on readings of meters installed at all the Distribution Transformers located on a feeder.**
- **Load factor based estimation.**
- **Estimation based on feeder wise theoretical calculation of losses.**

However, none of these methods provide **correct** estimation of unmetered consumption

Data mining is employed to meet the above challenges in this research. Data mining is defined as “a process of discovering various models, summaries and derived values from a given collection of data.” Various data mining analysis on fraud identification and detection in electricity profession are already invented, including artificial neural network, decision trees,

rough sets, wavelet-based feature extraction and statistical-based outlier detection and multiple classifiers. Consumer databases as inputs, we can directly have applied in most of these analyses. In most of these cases, data mining has been applied as a tool that enables the detection and prediction of fraud. An above all these applications applied data mining techniques to determine of fraud directly from their databases of consumer.
In addition to this, data mining techniques are also being used in the other types of businesses including telecommunications, insurance, risk management, and credit card provision. The present proposed work is some small different in terms of its study of fraud from time-series case derived from a load profiling case [8].

1.11 Objectives

It was the need to deal more efficaciously with unmetered power losses activities that motivated the present study. Specifically, the intention has been to use the knowledge gathered from consumer's load profiles to detect significant behavioural deviations that signal such activities. The unmetered power losses that has been observed in many countries is a significant concern. It is important, therefore, to be able to identify and predict possible unmetered power losses activity by means of analysing the data normally made available through Consumer Information and Billing Systems [19]. Such analysis focuses on consumer's behaviour changes by identifying significant deviations in their load consumption patterns made apparent through load profile and data-mining techniques.
The aim of the present research is to propose and develop a framework of analysis to be applied to consumer's behaviour to aid the identification, detection and prediction of unmetered power losses activity. This is to be achieved by pursuing significant deviations in their load consumption revealed by data mining techniques. The resulting identification framework for unmetered power losses analysis that has been developed here will significantly benefit both the electricity supply utilities and their consumers [20].

More specifically, the present study pursues the following objectives in its development and application of load behaviour profiling and data-mining techniques.

- To investigate whether abnormalities and irregularities of consumer's **behaviour that signal unmetered power losses activity can be identified, detected, and predicted through the proposed analytical Frame work by investigating and monitoring significant deviations in consumers**' load consumption.

- The proposed analytical framework using advanced data-mining techniques, including **Extreme Learning Machine [9]**, **Online Sequential ELM [10]**, and **Support Vector Machine [13]**, and applying two activation functions, namely sigmoid and radial basis function (RBF) nodes.

- To experiment with and produce the flow processes of the proposed analytical framework using **MGVCL** commercial consumers' load consumption data to comprise the training data and testing data for three comprehensive analyses: feature selection process, classification analysis, and prediction analysis.

1.12 Significant Benefits

Unmetered power losses activity is a major problem for many electrical utilities worldwide. Not only does it affect a company's profitability and credibility, but it also increases the cost of electricity to consumers. Therefore, the need to minimize the extent and impact this problem is crucial for both the utilities, including MGVCL Gujarat that is the focus here, and their consumers. The respective benefits flowing to each from the proposed framework of analysis using data-mining techniques are set out as shown in Table 1-2.

Table 1-2: Benefits gained from the unmetered power losses reduction by means of the proposed alternatives

Power Utilities	Consumers
Reduction of the operational costs of on-site physical checking as the inspection team is able directly to target suspicious unmetered power losses activities such as meter tampering and bypassing.	Reduction in the cost of electricity as the extent of unmetered power losses activity is decreased and the transfer of its cost impact to consumers is reduced.
Minimization of unmetered power losses problems such as faulty metering and illegal connections due to the more rapid method of detecting and predicting consumers' behaviour.	Improved consumer satisfaction as the system provides them with more reliable and efficient services.
Increased system efficiency and reliability as the generation of electricity is based on actual economic demand.	Strengthening consumer relationships as timely and reliable results can be produced to assist decision-making process.

The analysis and the results of the research reported in this thesis show the effectiveness and significance of identifying, detecting, and predicting unmetered power losses activity through the proposed analytical framework.

1.13 Thesis outline

Chapter 1: Introduction of power losses in India, Main factor of power losses and types of power losses. The commercial losses are caused by pilferage, defective meters, and errors in meter reading and in estimating unmetered supply of energy. Purposed data mining techniques and significant benefits.

Chapter 2: Consumers load profile study and load profile approached. Load profile and data mining techniques, different types of clustering, electrical power losses and fraud detection techniques.

Chapter 3: Data pre-processing analysis, feature selection analysis, detection analysis, classification analysis and prediction analysis.

Chapter 4: Unmetered power losses analysis framework, data pre-processing and data normalization. Load profiles for consumers of summer, winter and monsoon. Detection analysis, Key Algorithms for Consumer Behaviour Classification and Prediction (ELM, OS-ELM and SVM).

Chapter 5: Classification of electricity consumer behaviour using Extreme Learning Machine, Online Sequential Extreme Learning Machine, and Support Vector Machine. Result analysis and comparison for ELM, OS-ELM and SVM.

Chapter 6: Presents the main finding of the thesis and makes few suggesting for further researches work in this field.