

Smart Metering in Smart Grid

Purusharth Semwal, Sourish Palit, Shlok Indulkar and S.Senthilmurugan

Abstract: *The paper talks about smart metering in the smart grid and its implementation in India. The conventional energy meters have huge disadvantages as compared to the smart meters. There is a huge increase in demand for load in India. The problem is that these demands have not been satisfied fully. There are over 200 million households out of which 40 million households still have no electricity supply. Even if the demands were to be satisfied, numerous problems arise pertaining to the loss of energy which in turn affects the economy of a nation. Crimes such as power thefts are also increasing day by day. Not only this but the present scenario for the post-paid systems also seem to fail. Hence, the Smart Meter will solve the above problems. Smart Meter will not only measure energy but also exchange the power consumption information between utility companies and consumers. In the paper, we have proposed some solutions which could actually help in reducing the electricity's loss and advantages of smart meters. India is the place where most of the people can't afford to pay the bills for their electricity consumption or for the ones who don't even have such a connection, this might be a golden opportunity. The deployment of Smart Meter in India will result in detection of power theft at a faster rate. People don't have to wait in line to pay their electricity bills, they can easily recharge their Smart Meter using prepaid mode. Hence, its popularity is increasing day by day. Given below are smart meter architecture, prepaid mode, post-paid mode and a way to detect power theft. This idea can be used anywhere around the world and it would really be helpful.*

Index Terms: Smart Meter, Smart Grid, Prepaid Mode, Post-paid Mode, Power Theft Detection.

I. INTRODUCTION

Nowadays, electric power consumption is increasing at a high rate especially in urban areas. In the present scenario, the power sector of India is facing problems like AT & C losses, inefficient distribution, and transmission system.[3] It is because of the age-old power infrastructure. Moreover, Non-technical losses (NTL) like electricity theft, non-payment by customers, etc. have worsened the condition.[4] Generation and transmission costs are high due to operational losses which are exceeding by 30%. There are fluctuations of power cuts and voltage which are unscheduled, digital payments which are not acceptable in most of the cities. [5] Old equipment is used which needs regular maintenance which is not conducted properly.[6]

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Out of 200 million, 40 million households still have no electricity supply. The conventional energy meters were electromechanical meters which can't store the data and has one-way communication.[7] There is no memory element which can store the history of the consumption. Also, meter reading is done physically.[8] An official will come to your door and note down the reading displayed on the meter, and according to that, the electricity bill will come. Estimated readings were shown. The readings were rounded off to the nearest tens digit for the handy calculation.[9] Connections were done manually. No warning was given before for the due payment. Hence, the smart meter concept came to light.[10] The conventional billing system was slow, inaccurate, lack of reliability and flexibility. A Prepaid Energy Meter will empower utility center to gather consumer's bill before its consumption.[11] The possibility of prepaid metering will be imperative for the new research fields of Smart Grid and is an unavoidable advance in making any grid smarter than it is currently. The metering industry is under the transformation these days. India has the majority of generation, transmission and distribution network in the world. The design of smart meter with theft detection has been proposed [1]. The effect of hybrid electric vehicles on the smart grid has a huge impact [2]. The government has taken various initiatives like UDAY, Integrated power development scheme, Saubhagya scheme, etc. [12] The main objective of this is to install the 100 percent metering. India is likely to invest 45 billion rupees in smart meter distribution; this will help India to reduce 23 percent transmission and distribution losses. The market of India is ₹ 2354 crores and is to be expected to grow at CAGR of 8-10 percent over the next 5 to 6 years.[13] The first step is to create an advanced metering infrastructure. Smart Meter National Program (SMNP) is on the verge of replacing 25 crores traditional meters with smart meters in India. The billing efficiency can be increased up to 75-100 percent. The revenues of utility will be increased by 1,38,100 crores. Many state governments have started introducing smart meters under the Indian government's Smart Cities Mission.[14] This program goes for urban reestablishment with the mission to make 100 smart cities across the nation.[15] For example, as of late, the Uttar Pradesh Electricity Regulatory Commission (UPERC) affirmed an appeal recorded by Uttar Pradesh Power Corporation Ltd. (UPPCL) with respect to the rollout of smart meters in the state. The UPPCL is focusing on 4 million customers over five distribution organizations (DISCOMs). In the first phase, smart meters will be introduced in cities with high energy input >50 crore units and high Aggregate Technical & Commercial losses.



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In the second phase, cities with energy input ≥ 25 crore units will be profited and in the third phase, cities with energy input ≥ 15 crore units and < 25 crore units will be profited.[16]

In August 2018, the Energy Efficiency Services Limited (EESL) presented two memoranda of understanding (MoU) with North Bihar Power Distribution Company Limited (NBPDC) and South Bihar Power Distribution Company Limited (SBPDCL) to convey smart meters in 130 cities and adjoining rural zones covering around 18 lakh clients in the state.[18]

In October 2018, a tender for 30,000 smart meters was issued by Indore Smart City Development Limited under Indore Smart City venture. [17]

Back in March 2018, EESL issued a tender to secure 5 million smart power meters. The meters would be sent crosswise over India.[19]

As of late, the Asian Development Bank (ADB) effectively finished the pilot period of its satellite-based smart meter venture in a town in Varanasi in which 5,000 families got the meters.[20]

In the paper, we have discussed the role of Smart Meter in today's world. Its advantages and disadvantages are also debated. The prepaid mode of payment is now more preferred over the postpaid mode of payment. The proposed algorithm of postpaid mode and prepaid mode is also analyzed. The power theft is an increasing problem in India. The reasons for problem theft are examined. We have discussed the proposed algorithm of power theft detection from "A novel power theft detection algorithm for low voltage distribution network", by Arvind Kumar Gupta, Ayan Mukherjee, Aurobinda Routray, Rajashree Biswas.[9]

II. COMPARISON BETWEEN THE CONVENTIONAL GRID AND SMART GRID

The traditional power grid is the network of interconnections of generating stations, high voltage transmission lines, and distribution lines. It is electromechanical in nature which implies that the infrastructure comprises of mechanical devices that are electrically operated. It works very slowly by default. It lacks flexibility in the power source, just as in the transmission system. There is one-way communication between electricity providers and customers.

TABLE I: Difference Between Conventional Grid and Smart Grid

Sr. No	Conventional Grid	Smart Grid
1	One Way Communication	Two Way Communication
2	Centralised Generator	Distributed Generator
3	Manual Monitoring	Self-Monitoring
4	Limited Control	Pervasive Control
5	Manual Restoration	Self-Healing
6	Electromechanical	Digital
7	Less Sensors	More Sensors

Generally, a smart grid comes in action, which ensures the better connections, maintains the efficiency, reduce the environmental effects. Smart meter implementation can handle the power demands and use of smart meters. Smart meters consist of a digital display which can record the real

and reactive power, energy, consumed. Smart grids have automated bidirectional control. The smart energy meter includes the real-time clock (RTC), a data communication module, tamper detection, analog to digital converters, power management system.[16]

III. SMART METER

A Smart Meter is a major part of a Smart Grid framework. It is a useful asset which changes the activity of the power system. The power consumption is measured at a regular interval. This gathered information is sent to a central data management system through wired or wireless communication. They are fit for recording energy consumption information including frequency, voltage, current and power factor. [8]

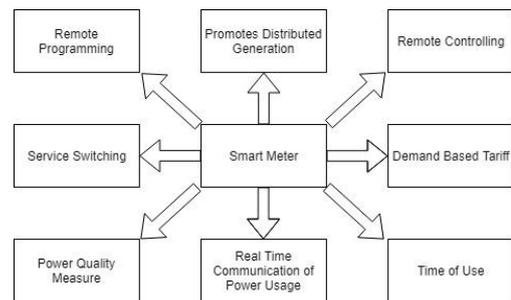


Fig1. Important functions of Smart Meters

At the outset, Automatic Meter Reading (AMR) systems were familiar which lets the utilities to take the readings remotely. After this, electric suppliers placed resources in Automatic Meter Infrastructure (AMI). It varies from AMR is that two-way communication is empowered between the utility companies and consumers. [6]

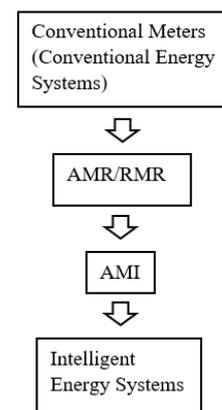


Fig 2. The representation of the evolution of smart meters[17]

Two-way communication alludes to the communication between electric providers and customers with the assistance of either wire or wireless communications. It is one of the vital features that separates smart meters from conventional meters.[20]

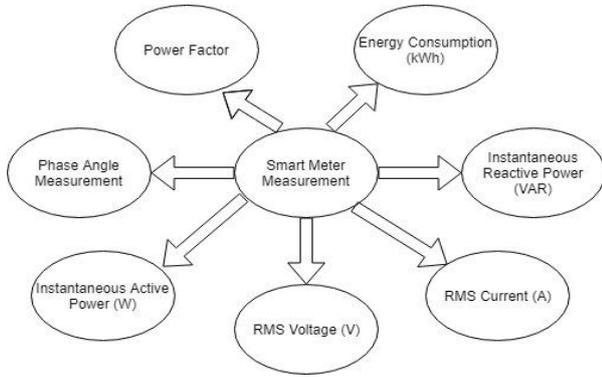


Fig 3. Measurements are taken by Smart Meter

What's more, many smart meters have extremely valuable alert capacities, which can be set by the recorded information to help consumers to remember their energy usage. Moreover, it can detect power outage fast and restore. Additionally, the customers have a choice of a decision of selection of tariffs, [12] It can help in the discovery of power theft and hence, it upgrades the security.

IV. THE ARCHITECTURE OF SMART METER

Consumer Premises refers to the residential or industrial areas where smart meters are installed to collect and record data.

Smart Meter consists of two parts

- Analog Part
- Digital Part

The Analog Part consists of

- Power supply
- Anti-Aliasing Filter
- Battery Charger
- Real-Time Clock (RTC)
- Voltage and Current Measurement
- Anti-Tampering Circuit
- Sigma Delta ADC
- Harmonics Analysis

The Digital Part consists of a microcontroller unit (with register and RAM). The work of the microcontroller is to do all the calculations, storing all the values and transmitting the stored data.

Communication Protocol establishes a connection or communication between the smart meter and MDMS.

The Meter Data Management System (MDMS) is where the data which enters the operation center is collected from the concentrator. It is then processed and stored properly. The tools which are available at MDMS enable operations and management at different sections. It also does other work such as data communication and data processing.[10]

Utility Center refers to the centers which organize and manages these types of connection.

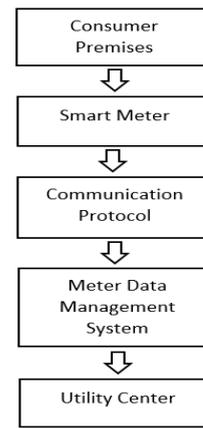


Fig 4. Smart Meter Architecture [14]

V.ADVANTAGES

Application of smart meters in the power systems can produce various advantages for different stakeholders.[13]

Advantages of Smart Meters for Utilities

- With the advanced monitoring technology and automated meter reading, the number of employees will be reduced.
- There will be a better use of power resources.
- The power system will offer dynamic pricing for the electricity market.
- The demand peaks will be less.[5]
- Smart Meters will monitor the electric systems fast.
- There will be less chance of power blackouts.
- Client premise safety will be improved.
- Interruptions and power theft will be detected easily.
- Operational costs will decrease.

Advantages of Smart Meters for Consumers [17]

- It permits the customers to get more data about their energy utilization
- It allows the consumer to manage energy use in the best possible manner.
- It empowers the customers to shift to an off-peak time period to reduce the electric bills.
- It lets the consumer shift between conventional and renewable resources based on the tariff.
- The accuracy of the billing is improved as the bill is based on actual electricity consumption.
- The bill estimation is reduced.
- Outage restoration is improved.
- Data quality and power quality are improved.

Advantages of Smart Meters for Government

- Encouragement of renewable energy resources.
- Smart Meters will provide support for the Smart Grid initiatives.

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- Smart Meters will provide better distribution and hence new power plants will be required less thus, reducing the pollution.
- Less emission of Greenhouse gases like CO₂.
- Better monitoring will result in the prevention of power outages.

VI. CHALLENGES

The advancement of the smart grid and smart metering framework in India isn't a simple undertaking as the Indian power sector represents various challenging issues such as the following:

The capital and operational cost of the smart meter are high, thus many times the launching of the smart grid has been delayed.

- The data collected and the process by the smart meter should be verified.
- It is a new, complex and time-consuming project.
- There are still people who have no idea how electricity is been delivered to their homes. Thus, people should be made aware of electricity consumption, the advantages of using smart meters, etc.
- There is a health concern about the emission of the pulsed radiofrequency (RF) radiation from wireless smart meters.
- The utility employers should also be educated regarding smart meters.
- Conversion from existing technology to new technology takes time.
- There is a concern on the intrusion of privacy and security of individual consumption data. The information gathered from the consumption data could give a critical knowledge of customer's behavior. This important data could be abused if strict rules and regulations are not adhered to.
- Access to funds is one of the real barriers in the execution of Smart Grid. Policymakers need to make increasingly favorable guidelines so as to pull in an ever-increasing number of private players.

VII. POSTPAID MODE

Utility charging is unavoidable in the world with respect to the concern post-paid energy meter. In India, numerous utilities are as yet using old methods for billing. An individual from your utility visits your home at a specific time (monthly, bimonthly or quarterly) and calculates the total amount based on unit consumption.[2]

Proposed Algorithm:

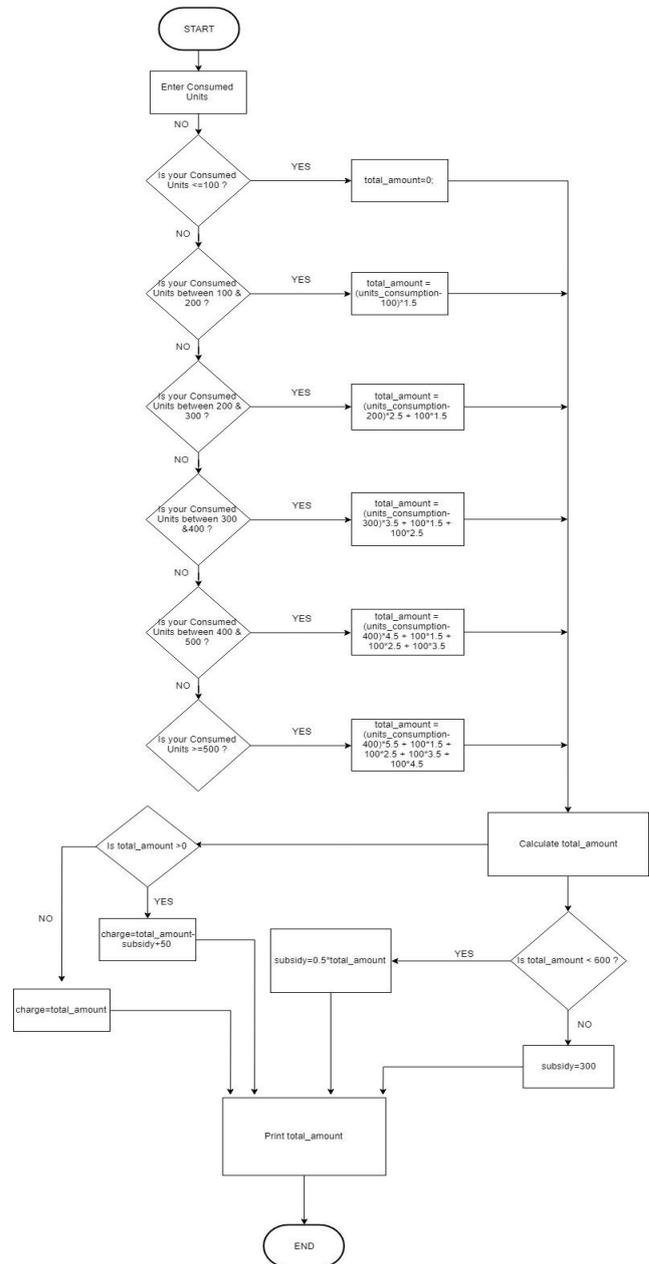


Fig 5. Flowchart for Postpaid Mode

Here, we are rounding off to nearest decimal.

Therefore, one can easily see that as the unit's consumption is more, the consumer has to pay more amount. It is done to motivate the consumer to use less electricity.

The consequence of this type of billing are:

- The procedural is time-consuming.
- The utility company has to employ extra personnel who goes to the door to door to note down the readings [18]
- Billing errors
- Power theft
- There is no verification of the meter reading
- The consumer is not aware of his electricity usage.[7]
- The consumer may not get their bill slip within due time.
- The reluctance of consumers towards paying electricity bills on time.

Therefore, in order to reduce revenue losses, Prepaid energy meters are preferred.

VIII. PREPAID MODE

The utility supply is fed to the energy meter where the prepaid card is fixed in it, the signals are fed to the card. The local supplier will control the supply, the supplier will disconnect the supply and request you to recharge it by online payment, as the utility gets the information about the balance details from the card.[15] There are high accuracy and great dynamic range, it can handle multi-tariff billing, prepayment meters are also available, it can detect the power factor, the readings are reliable and accurate, the structure is robust and stiff.[11]

In India, the step to implement the smart meters is the revolutionary step, as there is ease of payments and doing away with the paper bills.

Beginning from April 2019, the Indian government has planned to replace all power meters in the nation with smart prepaid meters. The way toward exchanging over is required to take almost three years.

This activity by the Ministry of Power (MoP) is relied upon to decrease the aggregate technical and commercial (AT&C) losses, boost energy conservation, and make bill payments bother free and ecologically friendly by getting rid of the paper money.

This move is additionally helpful to poor people as they would not have to pay the whole month's bill at once.

Power Minister R.K. Singh, in the past, made the declared that smart meters should be stated all over to bring down the losses. The administration likewise plans to introduce 10 million prepaid meters in Uttar Pradesh as a feature of the Saubhagya scheme which expects to energize more than four crore family units till March 2019.

Advantages of Prepaid mode:

- It helps in maintaining the energy consumption, you can use up to your limit.
- It tells you whether you are misusing it or not and you do not have to worry about the bill.[7]
- It tells you about the estimate that can overcharge you.
- You can cope up with the tariff if you are having the compatible meter.

Proposed Algorithm:

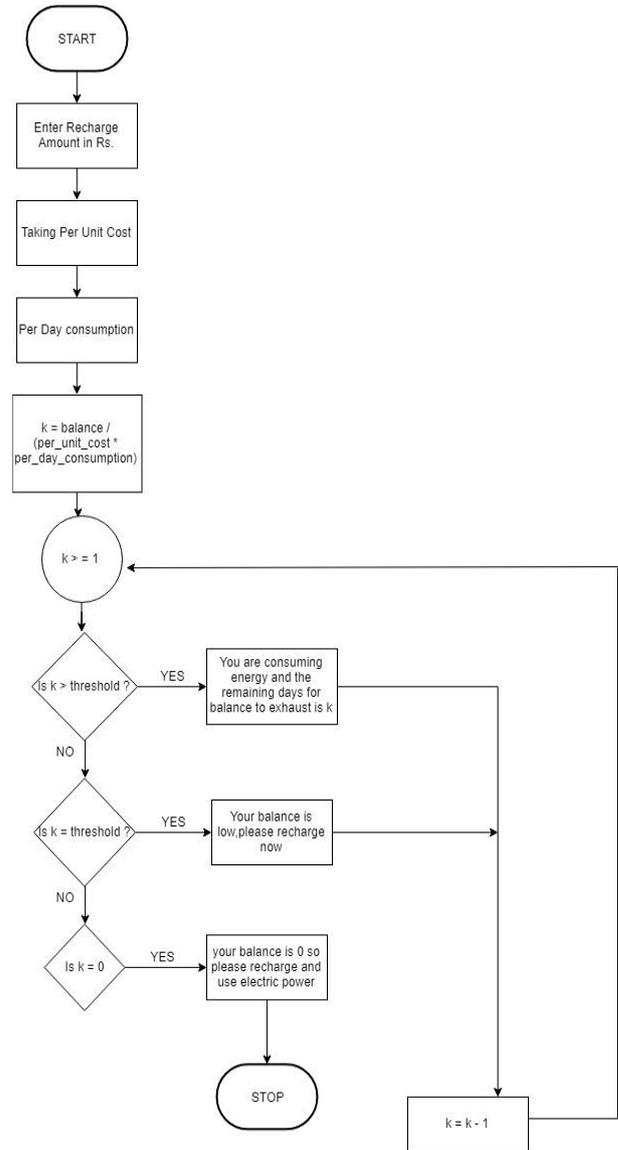


Fig. 6. Flowchart for Prepaid Mode

Here, we are taking the assumption that per day consumption is the same every day and the cost of each unit is around Rupees 5. Moreover, we took threshold value to be 4 days which means that if the number of days is less than threshold than it will start displaying that the consumer has a low balance and to recharge.

IX. POWER THEFT DETECTION

When it comes to electrical energy it consists of many losses in the field of generation, transmission, and distribution. When there is a high demand for energy there is always a huge difference in the supply and load. There are various reasons for this to happen, the main cause being the losses. But these losses cannot always be detected in the present scenario systems.[3] Where the energy losses in generating systems can be calculated in the substations, the losses occurring in transmission lines and in the distribution, systems cannot be precisely calculated. Losses come not only in the form of energy, but it can also mean some technical losses.[14]



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Technical losses can be calculated by getting information about the total load generated and the bill generated. Surprisingly it is always seen that the bill generated is always less as compared to the load generated by the substations. This is due to several physical factors which occur in transmission and distribution systems. The main factor which adds up to these issues is the occurrence of power theft.

Power theft is basically the act of stealing power without the owner's prior knowledge. In our case, it is stealing power from the government by not paying proper bills. Since in power thefts, the meter reading is not accurate and hence the bills are not accurate. Power theft is a punishable crime and it directly affects the nation's economy.[19]

There are several reasons for people to consume illegal power. The most common one is the high tariff which is taken from the consumers. There are many financial issues which occur which restricts people from paying their bills. Considering a place like India where poverty is really common the things are deemed to occur.

Methods of Electricity Theft

- Energy Meter By-passing
- Incorrect readings are taken by meter readers
- Unpaid bills by private organizations
- Tampering with the energy Meters
- Directly tapping from the cables (known as hooking)

Out of these hooking is one of the most common practices. About 80% of the global power theft is due to hooking.

We have discussed the proposed algorithm of power theft detection from "A novel power theft detection algorithm for low voltage distribution network", by Arvind Kumar Gupta, Ayan Mukherjee, Aurobinda Routray, Rajashree Biswas.[9] Proposed Algorithm for Power Theft Detection

Let us consider a system which consists of two meters – one connected on the line pole and one in the house load. Let P1 be the reading in the meter connected across the pole and P2 be the power consumed in the house in a single day. Let us take two threshold powers th1 and th2 which is assumed to be the maximum power which can be consumed to be 100 KWh.

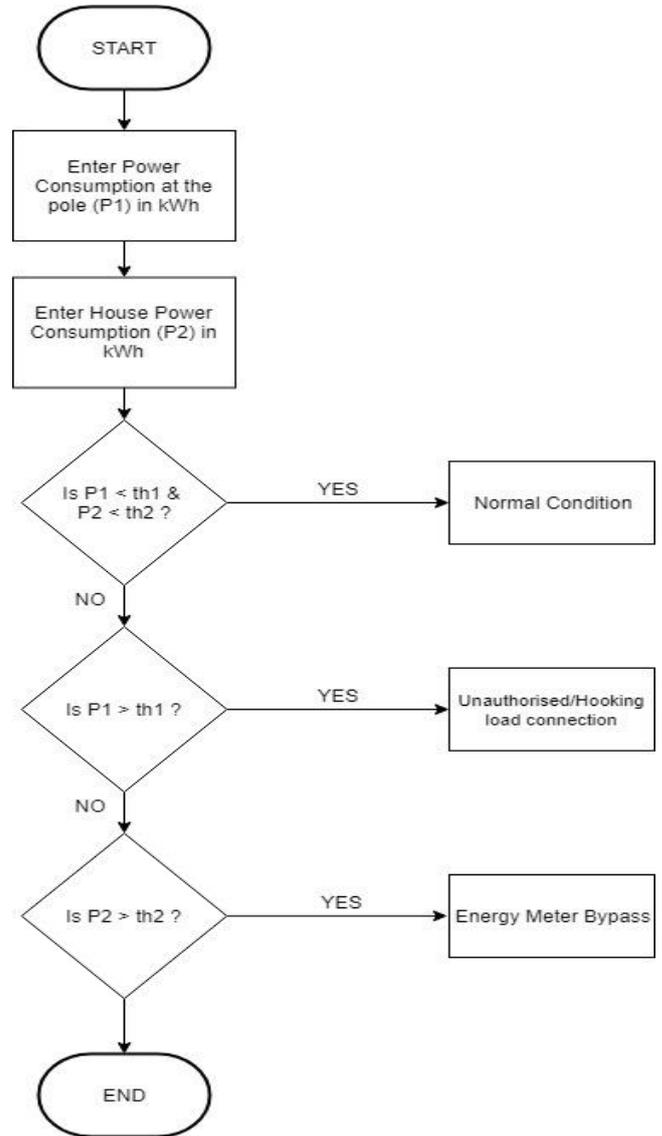


Fig. 7. Flowchart for Detection of Power Theft

X. RESULT

We did the programming in MATLAB platform where we got results for postpaid mode, prepaid mode, and detection of power theft.

For postpaid mode, different values of unit consumption (in kWh) are entered and corresponding outputs are displayed as shown in the table below.

TABLE II: Postpaid Mode Results

Units Consumed in KWh	Total Amount in Rs.
56	0
112	59
226	158
378	423
419	586
596	1478

For prepaid mode, for different values of money, we got a different number of days for which the utility will provide electricity to the consumers.

TABLE III: Prepaid Mode Results

Recharge Amount in Rs.	No of Days
250	7
400	17
1000	41
1500	61
3500	141

For power theft detection, we got the following results: -

TABLE IV: Power Theft Detection Results

P1 (kWh)	P2 (kWh)	Remarks
91	97	Normal Condition
126	95	Unauthorised/Hooking Load Connection
93	135	Energy Meter Bypass
117	115	Unauthorised/Hooking Load Connection

XI. CONCLUSION

A smart meter is still in the early stages as till today there is no large-scale execution of smart metering practices. The consumers should be benefitted from the establishment of smart meters and its use. Though there are many other challenges in the implementation of smart meters, it has a bright future in India. The smart grid will upgrade the strength and unwavering quality of intensity frameworks using AMI innovations. The accurate billing, good monitoring of power flow, detection of power losses are some advantages of smart meters using AMI. The objective of this paper was to give the learning on the job of Smart Meter innovation in the Smart Grid. The smart meter is more advantageous than conventional meters as it has been discussed. It can not only be used in Demand Side Management but also in increasing the security of the building. Moreover, the paper provided the proposed algorithm for postpaid mode and prepaid mode of payment of electricity. One can easily see that prepaid mode has advantages over postpaid mode as the prepaid mode follows one tariff while postpaid mode has different levels of the tariff. In India, power theft is one of the most important reasons for the loss of income for utility center and hence the government should find a way to tackle power theft as soon as possible. Hence, detection of power theft was also discussed

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