INTELLIGENT BILLING SYSTEM USING ARTIFICIAL INTELLIGENCE

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DECLARATION

We hereby declare that the research work presented in this study report or any part of it has not been submitted elsewhere for the fulfillment of any requirement for persuasion of any kind of degree or similar purpose.

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Executive Summary

Electricity is a vital element required for economic growth, poverty reduction and social development. The Government of Bangladesh, taking into account the vision of 2021 and 2041, has set a priority for power sector introducing Power Sector Master Plan(PSMP), 2016 to upgrade the existing utility service of Bangladesh and has been successful to some extent. Prior this master plan, with the aiding of international agencies, Bangladesh government had first struck the developmental change in this sector back in 1994 bringing about a total transparency-based, efficient unbundling scheme which caused significant changes. But there are still some challenges to work on specially of the distribution segment. Recent COVID-19 pandemic causing anarchy in billing system has given a serious thought on reforms of our ongoing billing system. Despite the prepaid metering system introduction in case of avoiding traditional billing and invoicing, forgeries and monitoring still lurk as a burning question in this regard. Here in this paper, we have made attempts to propose an intelligent billing system using artificial intelligence since intelligent billing is becoming an active field of research for its immense potential in efficient power distribution and billing system. We have studied several related studies which basically focus on advanced metering infrastructure(AMI) which in turns beckons the smart prepaid metering but don't delineate curbing the chicaneries practiced through these smart systems. This paper is an exploratory as well as an empirical study with a combination of quantitative and qualitative method applied for the collection of data through online survey, case studies and content analysis. It will delineate the application of a machine learning technique for examining the energy consumption data using artificial neural networks

and smart meter fine-grained data. Due to massive demand of electricity consumption and recent anarchy or complaints about billing system in our country, there is an urge from consumers to have a better electricity consumption metering system in power distribution companies so that the invoiced bill can be accepted spontaneously by them. There is an attempt, through this paper, to bring complicated machine learning to the billing history of customers so that abrupt changes in prepaid recharges and postpaid reading can be traced or forecasted through machine learning models which may lead to finding anomalies in the billing. The system will also encourage the users to reduce wastage of electricity which is an essential part of our everyday life. Thus, this automatic monitoring system will reduce human interference in the entire process.

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Chapter 1: Introduction

1.1 Foreword

Electricity is one of the most vital and phenomenal driving forces of development for any country. In this current era, we cannot even think of a day without electricity which was almost a very common scenario in the last decade in Bangladesh. Keeping pace with the advancement of time and technology, the government has realized that this is the most strategic sector to focus on. Consequently, to cement the dream of becoming a middle-income and developed country Bangladesh government has undertaken vision 2021 and 2041 respectively of which out of all the outlined plans, delineates the emphasis on electricity production, transmission, distribution and overall management with increasing electricity demand. Within the last decade only, electricity generation capacity has increased more than 12000 MW.**[1]** This enormous success has not come easy rather had to go through many more reformation. In 1994, the Government of Bangladesh undertook the Power Sector Reforms in Bangladesh (PSRB) policy paper in consultation with major development partner of which the Asian Development Bank (ADB) has played the instrumental role.**[2]**. It proposed the unbundling of the then single agent, Bangladesh Power Development Board (BPDB) to generation, transmission and distribution. These tasks ought to be distributed along with corporatization and proper incentivization of these sectors to rejuvenate the dormant sector. With a cordial supervision and management, we have come this far. Still there lies problems. The overall service rendering is not up to the mark and the billing anomalies are a larger portion of this dark side. Despite the boon of technological advancement, the conventional bill collection and then bill calculation is still at

large in Bangladesh. The meter readers visit house to house, collect meter readings, send those to the respective collection offices and the bill is calculated. This task is not only conventional and humongous but also error prone. To reduce and eliminate this problem prepaid metering and associated ideas have been introduced. But to utilize the prepaid metering facility throughout the country it takes time and resources. Until then this problem might continue. The recent billing anarchy has been termed as "Ghostly electricity bill" by the digital and print media in our country. Moreover, not all the consumers can be brought under the prepaid or similar metering system specially HT consumers. And with a view to achieving the developed country government has been leveraging special economic zones and many more facilities which cannot simply be regulated under the prepaid metering system. The household and commercial can be brought under prepaid metering but before bringing we need to address the issue with a proper tuning. In this work, we have proposed different ideas and propositions that can be incorporated into the electricity billing system especially through wireless network and communication technology and to buttress the issues regarding those propositions, we have introduced artificial intelligence with metering and billing system. We have introduced the issues regarding electricity theft with both prepaid and postpaid metering and billing system. Among the issues, non-monitoring of prepaid meters and forged meter reading are common. We have brought the very complicated machine learning to the billing history of customers so that abrupt changes in prepaid recharges and postpaid reading are well predicted through machine learning models. Thus, the machine learning models find anomalies in the billing system so to protect theft in electricity and help in monitoring the metering system.

1.2 Background

Bangladesh, overwhelmed with a large population is facing a large energy demand over the last couple of years due to taking numerous development projects for becoming a developed country within 2041. To realize the aforementioned goal, the country needs to excel in achieving continuous economic growth rate which largely depends upon the industrial development. Only the availability of energy with a strategic usage can ensure this smooth transition. Energy is the pivotal socio-economic development input and corner-stone of the modern industrial economy. And the power sector of this broad energy arena is not only a success story but also a true focus-oriented sector of the current government from its early age.**[3]**Power sector of Bangladesh has gone under many more scissors. The mother organization BPDB has been adorned many more times. Unbundling has been done for discrete responsibilities and overall improvement. These techniques have ushered the tremendous improvement. The rapid demand rate has also been addressed introducing Power Sector Master Plan(PSMP), 2016. Nonetheless, we cannot still attain the end-users' satisfaction. The overall service side is still lagging behind. Moreover, billing system frequently arises customers' grudge. And this grudge actually imparts the ultimate failure. It creates distrust. The traditional meter reading collection by meter reader is a monotonous and an expensive task. Moreover, the data can be erroneous. Besides, sometimes meters are installed in a place in the complex from where reading can't be fetched easily. The fetched reading is then inputted into system. This means many more loopholes are lurking in these stages. With the rapid increase of electricity consumption in our country, it is actually inevitable for injecting a better electricity

consumption metering system so that the invoiced bill will be accepted happily by the countrymen with the least dissatisfaction as well as the best energy management is ensured.

1.3 Statement of problem

Beyond any reasonable doubt, it's true that despite numerous policies, the lack of end customers' satisfaction produces the bleak outcome of government's achievement in power sector. Anomalies in electricity billing system is not a new one. It is rather a constant phenomenon. Besides the recent extra-ordinary billing anomaly, it was there all the time to some to moderate extent. Unified metering system and associated proposals are in stack and some are being implemented to address this billing issue. But the matter of fact that, not all sorts of customers can be brought under this pre-paid metering and also this scheme implementation over the whole country requires a great deal. Between this phase and onwards for a targeted audience, we need to devise a sustainable billing system integrated with artificial intelligence that reduces the issues in great extent. Thus, the artificial system with billing will help reduce energy theft, forged meter reading and increase customer satisfaction and more field monitoring.

1.4 Objectives

We broadly focus on addressing the following bullet points:

- To go through and understand the present situation regarding the issue thoroughly.
- To review the previous studies regarding this issue.
- To identify the recommendations/suggestions of the previous studies.

- Worldwide best practice assessment in this regard.
- To identify the shortcomings/loopholes of the proposed solutions.
- To propose a/several remedial suggestions.
- To assess the feasibility of the proposed suggestions.
- Significantly improve the operational efficiency minimizing cost and resources
- Covering maximum area
- Assuring the sustainability and as well as effectiveness
- Ensuring the re-usage of the proposed system/solution
- Enhancing overall customer service and realizing customer satisfaction

1.5 Research Questions

In this conducted research the following questions have been launched to address the problems and associated issues:

- What is the main billing anomaly?
- How often does billing anomaly occur?
- How energy fraud can be differentiated from regular pattern of usage behavior
- When does this anomaly occur most?
- Why energy consumption forecast is needed
- What is the intensity of billing amount deviation?
- Which category users do face this anomaly most?
- Has any customer ever felt that the invoiced bill is less than he/she might have thought?
- What thing(s) do affect the recent anomaly in case of invoicing bill?

- What sorts of difficulties do meter-readers face during data fetching in normal and abnormal situation?
- What are the main reasons behind the anomalies happened in postpaid meter?
- How well the idea of using prepaid metering can address these problem?
- What are the drawbacks of prepaid metering system?

1.6 Methodologies

The study methodology has been carried out in an exploratory nature and simulated in software with artificial deep learning model. For the purpose of the study, data have been collected from distribution agencies, technical persons and from online survey. Beside these sources, we have collected data from sources like websites, journals, research papers, articles and similar documents. We also checked the accuracy of study which is illustrated on graph.

1.7 Limitations

Time is one of the main limitations that has hindered a successful realization of the thorough research on this topic. Because of time constraints, we haven't been able to review all the possible suggested solutions or recommendations regarding the issue. Besides, because of the sudden outbreak of COVID-19, field level visits and rigorous data collection, checking and scrutinizing haven't been possible. As a result, despite depending on the secondary data, less access and granting data from distribution agencies for several constraints, we to some extent have lacked to illustrate the real scenario.

1.8 Delimitations

In spite of so many limitations, we can proudly say that the conducted research have brought about some new avenues. This study tries to find out every possible issue related to meter reading fetching and further processing. It delineates the challenges along the course which can be taken into consideration upon different accounts. Moreover, it has made some successful recommendations upon the software system responsible for invoicing. Some suggested ideas and proposals can be well utilized in some other cases if it deems not best-fitted for the targeted reason.

Chapter 2: Overview of the present situation

In this chapter we will briefly discuss the working procedures of post-paid and pre-paid metering systems, bright sides of using pre-paid metering, its types currently working in Bangladesh and future plan regarding this metering system. At the end of the chapter we will try to illustrate a tabular information regarding billing and pre-paid metering systems collected from DPDC.

2.1 Postpaid meter

Postpaid electric meters are the most common ones used for measuring electric units consumed. They are normally of two types namely: electromechanical and electronic meters.

2.1.1 Electromechanical meters

This is the most common type of electricity measurement meter. In case of a single phase AC supply, the meter operates through electromagnetic induction by counting revolution of a metal disc. The disc is nonmagnetic but electrically conductive. The disc rotates at a speed proportional to the power passing through meter. The meter's voltage and current coils consume very low power like 2 watt and this amount is not registered with meter. Below the disc, there are two sets of induction motor forming a two phase linear induction motor.

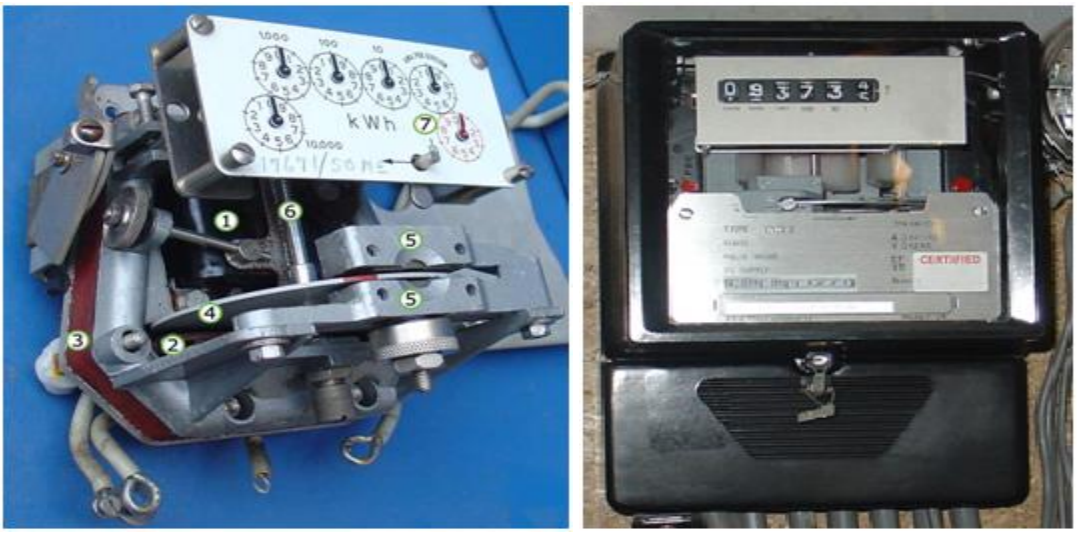

Fig 2.1.1Electromechanical meter internal and external picture

These coils produce magnetic flux in proportion to the voltage and current respectively. Voltage coil field is 90 degree delayed. It produces eddy currents in the disc and so a force is exerted on the disc in proportion to the produced current, voltage and power factor/phase angle between them. A permanent magnet plays a role of eddy current brake. The magnet exerts an opposite force proportional to the disc's rotation speed. If the two opposite forces are equal, then we can say the disc is rotating at same rate of power production. The disc drives count revolutions. There is a spindle consists of a worm gear which drives the register. The register is a series of dials. It records amount of energy consumed. This type of meter requires to take read manually by meter readers.

2.1.2 Electronic meters

These are smarter than electromechanical meters. In addition to energy consumption , they can calculate demand. These are of interval type meter where they calculate consumption in a

billing cycle interval and thus can calculate maximum demand. But in electromechanical meters , they are just accumulation type meters and they cannot understand peak / off peak power consumption and demand. Electronic meters can calculate peak /off peak power consumption.

Fig 2.1.2 Electronic post-paid meter

These meter use LCD/LED display for showing power consumption. The meter has power supply, metering engine, processing engine, microcontroller, real time clock (RTC), infrared communication ports/modules. The metering engine takes the voltage and current inputs and using voltage reference, samplers , quantifiers covert all analogue inputs to digitized equivalents. These digital inputs are then processed using a digital signal processor to calculate required metering parameters. Processing and communicating unit calculate various derived quantities from metering engine derived measurements. It also communicates using various protocols and interfaces with other connected modules. Then it plays master role and another module plays role of slave. So RTC and other add on modules are its slave. In modern time all

these modules are integrated in a single chip called microprocessor such as RTC, LCD controller, temperature sensor, memory and analog to digital converters.

2.1.3 Billing Using Postpaid meter

Currently Postpaid meters store energy information and meter readers go to home/industry where meters are installed. Then manually read the consumption amount and send information to distribution company. Distribution company invoices consumption bill processing those provided data accordingly. In Bangladesh, consumed units of electricity is divided into several unit slabs for generating bill. Here for lower slabs, unit price is low and higher when the slabs increase. This way authority not only discourages the wastage of electricity consumption but also makes it affordable for the lower income people. For HT and MT consumers, meters track highest energy usage of that meter in each billing period of 30 minute and among these values highest value is considered for his demand charge. Peak Time is a time when total usage of all meters is high. So,for cutting peak time demand off , per unit energy price for peak time is high. For off peak time they offer low per unit energy price. The meter records the amount of electricity used, and then the meter reader take reading, this information is passed to the supplier, who bills the consumer for the amount of electricity they consumed. The upside of this is that a consumer doesn't have to worry about running out of balance on their meter - it won't automatically cut off the supply of electricity due to lack of balance of meter.

2.1.4 Drawbacks of Postpaid meters

- Consumers are less concerned about unnecessary electricity consumption. So electricity misuse is common.

- Consumers consume beyond their affordable capability subconsciously.
- During pandemic, meter readers are also unable to go consumers' house and take meter reading . So, distributor companies made an assumption and generated bill on assumption. As a result, an unprecedented billing incidence occurred.
- Sometimes meter readers take bribe from consumers and take false meter reading for sole benefit. Thus, company faces loss.
- Accumulation type postpaid meters cannot decide peak time and off-peak time usage and it also cannot calculate maximum demand. So, these are not fit for energy price calculation.
- In conventional postpaid meters, meter tampering is easy. Meter readers go to take reading at a fixed time of month. So dishonest consumers can easily do this bad practice and due to lack of remote communication of meter , it is not possible to track this corruption.

2.2 Prepayment Metering System

By definition prepayment electricity system does not use billing in its classical form but collects the money up front. It rather works most likely recharge based cellular fashion where a consumer recharges his/her meter and uses until the recharged amount expires. In terms of money the consumer actually purchases unit of energy which is inserted into the meter through a special card.

2.2.1 Determining the energy consumption in Prepaid Meter

Present days prepaid meters are a wonder not only in the terms of smart electricity or energy usage but also keeping a track of the need of and measuring the usage properly. It helps user to measure how much he or she needs energy for a period of time and what measures might be taken to adopt the fair usage. In prepaid meters, energy consumption is calculated in kwh. When a consumer requests to recharge the meter, the request is sent to the due authority's vending station. Upon receiving the request, vending station inspects the tariffs associated with the meter and converts the recharged amount into a digitally produced hash code or some specified format code. This code actually bears the assigned energy units to be consumed.Some prepaid meters use STS(Standard Transfer Specification) technology . Through this technology, meters are only able to accept a specific 16 or 20 digits encrypted code which will be processed by the meter internally. The internal firmware of the meter is programmed as such which decrypts this code and converts it into energy in kwh format. This technology successfully bars any sort of fraudulent activities of recharging the meter. A flash light attached to the meter indicates whether the meter units are consumed or not. With the usage of energy units the meter balance lessens and the light flashes. Light flashes more with more consumption.

2.2.2 Common Architecture of the Prepaid Metering System

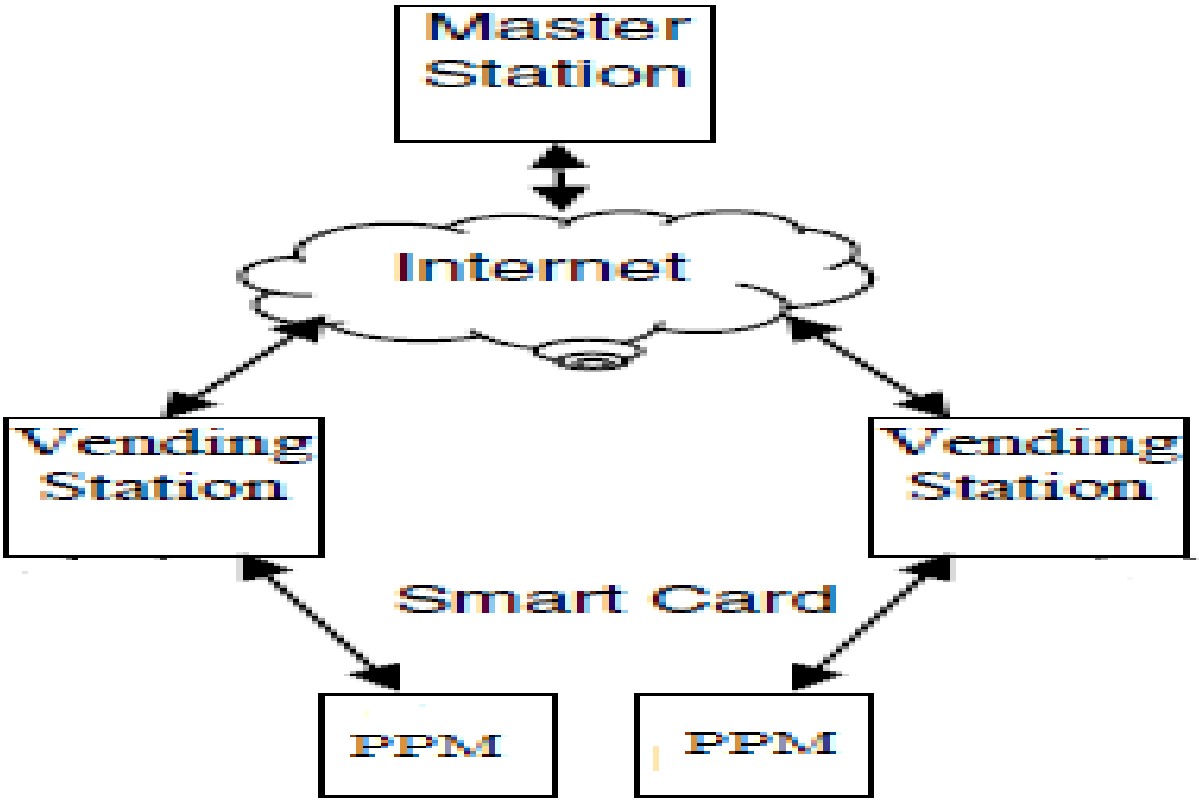

Fig 2.2.1 Topological architecture of prepaid metering system

2.2.3 Most common types of Prepaid Meters

2.2.3.1 Smart prepaid meter

Smart prepayment meters have all the same functionality as standard smart meters, allowing to view usage information at any time using the in-home display. This can help to manage electricity usage and find ways to cut down and save on bills.These modern prepayment meters are also more likely to have smart features to make electricity top ups easier. Consumers can usually complete a smart meter top up online or via an app to save them leaving the house.

Once top up electric on smart meter the credit will be added remotely, so consumers don't need to do anything with their meter.

Fig 2.2.2 Smart prepaid meter

2.2.3.2 Smart Card Prepaid Meter

Card based metering system is a newer invention in the field of electricity usage. It helps a consumer to recharge whenever he or she requires electricity. It facilitates the user to recharge in advance and keeps rest assured of uninterrupted electricity flow. It reduces many hassles not only for the customer but also for the people related to power sector specially distribution agencies. It also displays the use's consumption units and hence helps user maintain the smart and considerable usage of electricity.

Fig 2.2.3 Smart card prepaid meter

2.2.3.3 Keypad Prepaid Meter

User can buy electricity refill vouchers. These are available from payment counters in partnering banks, vending stations and other online outlets. User can also buy them from mobile banking. The user will be asked for the identification number of the meter which is on barcode label on the front of the meter. The voucher will give a 20 digit number. Enter this

number using the keypad on the front of the meter, the number user enter will be displayed on the LCD screen. If he/she makes a mistake he/she can press the backspace key to delete digits. Once user have entered and checked the token number, press the enter key to activate the electricity. Upon a correct insertion, the encrypted code will be converted into the energy units stored in the meters and a successful string is displayed on the display. On the contrary, fail or rejected message is shown.

Fig 2.2.4 Keypad prepaid meter

2.2.4 Benefits to utilities

Benefits of prepaid meter are praiseworthy. Through prepaid meters, distribution utilities can receive the payment beforehand which accredits the company balances than before. Utilities need to create tokens for the users which are delivered to the vending stations from where users can collect them. It cuts the traditional processes of bill collection, processing, creating

and printing the vouchers and emailing to the users. In the case of keypad prepaid meter, the need of physical token is not required. Through dialing up any vending station necessary information can be exchanged to receive the encrypted hash code over the phone. Upon a successful insertion of that code instantly brings the user the required energy units. Described scenarios in some advanced and smart utilities are handled by IVR(Interactive voice response). Many features of traditional features are also possible to exercise with prepaid meters. In addition, modern prepaid meters offer better accuracy and reliability. They offer better adjustment as well as resilience to environmental incidents. Although prepaid meters negate the meter reading collection process, it requires the distribution agencies to send staff to maintain the meters and inspect whether any tampering is made.

2.2.5 Benefits to consumers

Through the use of prepaid meters not only the utilities get benefitted but the same goes with the consumers. Prepaid meters can bring more control over energy consumption to the user. User can recharge upon the need. As long as the recharged units are there, there is no worries regarding the usage. Advance recharging facility is also there which adds an extra benefit. Hence user can have over control over the electricity usage. User can determine as well as regulate his or her consumption. It helps user be optimal regarding consumption. It lessens the traditional invoice receiving and going to the respective offices or bank booth to deposit the charged money. Thus standing in long queues for depositing the money is vanished with the population of prepaid metering. Thus money and time both are being saved. Also users are free from bearing the extra charge in case of failure to deposit the money timely. Additionally

prepaid meter establishes a positive relationship between the utilities and customers. It reduces hassles for both the consumer and utilities, cuts off theft and forgeries and builds trust between the consumer and utilities. It makes the distribution services easier and more maintainable.

2.2.6 Advantages of prepayment meters

- Helping customers to manage their debt and energy usage;
- Preventing large, unexpected bills.

2.2.7 Disadvantages of prepayment meters

- Costing is a bit higher than the average.
- Not all categories of consumers can be brought under this scheme e.g industry, plant
- If user can't recharge timely or after a specific period electricity will be cut off and things will get rotten and similar incidents may occur when consumer may leave the residence for a period of time. This adds an extra botheration for the consumer.
- If any issue arises regarding tariff and maintenance, complicacies may arise as these meters and their maintenance are delicate.

2.3 Findings from a distribution company

As stated earlier, during the pandemic situation it was really a very tough job to collect the required data let alone conduct a live investigation. It was a hard time for everyone. Despite all

odds, DPDC, a well-known electricity distribution company responsible for distributing electricity to the southern part of capital city, Dhaka and some portions of Narayanganj, provided us with a list of complaints and resolution from which we can have a glimpse of complaints regarding billing and pre-paid metering issues.

Complaint Type	No of Complaint	No of Solved
Over Billing	437	437
Bill Correction	131	131
Reading Mismatch between Meter & Bill	88	88
Paid Within Due Date Still Showing Arrears/Sur-Charge	58	58
Meter Inspection	30	30
Prepaid (Taking Extra money in Pre-Paid Recharge)	23	23
Master Data Correction	21	21
Payment Related Problem	18	18
Meter/Reading Related Problem	16	16
Prepaid (No Electricity After Recharge)	14	14
Prepaid (Meters are cutting more money)	14	14
Prepaid Vending Problem	11	11
Prepaid (Meter recharge problem but there is Electricity)	7	7
Prepaid (Meter recharge problem and No Electricity)	5	5
No Reading Shown on Bill	4	4
Arrear Related Problem	3	3

Complaint Type	No of Complaint	No of Solved
Prepaid Recharge	3	3
Prepaid (Customers not understand vending calculation)	2	2

Table 2.3.1 Category wise Complaints from 26.04.19 to 31.08.20

From the above table, we can have a clear picture of how many problems the consumers face regarding billing and pre-paid metering issues. Although the above table doesn't describe the whole scenario but still it indicates the severity of this problem. The pre-paid metering involves some technical and recharging glitches which need to be addressed for its popularity and well acceptance.

Chapter 3: Literature Review

Numerous studies have been found addressing this meter reading and additionally bill calculation process issues around the world. In Bangladesh, many studies have been carried out keeping a pace with the world-wide practice and ideas but with some modification, obviously for the purpose of applicability, availability, implementation hurdles, costing and many more factors.

3.1 AMR using digital wattmeter and Wi-max[4]

In this paper an 'Automatic Electric Meter Reading (AMR)' system has been proposed. It is a metering system that in a package not only collects the meter reading data but also processes the data for billing and further task e.g. decision purposes. This AMR system primarily consists of four basic units namely reading unit, communication unit, data receiving and processing unit and billing system. For reading unit, disk rotation of the energy meter is proposed to be identified and stored the data in microcontroller which eventually keeps the current analog energy meter unchanged. In this an external module is required to be added to the conventional meters. For the purpose of communication module, Wi-max technology is used between the meter end and the server end. This was highly suggested because of its huge coverage. Data receiving unit processes meter reading data with the help of a micro-controller. A computer application will perform this task which eventually reduces any sort of risks of meter tampering or any other forgeries. Despite having many other proposed AMR system the authors claim their study to be most effective for Bangladesh considering many issues of the

other systems. They also claim their study is innovative in the fashion of implementation idea. The study was a project of a group of researchers from American International University, Dhaka, Bangladesh conducted at the Electrical Circuit Laboratory of the university during October 2009 to November 2010.

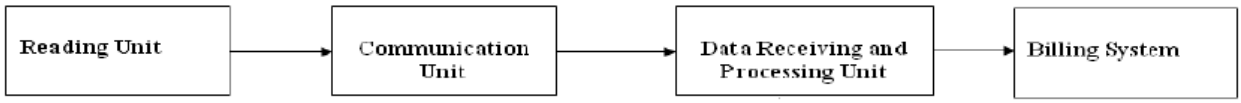

Fig 3.1.1 Block diagram of the whole proposed AMR system

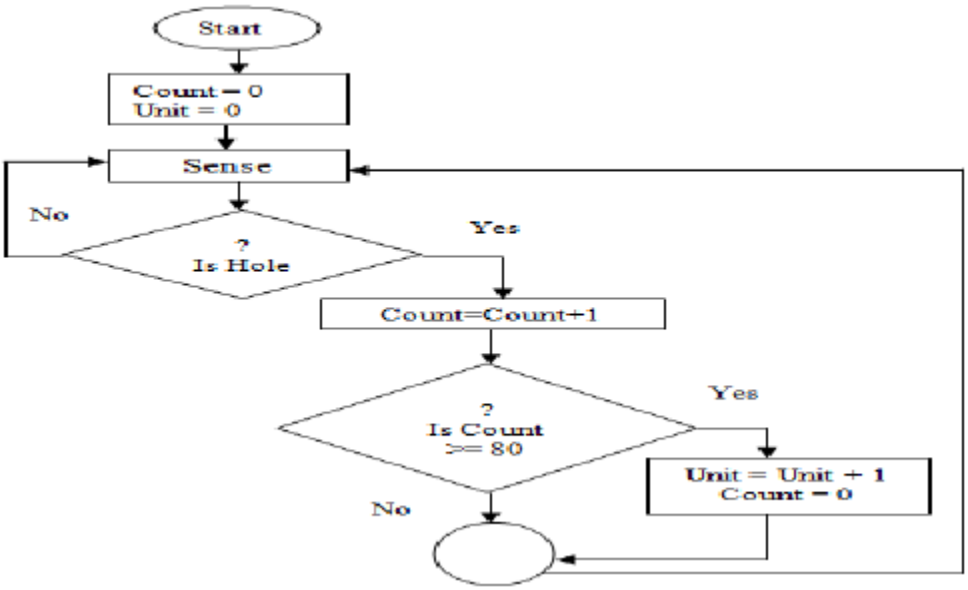

Fig 3.1.2 Sample flow chart of the reading unit

3.2 Automated Electricity Bill Monitoring[5]

This study combines the usage of growing ICT dominance with a view to not only measuring the spent electricity unit but also automate the unit collection, bill processing and create awareness among the people of using electric energy rationally. The following conceptual design of the proposed system mainly consists of four modules:

A. User Management

User will be registered through a system. Through the respective account user will be contacted regarding the usage and consumption of electricity and associated bill/invoice.

B. Monitoring Energy Consumption

This module notifies the user about the usage and consumption of electricity unit. This can be viewed in different manners like daily, monthly or hourly basis. The central admin of the system can monitor the total consumption of any area or any particular house of an area.

C. Creating Awareness Among Consumers

In this module user can set their usage limit and accordingly user will be notified at the threshold or if the limit is crossed. This will surely help create awareness among the users.

D. Automatic Bill Generation

In this module the bill generation process is made automated based on the consumption by the user and will be notified through a SMS.

In a nutshell the study focuses on rational usage, making people aware and last but not the least saving the power as well as creating a healthy environment in a broader spectrum of the country.

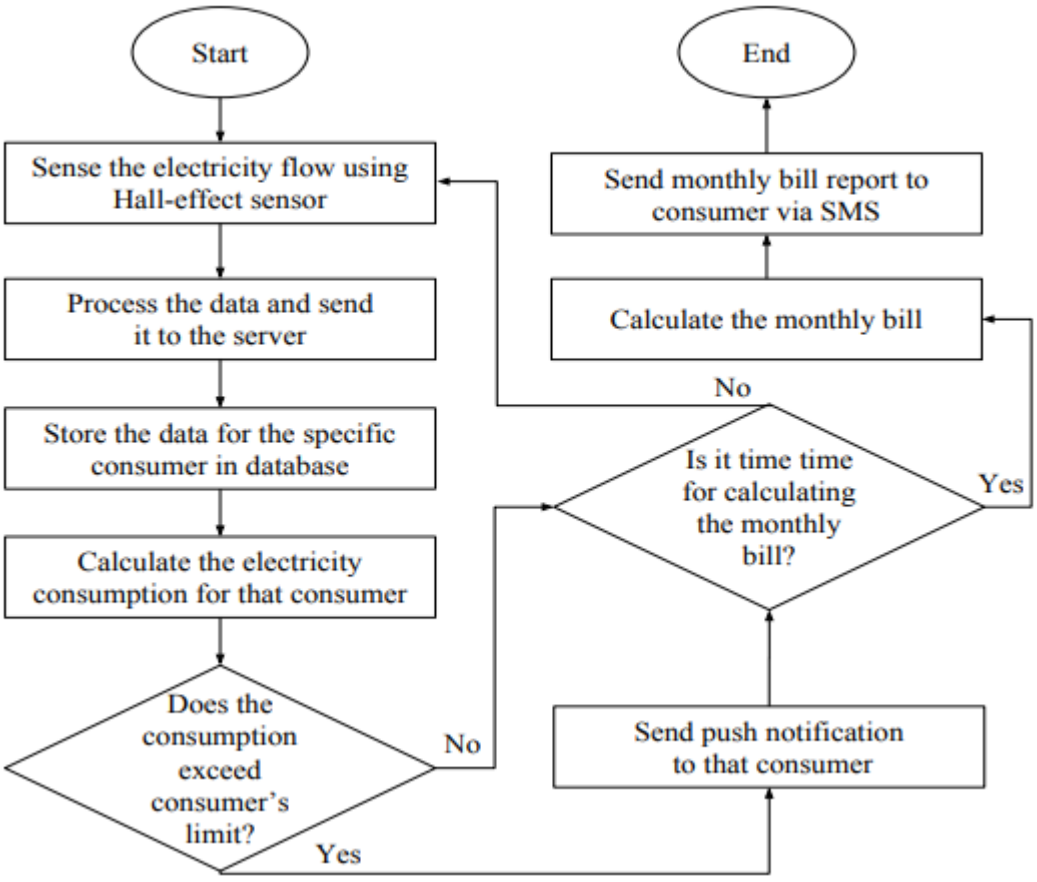

Fig 3.2.1 Flow chart showing the work flow of the proposed system

Reading of consumption rate taken from existing electric meter (R) (Watt)	Reading of consumption rate taken from the prototype system (C) (Watt)	Deviation ($D = \|R - C\|$)	Percentage of Deviation ($\frac{D}{R} * 100$)
59.75	59.69	0.06	0.10
57.54	57.54	0.00	0.00
56.89	56.76	0.13	0.23
57.33	57.37	0.04	0.07
56.67	56.68	0.01	0.02
55.48	55.48	0.00	0.00
56.37	56.37	0.00	0.00
56.45	56.32	0.13	0.23
57.90	58.00	0.10	0.17
56.23	56.23	0.00	0.00
55.78	55.80	0.02	0.04
56.45	56.45	0.00	0.00

Fig 3.2.2 Difference between the actual reading and reading of the proposed system

3.3 GSM based Automated Electricity Billing System[6]

In this paper Automated Meter Reading(AMR) system is proposed but using the Global System for Mobile Communication(GSM) technology. Proposed system has the following four units:

A. Reading Unit

In this module a miniature GSM module will be connected to the existing meters which convert the analog meter reading into digital data. This module holds a SIM which transmits the converted digital data to the distribution end.

B. Communication Unit

In this module, a GSM network will be used between the meter and server end for successful data transmission and receiving. This is widely used communication network of low cost and reliable as well.

C. Receiving Unit

A GSM based modem is used at the distribution agency station to receive the transmitted digital data which basically holds the user consumption data.

D. Processing Unit

The received data is then sent to a computerized system for further processing and calculating and ultimately generating the invoice of electricity consumption.

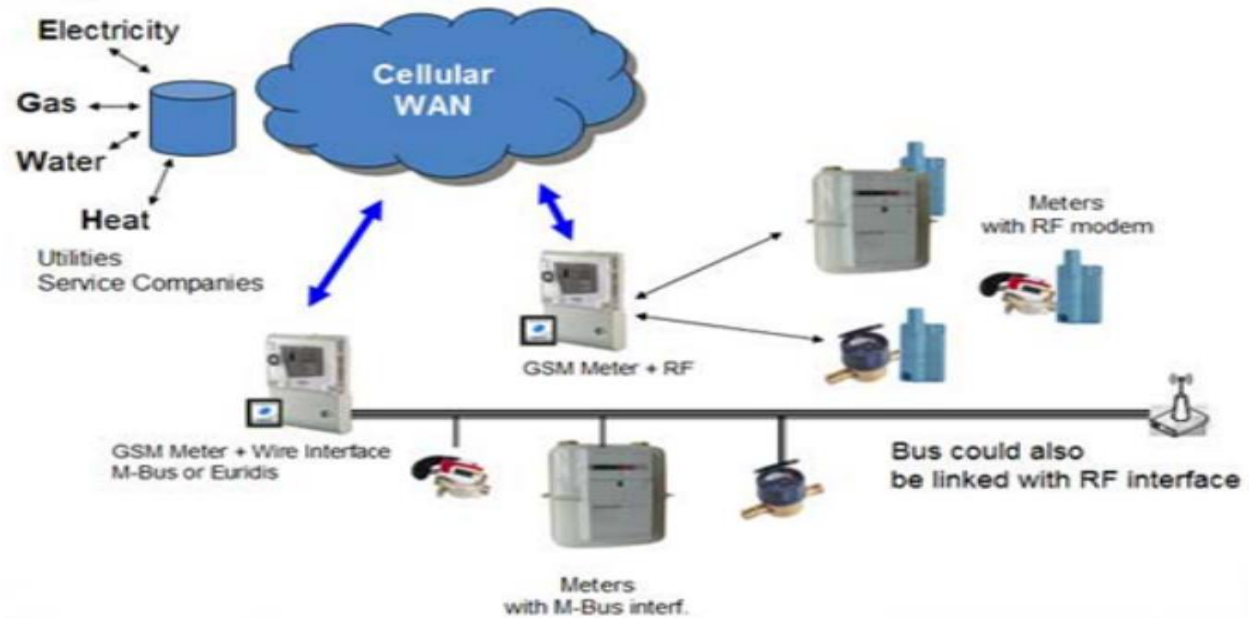

Fig 3.3.1 GSM network-based system

Besides, many other studies and proposals have been made consisting of SMS based metering system**[7]**, IOT based solution**[8],** prepaid metering**[9]**, smart metering**[10]**etc have been carried out for addressing the problem. More or less all the studies have several limitations but at the same time proposed some good recommendations. Currently at the policy level unified

prepaid metering system looking forward to incorporate the smart grid system has been being implemented which is shedding rays of good hope. Although many issues have been surfaced from using pre-paid metering**[11], [12]** authority is trying its best to address and minimize these issues. Nevertheless, as has been stated earlier, pre-paid metering scheme can't be established over the whole country, hence existing meter reading and invoice generating system should be ameliorated.

Chapter 4: Proposed Intelligent Billing System using AI

Energy fraud or anomaly detection is a critical aspect of smart grid security and privacy preservation. It is also an indispensable part of intelligent billing system. Machine learning and data mining along with artificial intelligence have been widely used by researchers for extensive intelligent analysis of data to recognize normal patterns of behavior such that deviations can be detected as anomalies. In this section, we will discuss a novel application of artificial intelligence for examining the energy consumption data to report energy fraud and forecast electricity consumption by using neural network. Our proposed technique is able to pinpoint successfully different forms of bypassing smart or traditional metering system and adopting similar means.

This chapter starts with describing the basic concept of background knowledge on artificial neural networks and support vector machine, so that the ideas proposed in the subsequent chapters can be easily perceived. Afterwards, we shed a detailed lights on data extraction and preprocessing, which are the most relevant and important sections for realizing and experimenting the study. Later, we give an in-depth discussion on energy fraud and anomaly detection procedure using artificial intelligent and its different components. We also discuss the major limitation of these procedure. We end this chapter by giving a summary of the topics discussed.

4.1 Background Knowledge

4.1.1 Artificial Neural Networks

Artificial neural networks (ANN) are computational techniques modeled on the learning processes of the human cognitive system and the neurological functions of the brain. In recent times, artificial neural networks have been able to catch attention of its successful application in solving a variable range of problems of different fields due its wide degree of modularity. Neural networks are nothing but a distributed information processing system that consists of different computational nodes communicating through different channels across the network based on some weights. Inspired by the architecture of the human brain, neural networks exhibit certain features such as the ability to learn complex patterns of information and generalize the learned information. Neural networks are simply parameterized non-linear functions that can be fitted to data for prediction purposes.

The main attractiveness of neural networks is their flexibility in approximating a wide range of functional relationships between inputs and output. Indeed, advanced neural network with sufficient data can approximate any discretionary functions. One of the most attention-grabbing properties of neural networks is their ability to work and forecast even on incomplete, noisy, and fuzzy data. Moreover, they are doing not need a priori hypothesis and don't impose any functional form between inputs and output.

For this reason, neural networks are quite practical to use in the cases where knowledge of the functional form relating inputs and output is lacking, or when a prior assumption about such a relationship should be avoided.

The success of the NN models depends on properly selected parameters such as the number of nodes (neurons) and layers, the nonlinear function used in the nodes, learning algorithm, initial weights of the inputs and layers, and the number of epochs that the model is iterated.

In ANN methodology, the sample data usually is split into 2 categories that are named as training set and test set. First the neural network learns the relationship between output and input criteria with the help of training data set, whereas within the validation process, test set is employed to assess the performance of the model.

4.1.2 Support Vector Machine

Vapnik**[14]** developed Support Vector Machine (SVM) which constitutes one of the most robustand accurate methods in data mining algorithms. Its theoretical foundation derived from statistical learning theory. Statistical methods and machine learning methods are combined with SPV method. SVM is a supervised learning method that generates input-output mapping functions from a set of training data.

Observations constitute source of SVM learning process. There is an input space and output space and a training set. The nature of the output space decides the learning type. Learning types can be of any kind including type of binary or multiple classification problems. The standard SVM formulation solves only the binary classification problems.

Predicted value in SPM methodology represents “attribute” where transformed attribute defines “feature”. Hyperplane is defined by the transformed attribute. The task of selecting the

most appropriate representation is known as “feature selection”. A set features that describe one case is called a “vector”.

Mapping data to a high dimensional feature space is the working manner of SVM where the mapping functions can be either classification or regression function. SVM methodology is among maximal margin classifier types. There are four kernel functions (linear function, polynomial function, and radial based function, sigmoid function) to be used in classification problems when the input data is not easily separable.

Optimal hyperplane is found by SVM which separates the clusters of vectors in such a way that cases with one category of the target variable on one side of the plane and cases with the other category are on the other side of the plane. Support vectors are the ones near the hyperplane. A separator which is drawn as a hyperplane is found between the separated classes.

The ultimate aim of SVM is to establish a maximal margin between the separated classes. Establishing a maximal margin between the separated classes will enable to have a good classification performance on the training data as well as to provide high predictive accuracy for the future data from the same distribution. The characteristic of new data after separation can be used for prediction. SVM’s learning ability is independent of the dimensionality of the future space and that situation leads to SVM providing good performance**[15]**.

In the support vector machine (SVM) technique presented on top only applies to classification and output unit is restricted to take binary values. However, the SVM models are extended for general estimation and prediction problems which is known as support vector regression (SVR)

technique. Usage of support vector regression (SVR) technique eliminates the restriction on output variable since SVR methodology permits use of nonlinear functions.

4.2 Data extraction and preparation

Before the neural network approach is described, it is imperative to introduce the data to be analyzed for deriving computational intelligence. The dataset under investigation consists of smart meter consumption data from approximately 40,000 residential households and 3000 businesses. These representative samples were anonymously collected from the billing history (2014 — 2019) of Shah Ali S&D database. The raw data are stored in an excel file saving around one million entries corresponding to diverse power meter readings. 'Table 1 represents a small sample of one of these data files where the data is represented in the columns. The first column represents the smart meter ID which is linked to a particular consumer. The second column shows the month (month no. January starting as 1, February 2 and so on)associated with the meter reading,3^{th} column is sanction load (kilo-watt),4^{th} column is tariff (tariff string e.g. C2, E, A defined by Bangladesh Energy Regulatory Commission),5^{th} to 9^{th} are peak consumption (kilo-watt-hour), off peak consumption(kilo-watt-hour), peak kvarh (kilo-volt-ampere-hour) ,off-peak kvarh(kilo-volt-ampere-hour), kw-reading/maximum demand reading (kilo-watt)accordinglyand the last column or 10^{th} column is the energy consumption price in taka.

Meter Id	Month	Sanction Load	Tariff	Pick	Off Pick	Pick Kvar	Off Kvar	Max Demand	Price
1392	01	2	A	23	56	5	12	1	1230
…	…	…	…	…	…	…	…	…	…
…	…	….	…	…	…	…	…	…	…
1393	01	5	A	34	123	12	20	4	2560
…	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…
1393	12	5	A	32	125	10	15	3	2245

Table 4.2.1 Sample Row Data Structure

It is well known that the effectiveness of data processing depends not only on the data analysis algorithms used but also on the quality of the data. Therefore, for achieving better results in energy fraud detection, a suite of data pre-processing techniques is employed before any further analysis. In this section, we describe the two main procedures utilized for pre-processing the raw energy consumption data before they are analyzed: data cleaning and feature selection. In addition, to facilitate faster access to data in the files, we applied some indexing and compression algorithms widely used in information retrieval systems.

4.2.1 Data Cleaning

Data cleansing/cleaning is a data mining process which focuses on identifying and correcting inaccurateness, incompleteness, and inconsistency in raw data. It generally involves a few tasks such as identifying and addressing missing values, reducing noise and inconsistencies, and detecting outliers**[16]**.

At a first stage, the data are explored for missing values. Since energy consumption data are time series data, it is quite straightforward to find all missing points as they correspond to missing time stamps. When such rare missing data points are found for a particular month, it was replaced with average energy consumption value for that particular year**[17]**.

The second cleaning step involves identifying and eliminating outliers. In this regard, the mean and standard deviation for each month is computed. After calculation, all measurements that do not lie within three standard deviation of the mean (we assume that around 1 % of the data are outliers or noisy/unimportant data) are removed from set. The assumption is that these outliers should not be considered as fraud and may correspond to peak energy consumption activities during holidays or special occasions such as birthdays, celebrations.

Lastly, we check the data with respect to real world inconsistencies in date/time stamps. For example, if we have a time stamp for the 13^{th} month, we either attempt to correct the inconsistency or remove the entry.

4.2.2 Feature Selection

The experimental smart meter data contain several important parameters such as month, and some consumer energy consumption values in kwh. We decided to concentrate on all attribute of the “monthly” data.

The main reason behind this is that we are trying to find anomaly or fraud activity based on month. We do not consider hourly or weekly data of consumption they cannot significantly influence the energy consumption measurements, conducting experiments with “weekly or hourly” feature included did not show any significant improvements in results. Theseare thus omitted for simplicity.

4.2.3 Indexing and compressing

The data files contain millions of various meter ID entries. In order to efficiently process the reading of consumer energy, we created an index which maps each meter ID to its own measurement data. Such an index provides quicker data retrieval from all files for a particular ID. In addition, the index is compressed by delta encoding widely used in information retrieval systems to store or transmit data in the form of differences between sequential data rather than complete files**[18]**.

4.3 Anomaly in consumption pattern detection approach

Machine learning is widely used in many areas of research for deriving computational intelligence. It allows understanding of the underlying behavior of complex systems. A neural

network is one of the most common machine learning approaches used in fraud detection due to its noise-robustness and fast response qualities**[19, 20]**.

A neural network consists of three different types of layers**[16]**. The first layer includes various features of the dataset under investigation as input. The second layer usually comprises of a few hidden layers having a varied number of nodes. And the last layer is an output layer representing the classification result of the neural network. The main goal of applying a neural network technique in this scenario is to learn consumption behavior per consumer and predict future energy consumption measurements. We believe that it is possible to detect energy fraud by comparing neural network predicted values with real measurements and applying statistics to analyze any deviations.

Our energy consumption anomaly detection approach consists of the following.

4.3.1 Selection of Input/output Parameters for Neural Network Structure

Careful articulation of input/output parameters in a neural network structure is very important for performance and precision.

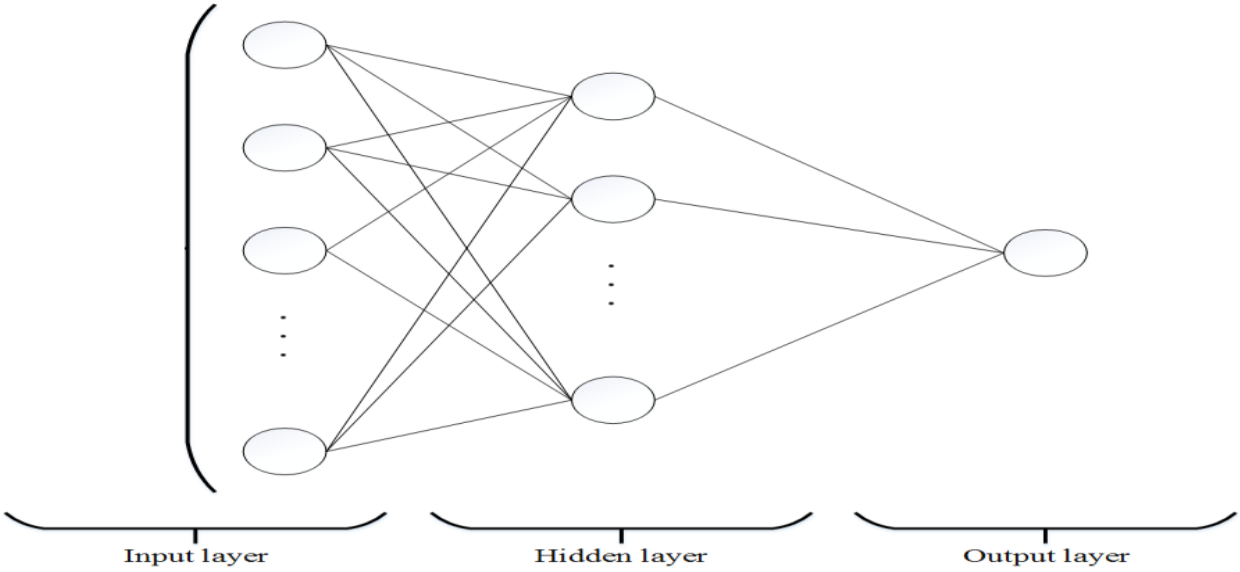

Fig 4.3.1 Neural Network Structure

The number of consecutive months (N) of last 2 years serve as input data of the input layer attribute for the neural network. Each month contains 6 attributes due to the fact that monthly meter readings of a particular consumer needs to express first 5 attributes in the dataset and 6^{th} attribute is the output value which is the energy consumption kwh of that month in the dataset set. Therefore, the input layer contains a total number of 5 nodes.

The hidden layer is adjustable and in our experiment, it consists of only 1 layer of nodes for simplicity. The output layer consists of only one attribute, which represents the expected energy consumption price in the smart meter reading data series following the consecutive data points. Fig. 1 shows the energy consumption behavior by neural network structure employed in this research.

4.3.2 Generation of Training and Validation Datasets

Our dataset carries the billing information of last 2 years of different consumer .We divide our whole dataset in two parts, training datasets and validation datasets. The training datasets contains 90% of total data where rest of them are used as a validation dataset. We divide our dataset in a way so that validation set and training set both carry the information of every consumer. Each row in the data are divide in two part, first 9 value of each row act as a input attribute and last one is the corresponding output of that row.

4.3.3 Training the Neural Network

The neural network is trained using the training dataset which results in learning of the consumer energy consumption behavior.

4.3.4 Prediction

This task is accomplished by running the neutral network using the validation dataset. The output of the neural network predicts the value of the expected data point in the smart meter reading data series following the consecutive data points fed as input.

4.3.5 Detection of Deviation

The Root Mean Squared Error (RMSE**[15]**) serves as the deviation indicator between the predicted value and the actual value in the validation dataset and is calculated as in (1):

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(y_t' - y_t)^2}{n}} \qquad (1)$$

Where y_t' is a predicted energy reading by the neural network, y_t, is an actual energy consumption reading in the validation set, and n is the total number of instances. If the RMSE is above a certain threshold, then it is inferred that the training set depicts a different behavior than the validation set and therefore the data in the validation set possibly correspond to an energy fraud.

Chapter 5: Experimental Study

To show our experiment and its result, we will first describe working procedure step by step. The proposed automated metering system equipped with artificial intelligence to monitor consumption anomalies and fraudulent activities is run against historical billing data of Shahali Sales & Distribution Division (a consumer facing division office of Dhaka Electric Supply Company, Dhaka, Bangladesh).

5.1 Experimental Data

The data consists of two excel files –

1. Training Data.xls – contains monthly consumption of around 50000 consumers/meters from January, 2018 to December, 2019. The file can be found at https://drive.google.com/file/d/1vXMqIaGBmWf8AFHa-Le65FRL0FAGpwMv/view?usp=sharing . The file contains almost 1 million entries of monthly energy consumption of almost 50000 consumes. On an average, each consumer has 24 months of consumption data.
2. Test Data.xls – contains monthly consumption of around 50000 consumers/meters of January, 2020. The file can be found at https://drive.google.com/file/d/1rMe765dBR7QBIv2m6LcfyQc0k7lS91LT/view?usp=sharing. The file contains monthly consumption of same 50000 (approximately) of the month of January, 2020.

The data mentioned at point 1 will used to train our artificial neural network. The trained neural network model will be tested to find its accuracy again the data mentioned at point 2.

5.2 Working Procedure

Now with the data mentioned above, we will follow the procedure step by step listed below to find our desired trained neural network. This neural network is our intelligence for automated billing/metering system. We will look for continuous deviation of a consumer's consumption from the predicted consumption by the neural network model by a certain threshold. Thus, we can isolate out the consumers with suspicious consumption pattern those may require human inspection. This way the human inspection can look if the consumer's consumption is okay or consumption is bypassed or forged meter reading.

- ✓ We will remove the columns that are not in line with out experiment. In other words, we will only keep the following columns that can give insight for desired neural network. We will keep account no, month, year, sanction tariff, sanction load and total unit consumed and remove/ignore other data attributes. We will do this both for training data and test data. These features consist of the input layer, depicted atthe figure**5.2.1**.
- ✓ We will use every row of Training data.xls file to be a feature vector for neural network. We have used python panda library to simulate neural network. We feed the feature vectors to neural network model and construct the basis for intelligence of our proposed metering system.
- ✓ After training is done, we will find the neural network in desired state. Then we will use the test data to verify how good the neural network is performing. In other words, we

will find the total consumption of the consumers in the test data in January, 2020. Then we will compare how much the prediction deviates from actual data.

- ✓ In this step, we will analyze the test result. We will divide the difference of predicted consumption to actual consumption into 10 slabs namely 0-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-100%. How much difference is anomaly? Finding a reasonable answer is another area of further study. However, for instance, we take 100% difference as anomaly. Again, the amount that can trigger anomaly is dependent on the type consumer e.g. residential, commercial and others. If the anomaly continues for a long period (another area of study) for the same consumer, this case may be isolated for human inspection.

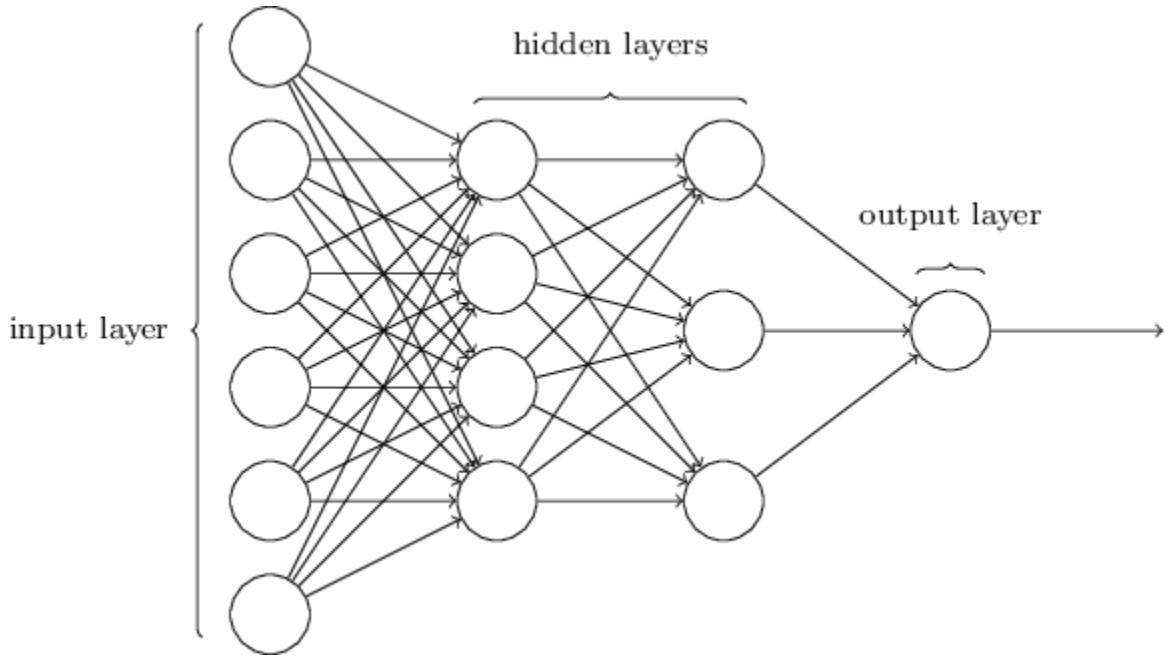

Fig 5.2.1 Neural Network Model

We have hosted our simulation code in GitHub repository. The code is written in python using Google's tensorflow library. We have used python packages e.g. keras, sklearn, panda, numpy.

The code can be found at https://github.com/mujahid1005011/bpmi_thesis. The repository contains necessary simulation code and cleaned data. The included Readme.txt file contains necessary instructions about how to run the code.

5.3 Simulation Result

We have trained the neural network with almost 1 million monthly consumption history and tested against almost 47000 consumers' consumption. The simulation code run with regression neural network model. The code snippet below shows the simulation result of actual consumption versus predicted consumption after training the neural network. The box contains the main simulation code written in python.

```
import numpy as np
import tensorflow as tf
import pandas as pd
from keras.layers import Dense, Activation
from keras.models import Sequential
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler, LabelEncoder, OrdinalEncoder, OneHotEncoder

# Importing the dataset

dataset = pd.read_excel('BPMI_Thesis_train_data.xlsx').to_numpy()
X = np.concatenate([dataset[:, 0:3], dataset[:, 4:5]], axis=-1)
y = dataset[:, 5]

y = y.astype(np.float)

X_train = X
y_train = y

test_dataset = pd.read_excel('BPMI_Thesis_test_data.xlsx').to_numpy()
X_test = np.concatenate([test_dataset[:, 0:3], test_dataset[:, 4:5]], axis=-1)
y_test = test_dataset[:, 5]
```

```
try:
   # Feature Scaling
sc = StandardScaler()
X_train = sc.fit_transform(X_train)
X_test = sc.fit_transform(X_test)

   # Adding the input layer and the first hidden layer
model.add(Dense(32, activation='relu', input_dim=4))

   # Adding the second hidden layer
model.add(Dense(units=32, activation='relu'))

   # Adding the third hidden layer
model.add(Dense(units=32, activation='relu'))

   # Adding the output layer

model.add(Dense(units=1))

model.add(Dense(1))
   # Compiling the ANN
model.compile(optimizer='adam', loss='mean_squared_error')

   # Fitting the ANN to the Training set
   #print(X_train)
model.fit(X_train, y_train, batch_size=10, epochs=100)

y_pred = model.predict(X_test)

   slots = {
      100: 0,
      90: 0,
      80: 0,
      70: 0,
      60: 0,
      50: 0,
      40: 0,
      30: 0,
      20: 0,
      10: 0
   }
   index = 0
   import math
   for y in y_test:
y_p = y_pred[index][0]
```

```
diff = 1 if y == 0 else math.sqrt((y - y_p) * (y - y_p) * 100 / y)       index += 1
        included = False
        for x in slots.keys():
            if diff >= x:
                slots[x] += 1
                included = True
                break
        if not included:
            slots[10] += 1

    import copy
tests_len = len(y_test)
slots_per = copy.deepcopy(slots)
    for x in slots.keys():
slots_per[x] = (slots[x] * 100.0) / (tests_len * 1.0)

    print(slots_per)
    print(slots)

plt.plot(y_test, color='red', label='Actual data')
plt.plot(y_pred, color='blue', label='Predicted data')
plt.title('Prediction')
plt.legend()
plt.show()
except Exception as e:
    import traceback
    print(traceback.format_exc())
```

Here we have shown only around 4000 results instead 47000 to emphasize visual clarity. Here we can see some spikes that symbolizes the noticeable difference between predicted and actual data. That is an area of where can use more historical data to make the neural network model more accurate.

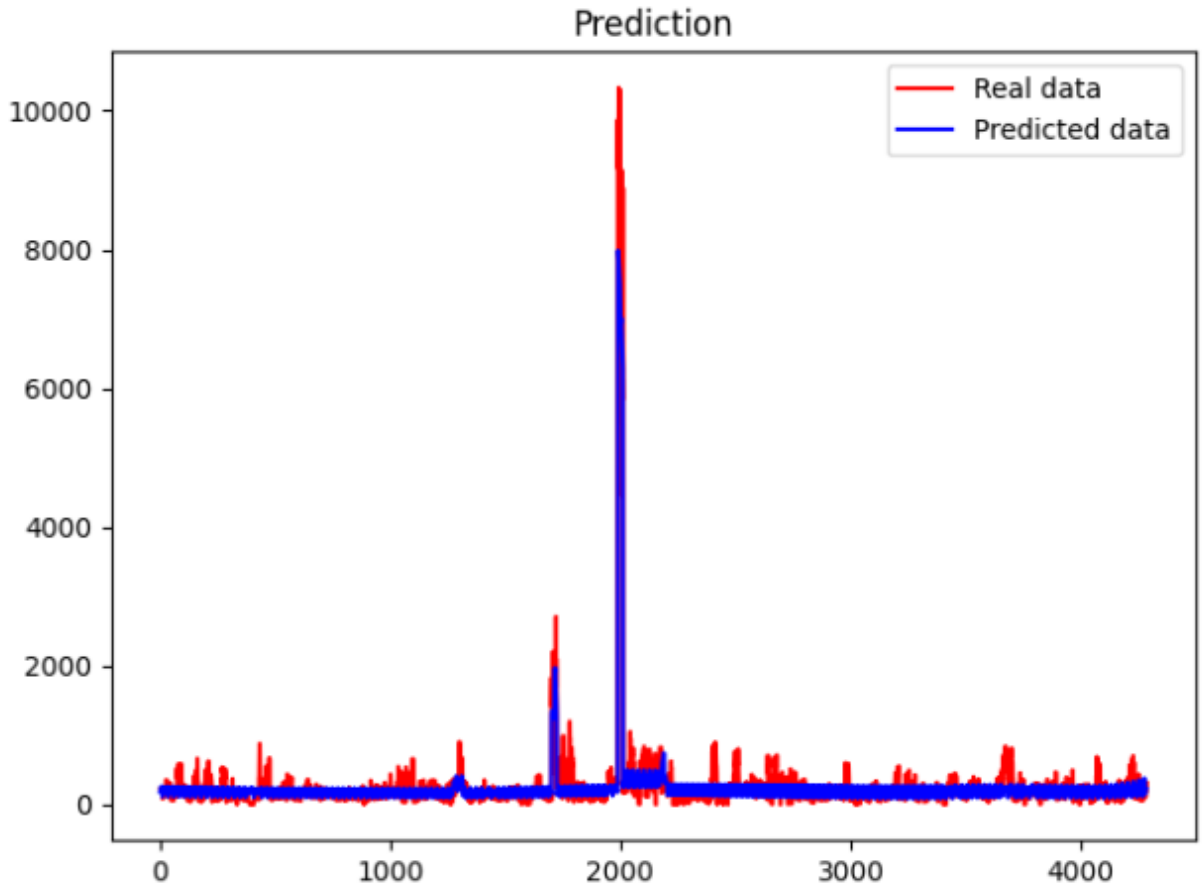

Fig 5.3.1 Simulation Result Comparison Actual vs Predicted (Only 4000 of almost 47000 rows)

We have also categorized the difference between actual and predicted consumption into 10 slots. Here are more than 40% has less than 10% difference and less than 10% has more than 100% difference.

0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90%-100%	100-above
40.56	**15.6%**	**5.56%**	**4.44%**	**4.4%**	**3.3**	**3.14**	**1.99%**	**11.48**	**1%**	**8.52**

5.4 Limitations of Experiment

There are enormous areas where we can improve our study and further increase the horizon of the research topic. Now we will point some pros and cons of our study –

- Data Limitation: the data is monthly consumption basis and lack some other features those could be insightful e.g. consumer age, time temperature etc.
- There is scope for determining what percentage in difference can determine the consumption as anomaly provided the error rate in result.
- Our study did not include what distribution of consumption anomaly can be isolated a energy theft or abnormal consumption.
- The data did not include prepaid meter recharges and consumption. But this can be adapted into current model trivially.

Chapter 6: Conclusion

The findings of data and their corresponding analysis with regard to the research questions and objectives delineate that anomalies in electricity billing system is not a new phenomenon. Various attempts have already been made to address those vexing problems of non-technical losses such as contracting out meter reading and billing, pre-paid meters, computerized billing ,cut-offs and legal penalties. But nothing has been proved to be that much successful so far.With the rapid energy demand as well as service modernization in this present era, itis almost indispensible for the utility service providers for introducing user friendly service and invoicing system. This paper has shown several existing smart meters assisted economic energy consumption schemes for consumers and power outage reduction scheme for distribution utility companies that has enhanced the quality of service. In this regard, we have proposed an intelligent billing system using artificial intelligence for a stable and economically viable electricity distribution system and an effective and trust worthy bill collection system throughout the country.We believe It will facilitate the newly introduced prepaid metering service quality as well make this project sustainable. Service with a better management can be ensured through this proposed scheme.Despite so many limitation we have outreached some corners which we believe herald some newer scopes to be injected or to be experimented on. It also entails the challenges along the course which can be taken into consideration. Finally, an in-depth discussion on energy fraud and anomaly detection procedure using artificial intelligence and its different components has been given with some considerable recommendations.

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