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Power Grid Smart Meters: Current Status, Issues, Benefits, and Trials

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Abstract:. *This investigation affords a comprehensive appraisal of the hardware and communication technology of smart meters. Problems with smart meter data handling and implementation are also discussed. This paper deals with specifics of the efficient grid and smart meters that made it possible to control electricity theft in India*

Keywords: efficient grid, smart meters, electricity theft, and consumption

I. INTRODUCTION

Smart meters are a kind of modern energy meter that transmits data about a household's energy use to the utility company in a safe and reliable way. Smart meters' two-way data transmission capabilities let utilities learn about customer-premises energy feed-back to the power grid. Efficient meters can communicate securely and carry out control orders both locally and remotely. Therefore, all of the customer's electronics and appliances may be tracked and managed by the smart meter. They may gather diagnostic data about the distribution grid and household uses, and share this data with nearby meters. They keep tabs on how much power is used, facilitate the use of distributed power plants, and combine energy storage units. In the not-too-distant future, homes will include distributed power production sources as an inherent component of their infrastructure. Utilities must gather vast amounts of real-time data to support the plethora of new services and demand-management strategies.

With the use of smart meters, clients may be charged just for the electricity they draw from the grid, rather than for any energy used by their own distributed generating or storage systems. A client will also get credit for energy exported to the grid. The information sent by a smart meter normally includes the meters identify, the current time, and the energy consumption rates at that precise moment. In the event of a neighbourhood malfunction or incident, smart meters may remotely restrict the maximum power usage, manage household appliances, and cut off or reconnect electrical supply to any customer [1], [2].

Smart grid environments rely heavily on smart meters to track grid health and energy consumption patterns for individual customers. The utility can better manage and optimize power demand if it collects consumption data from all consumers at regular intervals. Customers may save money by following the advice of home energy management solutions that use smart meters. Because of this, smart meters may be used to regulate the temperature of a home's lighting, heating, and cooling systems [3]. Appliances in the house may be set to automatically turn on and off at certain times by the smart meter. Also, utilities may advance supply efficacy and energy distribution eminence via the usage of efficient meters for screening illegal use and energy theft [4].

Communication Technologies

Smart meter deployment requires extensive communication amid the usefulness, the meter, and the connected domestic appliances. The particular statistics is very private and should be restricted to just a select group of employees. Owing to the confidentiality of statistics, tight protocols have been established for gathering, transmitting, storing, and maintaining records of energy use. The communication standards and rules were developed to pledge the privacy of any figures sent to network. This information must accurately reflect the true state of the user's energy consumption and the grids, free from any manipulation or miscalculation. Therefore, it is essential that this information is legitimate and accurately reflects the target devices [5]. The general design of a communication network that can execute all the aforementioned functionalities is shown in Figure 1. Strategies in the transmission division guarantee reliable energy transmission, control systems in the dispersal segment monitor and correct faults, and communiqué strategies.

The chosen shared system must allow for the necessary functioning of the efficient meter system during a power loss and allow for automated distribution. Also, the chosen network and its parts need to be efficient and inexpensive, and they must be able to line up the transportation of facts depending on its stint and route system [6]. The optimal choice of communication technology would minimize costs while maximizing benefits while minimizing the likelihood of repeats.

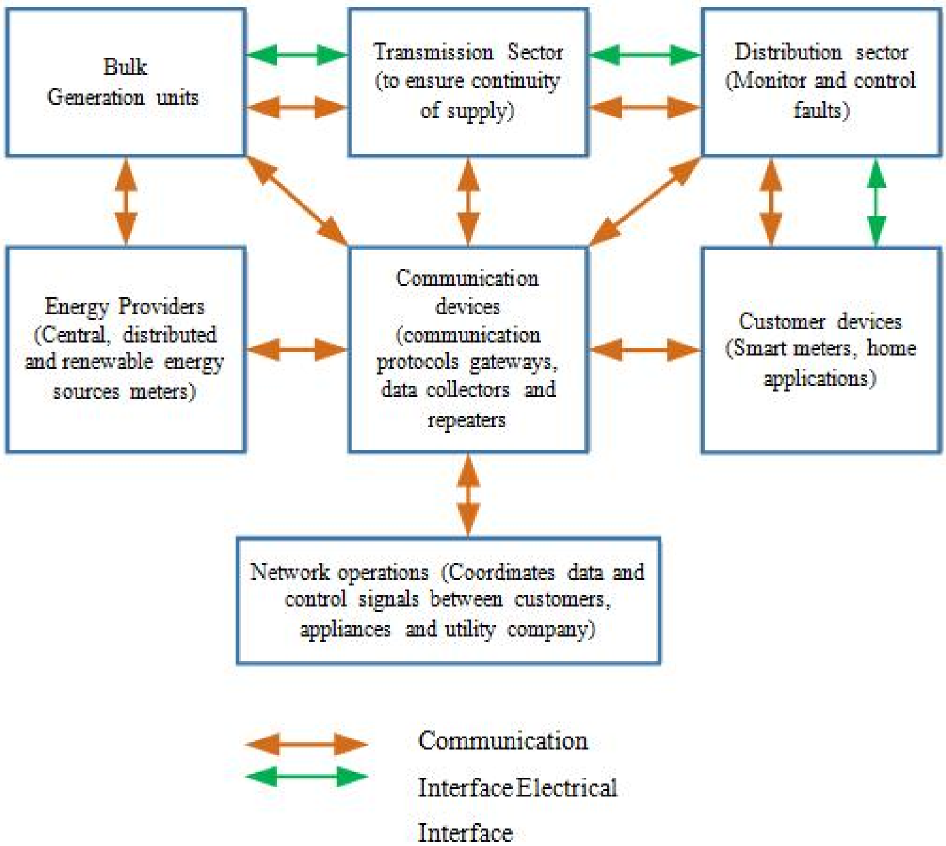

Figure 1: The electrical and communication infrastructure necessary for a smart grid [41].

Control signal transfer and data on energy use may both be accomplished using Bluetooth technology. Bluetooth based meter which collects wirelessly and transfers the power usage statistics to main base station in order to execute this approach. Alternative methods of data transport that are compatible with higher level communication suites [6], PLC uses current electrical network, cellular/pager network, mesh system, registered and unregistered transistors, radio communication modems [7]. Data gathering in smart meter applications may be successfully automated with the help of PLC technology [8]. IPv6 can be implemented on the physical layer at lower data speeds while introducing a considerable overhead. However, when IPv6 is used in conjunction with a MAC method, the interruption period is condensed and the throughput is increased. Although the effective data transfer rate may be reduced by this combination, the MAC layer overhead will remain unaffected [46]. Because of its benefits over competing technologies and its ability to encounter the stringent security necessities of efficient grid communications, IP-based network protocol should be given serious consideration. TCP/IP also provides an effective framework for inter-device communication [9].

In addition, audiovisual aid sessions like video and (VoIP) are managed using the text-based signaling standard Session Initiation standard (SIP). SIP combines several aspects of the Hyper Text Transfer Protocol and the (SMTP). SIP is a freely available, standards-based technology that offers a stable channel of communiqué for smart grid programs [10]. TCP, UDP, and SCTP are all viable foundations upon which to build a SIP implementation.

This architecture's breakup reduces its susceptibility to assaults from other TCP/IP gadgets. As DNP3 currently stands, it is not secure enough for use in collaborative operations without additional safeguards like data object protection and a security layer. To stop hackers from tampering with data and gadget functionality, data object security tax on more criteria for accessing data.

In their study, S. Rusitschka et al. demonstrate a P2P-based power meter. By means of a peer-to-peer network expands the scope of what may be done. Several value-added services may be used as well. Since P2P communication relies on the internet, it helps to develop efficient grid communication networks economically [50]. Additionally, the P2P link makes efficient use of the facilities of the households involved. Zigbee [11] is yet another network that has the capacity to send data and control signals through a communication network. In order to decrease reaction period and substantiation adjournment. In addition, they have implemented the best possible security material management system. The cryptographic core is able to keep its lowest clock frequency within its restrictions thanks to the aforementioned design techniques and the acquired reaction time, which guarantees a decrease in total dynamic power consumption [12].

Data and control signals might also be sent wirelessly over great distances using General Packet Radio Service (GPRS) technology. There have been very few evaluations of GPRS communication network features in comparison to other communiqué network technologies. However, building a GPRS network in many areas would be hampered by a lack of instruments for identifying a network breakdown. Determining the accessibility and eminence of the signal is necessary before establishing a GPRS based communication system in a given area [13]. Time spent analyzing data and learning about the distribution network's health may be cut in half with the use of analogous meting out and the (FPGA) technology. Smart meters create less data when reconfigurable logic is used for data processing [14].

Issues and Challenges

As an alternative to replacing the grid entirely, better grid management is worth considering. Given the smart grid's technological benefits and improved operational competence, incorporating it into the current grid management system is a worthwhile option. Nevertheless, a number of difficulties related per the smart meter system's conception, rollout, and upkeep occur. Smart meter installation and upkeep in a supply grid may cost more than a few billion dollars. This expenditure must thus be made in order to meet the anticipated rise in both central and decentralized energy production. Utilities will first have difficulties in transitioning from traditional energy meters to smart meters. The rollout of smart meters might be stymied by a lack of infrastructure to ensure that the new technology works in tandem with the current ones. All of the appliances and devices in the supply and metering system need to be linked to the communiqué network for smart meter system to function properly. The greater the number of users, the more challenging it is to integrate these gadgets. It may be difficult to deploy communication networks in certain areas owing to terrestrial challenges. Utilities in the United States may not urge their consumers to save energy since they are financially motivated to sell as much power as possible [15].

Data collection and transmission on energy use is a costly and time-consuming operation that must be automated. Some consumers may worry that the constant flow of data and signals from their smart meters poses a security risk to their personal information. This information may also disclose when and how often individuals were at home, as well as which appliances were in use. The core problem would be settling which parameters should be sent and who has access to them [16].

II. ANALYSIS AND DEVELOPMENT OF ENERGY CONSUMPTION PATTERNS

In this chapter, we'll discuss why it's crucial to scrutinize power usage statistics and the characteristics of power consumption data in order to track down unauthorized users. If you want to find out who is using too much electricity, the best method to do so is to look at the data or power system metrics that describe a condition on the client end. The rapid power usage of customers is the single most important metric for capturing variations in consumer behavior. Utilities also need to analyze consumer energy use habits to study more approximately the nature of the system from the customer's perspective. Collecting Information on Energy Use

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Accessing, collecting, and analyzing instantaneous energy use of consumers is now feasible with the arrival of efficient meters and supplementary smart grid technology, as discussed in chapter 3. Customers' energy use data is used to categorize or detect unauthorized users, a function made possible by the smart grid. Because utilities and consumers value their privacy, the energy usage data necessary to evaluate the suggested algorithms cannot be made public. This information is the result of the following MATLAB operation.

The necessary data has been generated meticulously to correspond closely with real-world facts. Electricity load information for a distribution feeder, collected on an hourly basis, is available from PJM databases [17]. The numbers here show the power used by a feeder that serves a city or other big area. Many different types of consumers, including homes and small businesses, are assumed to share the feeder. It's possible that each area has many consumers that fall within the aforementioned demographics. Each customer type and range has been assigned an energy consumption range, and those figures represent their share of the total grid load. To achieve this goal, all grid users are classified into subsets according to their average monthly energy usage. The following factors are included in this breakdown:

Time of year, as in summer, winter, or another season

Types of clients

- Agronomic (small, large),
- Commercial (small, medium, large),
- Housing (small, medium, large)

Table 1 Different categories of farmers by their energy use levels.

Consumption	Small	Large
kWh / M	0-100.0	100-300.0
kWh/ D	0-3.330	3.333-10.00
kWh / H	0-0.140	0.14-0.420

Table 2 Categories of commercial clients founded on the varieties of power usage.

Consumption	S	M	L
kWh / M	0-500.0	500.0-2000.0	2000.0-20000.0
kWh / D	0-16.6780	16.68-66.68	66.66-666.66
kWh / H	0-0.697	0.699-2.777	2.789-27.97

Table 3 Power consumption profiles of residential customers.

Consumption	S	Medium	L
kWh /M	<300.0	300-600	>600.0
kWh /D	1.6680-10.0	10.0-20.0	20-340.3340
kWh /H	0.0680-0.4160	0.4170-0.834	0.8340-1.390

It has been considered that each neighborhood may consist of multiple customers representing some or all of the categories (of customers) illustrated above. Therefore, load on each neighborhood has been divided among these customers in several possible combinations (number of customers per each type and ranges of types). As a result, about 20,000 average consumption patterns representing energy consumption of 20,000 customers over a day is worked out. These power usage outlines feature instantaneous power usage collected 96 times a day. In other words, energy consumption readings from smart meters are assumed to be collected in real-time from 20,000 customers at 15-minute intervals.to be collected in real-time from 20,000 customers at 15-minute intervals.

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Validation of power usage Data

Usage of power by a client relies on their needs, patterns of diverse clients are varied. Additionally, weather is a major role in how much power is used. Therefore, data on energy consumption may be analyzed in terms of aspects such as customer size, location, spell, weather, and time of day.

Here we see two of the established patterns of energy usage in action. The typical weekend energy use of a modest residential client is shown in Figure 4-1. Most of the appliances in this scenario can be utilized throughout the daytime in the summer. Since only the most fundamental electrical equipment are permitted to be utilized during the day, power usage is somewhat greater than at night. A big customer's energy usage in the same region may peak during the day (relative to the night) if huge air conditioning systems are in use. Figure 4- 2 depicts an illustrative daily energy use trend for another kind of modest home client. Since amplified usage of ac’s and freezers, summer is the most energy-intensive season.

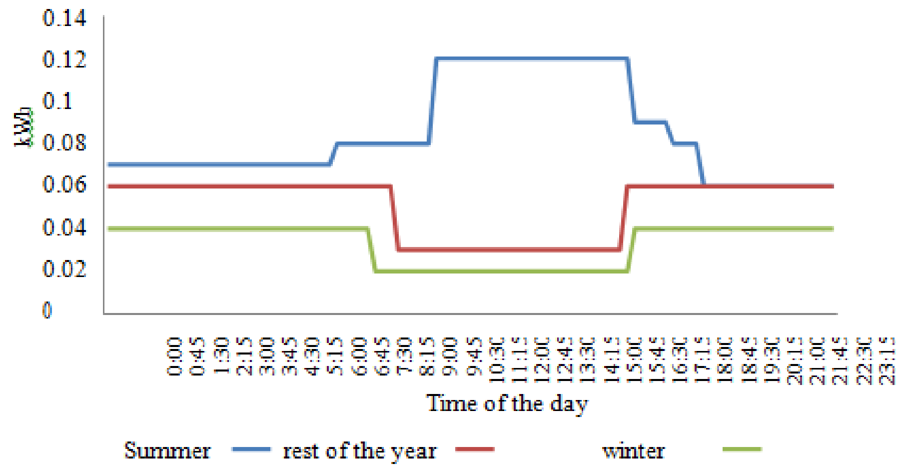

Figure 4-1: One household's typical weekend energy use over all three seasons, broken down instantaneously.

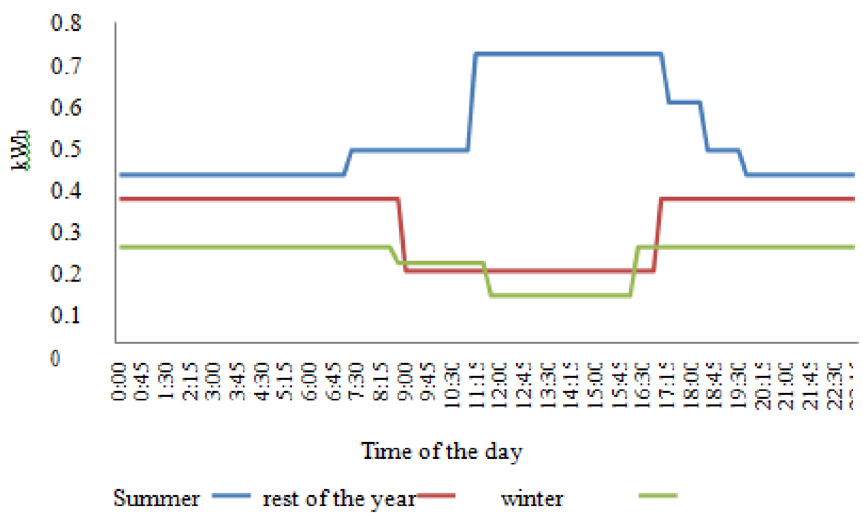

Figure 2: Instantaneous power usage outline of a different housing customer ona daily basis of a week for three seasons.

Many small customers report extremely low nighttime usage because they rely on low-load devices to supply their fundamental requirements. However, big business clients use heavy loads, such as air conditioners and storage units, whose outcome in high power usage. Because of the expensive cost of keeping the building at a comfortable temperature, energy use is likely to be low during the colder months of the year.

Think of a community with a mix of small, medium, and big residential and small, medium, and large business clients, and apply the learned energy consumption trends to them. Distribution losses of 30.9% on a workday in the summer reflect the energy usage of that area, as observed in Figure 3. Figure 3 displays actual energy usage as measured by all meters in the area in real time. It is possible to trace the energy loss curve given the total amount of energy provided. Consequently, given a period of 24 hours, the typical cost of over-all energy provided is 489.029 kWh, while the average value of power lost is 151.121 kWh.

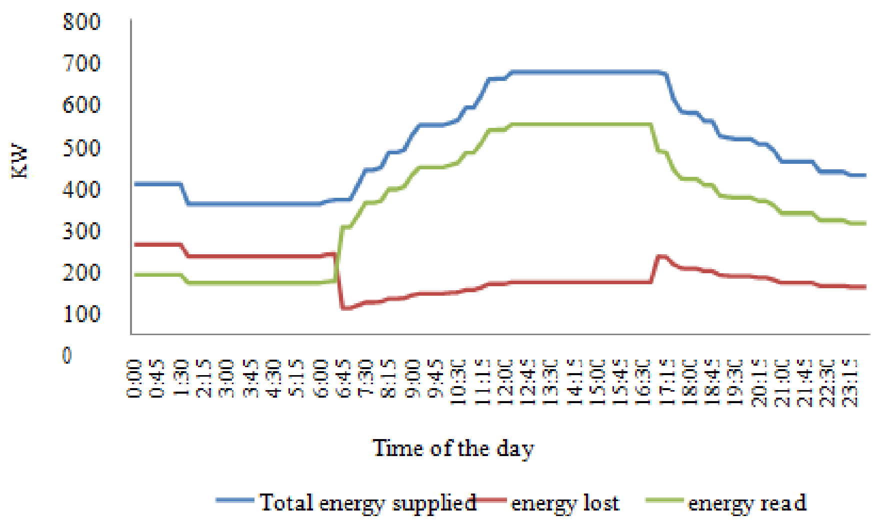

Figure 3: Overall load on feeder for a locality with total losses of 30.9 % on asummer day.

Figure 4-4 depicts the energy use of a single modest residential customer over the course of a single day throughout the week. The three possible scenarios of the same customer's energy use are shown in Figure 4-5.

One example of permissible consumption is when a client uses all of their home's energy supply.

An example of partial unlawful consumption is when a client uses the legal amount of energy they need for their home but uses the illegal amount for other purposes.

Third, total unlawful consumption, which occurs when a person illegally uses all or almost all of the energy supply for their home.

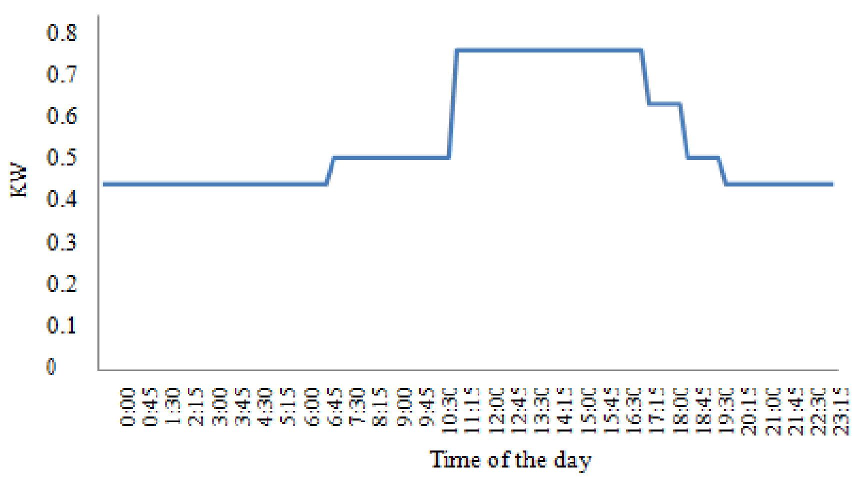

Figure 4: A modest customer's estimated energy use trend on a summer weekday.

Figure 5: Smart meter data may be used to forecast energy use under three scenarios: actual use, partial use, and theft.
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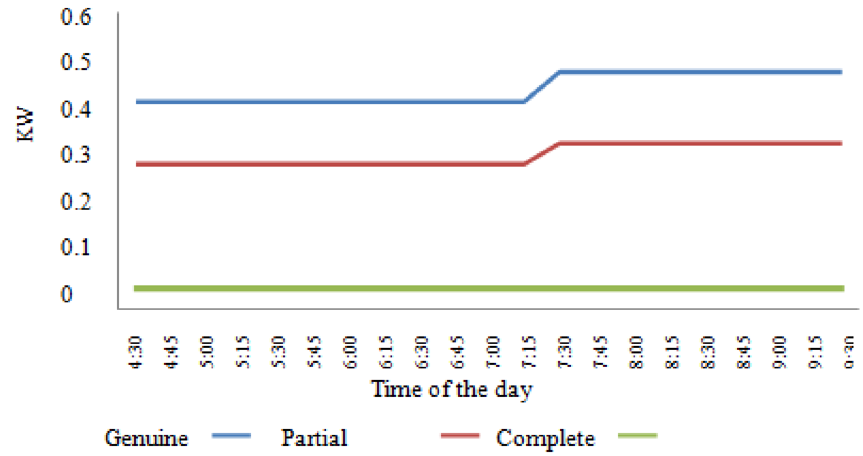

Figure 5: Smart meter data may be used to forecast energy use under three scenarios: actual use, partial use, and theft.

The energy consumption patterns (created) for 20,000 consumers have been utilized for the development and validation of the suggested encoding and detection (classification) methods. Figures 1, 2, and 4 show the aggregate power usage outlines of these customers, comparable but not identical to one another in terms when compared to power readings (96 inputs). The collected information has been employed to ascertain accuracy of the suggested detection algorithm, which seeks to identify anomalies in consumers' energy usage habits in order to classify them into distinct categories. In essence, the proposed algorithm captures the pattern of energy consumption with reference to the overall load on the grid.

III. CONCLUSION

Irregularities representing electricity consumption by illegal consumers must also be incorporated into some data samples of the developed data. Therefore, energy consumption readings of some customers at some timestamps have been reduced, and some readings are replaced by zero. These modifications are carried out on energy consumption data samples belonging to random customers and at random instances of time. Zero represents no-consumption and modified energy consumption represents partial legal consumption. Therefore, the process of developing power usage datais complete. In the final dataset, some of the energy patterns demonstrate the consumption by genuine customers, some partial illegal consumers and the rest represent complete illegal consumers.

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