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SYSTEMATIC ANALYSIS OF SMART METER TECHNOLOGIES AND THEIR IMPLANTATION CHALLENGES IN PAKISTAN

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ABSTRACT: *The world economy losses more than 89 billion dollar per year due to electricity theft, irregularities in billing and physical destruction of traditional electricity meters. Therefore, many countries adopted the SM (Smart Meters) to decrease their losses. SM are the next generation of traditional metering system. These are not only used for automatic meter reading but their features make them very useful for monitoring, theft prevention, and energy management. The features of SM provide the automated services and develop an interaction between ESP (Electrical Service Providers) and consumers. However, it is not an easy task to replace the existing traditional metering system because of their implementation challenges such as infrastructure cost issues, installation complexities, acceptance, universal interface, network coverage problems, security, privacy, health and availability of SG (Smart Grid) station issues occur during the implementation SM and SG stations. In Pakistan, the government initiated a project last year to install the SM in multiple phases with the collaboration of USAID. However, the government has been facing many barriers and challenges at early stages of the project. We review and discuss smart metering technology and its implementation challenges in Pakistan in this paper.*

KEYWORDS: Traditional meters, Smart meters, smart meter and Smart Grid, SM architecture,

1. INTRODUCTION

Electrical power is basic necessity for the development of a country. The industrial survival and social structure of the country depends on the uninterrupted ESP (Electricity Service Providers) [1].The electrical energy is superior to the other forms of available energies because, it can generate from various sources such as water, gas, coal, and nuclear reactor. In addition, it can be easily converted from natural sources such as solar , wind and sea weaves [1]. Electrical power is commodity like other products which is generated or produced by different private or government organizations. In Pakistan, the electricity losses are about 89.89 billion rupees due to inappropriate power management and theft. Recently, government has come to a reasonable solution and introduced smart energy meters with AMR (Automatic Meter Reading) facility in some main cities at domestic level to reduce the electricity theft cases [2]. However, majority of of conventional metering system are still active in country. Smart metering is the next generation of existing metering and it used to send automatic meter reading to ESP and send updates about electricity consumption to its consumers. These smart electricity meters will be used for theft identification and monitoring the real time electricity consumption. However; the installed SM do not have any feature of interactive communication between ESP and consumers. In addition, they do not provide automatic load management to reduce illegal usage of power without permission, better understanding of energy demand patterns, manage meter failures, prevent power theft and maintain the transparency in billing system. Many researchers have been working on energy saving and monitoring with the implementation of automatic metering. Different types of intelligent metering systems were introduced in last decade which remotely performs tasks such as energy saving, controlling and monitoring. Currently, numerous intelligent metering systems has been deployed in various developed and developing countries such as in the UK, India, Ghana, U.S.A, China, Italy and the Netherland [3].Number of researchers proposed different smart metering technology based on GPRS and GSM transmissions mediums[4][5].GPRS based SM only focused or to sending the meter reading to ESP. GSM based SM are used to transmitting the meter reading ,generation of electricity bills and manage the collected data globally. An Indian researcher[6] proposed prepaid energy, which need a valid scratch card for activation of electrical power. By implantation of these smart meters ESP will be able to monitor and control energy consumption at consumer premises effectively. The ESP continuously monitors the units being consumed and disconnects power remotely when the prepaid scratch card is excused[6]. For thereactivation of the electricity, consumers again insert the scratch card into a SM[7]. Another SM method was proposed for automatic bill collection, read the consumption unit and transmit to ESP on reception of specific message from the company [8]. A prototype SM module based on GSM technology was developed by experts for energy monitoring and control. This prototype module acquire the energy consumption pattern from the consumer premise and send it to ESP using SMS(short message service) and GPRS technology. At the electricity supply side a server manages all received meter reading, generate bills, monitor the electricity consumption pattern, update database and then maintain every individual consumer profile[9]. The rest of the paper is structured as a comparison between traditional and smart metering system is presented in Section II and section III demonstrated the various categories of SM adopted in developed and developing countries. Need of smart meter in Pakistan has been discussed in section IV and barriers and challenges with the implementation of SM in Pakistan is presented in section V. Finally a conclusion is drawn in section VI.

2. METERING TECHNOLOGIES

Metering technologies are divided into two main categories, traditional metering system and smart metering system.

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2.1 Traditional Metering System

Traditional meters are based on electromechanical system Reading is obtained by manual observation of the meter therefore to get meter reading we needs additional resources and human employment. The ESP appointed meter readers visit every home for reading and collecting energy consumption data for bill generation. This is a time consuming and tedious job for meter readers. In addition, it is more tough and cumbersome in rainy days and restricted areas of country.Figure. 1 shows that the electricity meter reader receiving electromechanical and digital meter reading manually on a paper and through infrared sensors. It causes human errors, commit the malpractices and manipulate consumer usage data and generate inaccurate bills Single phase electromechanical and digital meters are shown in Figure. 2 These meters only shows and store the consumption of electricity units. In these meters, there is no any antitheft solution, AMR (transmit meter reading automatically) and no load management features have been proposed yet[10]. However in Pakistan recently andriod base smart metering technology has been introduced by the government of Pakistan but still it faces a lot difficulties for implementation and installation these smart systems. only 29000 smart meters have been installed in various vicnities of Pakistan. Therefore the ESP companies have started to install the smart electricity meters for theft identification and monitor the real time electricity consumption.

Figure 1. Traditional meter reading system

2.2Smart Metering System

SM (Smart meter) is the next generation of metering technology, these SM are used to automatic meter reading, real time energy monitoring, send unit consumption information with the "time of interval" to ESP and also send different alerts to consumers. SM enables two way communications between consumers and ESP. Some kind of SM sends the information on daily, quarterly and monthly bases. SM is commonly

Figure 2. Electromechnical & Digital Meter system

Table 1 present the comparison of various metering technologies using different wireless technologies used for data transmission.

Table 1. A comparison between various metering technologies

Features of meter	Electro mechanical meters	Digital meters	GSM/GPRS/SMS smart meters	PLC smart meters	Bluetooth/ ZigBee smart meter
Meter Reading Recording	Yes	Yes	Yes	Yes	Yes
Energy Controlling Network Technology	No	No	Yes	Yes	Yes
Reliability and performance Demand	No	No	Yes	Yes	Yes
Remote Communication	No	No	Yes	Yes	Yes
Tampering Detection	No	No	Yes	Yes	Yes
Wide wireless Coverage	No	No	Yes	No	No
Commonly used	Yes	Yes	Yes	No	No
Cost Effective	Yes	Yes	No	No	No

involving real time information transmission from the remote premises and performs a role of energy monitor and theft detector. Whenever intruder will try to tampering, SM sends alerts to ESP and some SM trip the electricity automatically. In SMSG (smart meter and smart grid), smart meters are the basiccomponents of SG (smart grid) architecture. They continuously capture the consumer unit consumption for load forecasting[11], which makes grid station capable to manage the electrical power load.

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Table 2. Technological Features of SM

Countries that have implemented smart meters	Manufacturer	Smart meter modules	Communication features	Technical features	Warning system	Need smart grid station
U.S.A	Itron, Inc. (NASDAQ: ITRI) [12]	CENTRON 4G LTE SM	4G LTE , IP,ZigBee	• High-speed • Wide coverage • Support smart gird • Low latency	Yes	Yes
U.S.A	General Electric (GE)[13]	SGM1100, SGM1000, SM series	ZigBee, PLC modem	• Different-measurements • Water, gas, electricity • Good security system • Scalability • Remote configuration	No	Yes
China	Hangzhou Pax Electronic Technology Co., Ltd[14]	WS310-GPRS smart energy meter	DTSD5 GPRS	• Remote reading and configuration • High power • Advanced Automatic Meter Reading (AMR) applications • Cost-effective solution	Yes	No
Switzerland	Liechtensteinische Kraftwerke (LKW)[15]	E450 advanced residential meter	PLC Communication, VPN	• Accurate monthly and quarterly billing system • Monitoring Consumption by online portal • Remotely configure the meter	No	Yes
Germany	Elster Group[16]	EK280	GSM / GPRS modem	• Temperature sensor • Remote data transfer • Gas measurement • Separate interface	Yes	No
French	Schneider Electric Corporate[17]	(AMI)Advance Metering Infrastructure	SCADA (supervisory control and data acquisition), Operations Technology (OT), Information Technology (IT)	• Power consumption information • Smartphone, or tablet PC • Seamless integration of multiple • Remote appliance control program	Yes	Yes

The single installed systems from both SMSG will not be able to work accordingly, all the capabilities of the smart system are dependent on availability of both SM. These SM allow consumers to monitor and control the power appliances according to their need and comfort, however, some experts are working on these systems for additional improvement. GSM based prepaid SMs have capabilities of reading, storing and transmitting electricity consumption units periodically for real time billing and report generation. In addition, power companies also send various requests and updates to smart meter from thier central data base server. But GSM based SMs do not have any on demand load management services. These SMs have just prepayment facilities for its customers, sometime the consumers have no money to pay in advance, so the proposed approaches do not provide any alternate solution

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for their customers. Technical features of various SMs are summarized in Table 2.

3. COUNTIES ADOPTED SMART METERING SYSTEMS

In 2012, a group of experts in the USA proposed a system and method for controlling and monitoring an individual customer energy profile including the energy usage pattern. In this system every device with in home has an active load indicator which shows the energy consumption and it may be used for control events [18].These control events are often set by consumers according to their priorities and control events associated with their surrounding data such as nearest service point. Environmental data is used to create consumers electricity consumption profile for every individual service point. This can be used by ESP to identify the services points which consume more energy[18]. Furthermore, an intelligent load algorithm determines how to prevent those points which consume more electricity as compared to others. By using this system and method the ESP identify consumer's electricity usage patterns and preferences.However, this system proposed addition of an active load indicator with each appliance to monitor load. This additional load indicator increases the cost of system. Developed countries may able to afford cost of this system but proposed system is not suitable for developing countries.The UK government adopted policy to efficiently manage electrical energy. In which, a SM will be implemented in every home by 2020[19]. In this program, 26 million homes will be equipped with SM which will send real time information of electricity and gas consumption directly to companies. According to the Department for Energy and Climate Change (DECC), it will be one of the biggest smart metering project in Europe. it claimeds that after the implantation of this project the ESP of UK will save £2.5 billion £3.6 billion over the next 20 years[19]. In addition, with thisproject the ESP will decrease their running cost and time consumed in dealing with bills assessment. However, the numbers of consumers resist that house owners should not bear the heavyweight costs for new SM. Furthermore, in this project, it easier for householders to sell power they generate through micro generation for instance wind and solar and sold to ESP [19]. Figure. 3 shows the smart technologies implemented in various countries.

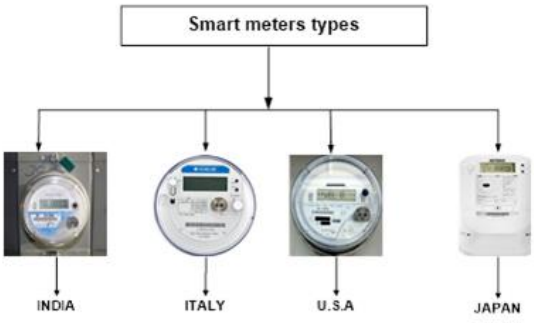

Figure 3. Smart meters in different countries

In Ghana,[20]the Ghanaian Electrometer (GEM) company started to install the prepaid SM in a country. The company provides pre-paid SM and credit card to its customers instead of monthly payments. According to the U.S.A energy information administration 89% smart meters have been installed in the residential area of the country. SM with AMI infrastructure record the electricity usage with minimum time of intervals[21]. Developed countries such as China, Italy, Netherlands, the UK and the U.S.A replaced traditional electricity meters with SM and smart grid. However, the developing countries such as Pakistan, India and Ghana have started to install the AMI infrastructure for automatic meter reading purposes without major support of smart grid(Table 3 comprises smart meter technologies in various countries). Different Automatic Meter Infrastructure with combination of SMSG station have been installed at consumer premises for power saving and scheduling of available energy in system. These systems are able to identify the peak demand time and real time pricing of electricity unit. When there is peak demand time, the smart meters automatically switch off the appliances which consume high power. According to Japanese TEPCO (Tokyo Electric Power Company) installed 100,000 smart meters in various cities of Japan and in future planned to install 27 million SMs by 2020 at domestic level.In Italy, government made effective legislation to rollout of more SM at residential customers, Ericsson company developed AMI

Table 3. Smart meter technologies implemented in various countries

infrastructure and gave technical assistance to install SMs

Country	Power company	Architecture		Number of installed meter
		Smart Meter	Smart Meter with smart grid station	
Japan[22]	Tokyo Electric Power Company (TEPCO)	Yes	Yes	27 million by 2020
U.S.A[23]	Itron's smart meters	Yes	Yes	51,924,502
China[24]	State Grid Corporation of China (SGCC)	Yes	Yes	Estimated market 330 million smart meter
Netherlands[25]	(Oxxio)electricity and natural gas utility	Yes	Yes	7millio by 2020
Italy[26]	Ente nazionale per l'energia elettrica(Enel SpA)	Yes	Yes	2.6 million
UK[27]	Data Communications Company (DCC)	Yes	Yes	1 million
India[28]	Chamundeshwari Electricity Supply Corporation Limited ("CESC")	Yes	Yes	Expected 1.5 million at end of 2015
Pakistan[29]	MicoTech Industry	Yes	No	3,5000

[30]. The data center for smart metering is already fully functional and one million SM have been installed in overall country. Furthermore, 1.6 million SMs should have been be installed by the end of 2009[30]. Other countries in Europe such as Netherlands planned to install 3 million smart meters before 2021[31]. According to 2014-2018 market research report of China Smart Metering Industry [32].The advancing SG manufacture in China urged the continuous growth of smart meter demand.According to [32] 370 million SMs installed at domestic level by the end of 2013 and it will go up to 500 million in 2015[32].

4. NEED OF SMART METERS IN PAKISTAN

Pakistan is a country where all natural resources are available for the electricity generation but unfortunately

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country is in severe energy crisis. The government of Pakistan losses at least 89.89 Billion rupees (See Figure. 4.) due to theft cases which is huge amount. To reduce the losses Government of Pakistan has decided to minimize the electricity theft.The government introduced smart energy meters with AMR facility at domestic level in some cities. The Pakistan's economy losses nearly 89.89 billion rupees annually due to electricity theft report by the different electricity power distribution companies in a country. Such as FESCO (Faisalabad Electric Supply company)losses about Rs 0.6 billion, GEPCO (Gujranwala Electric Power company) losses Rs 0.36 billion, LESCO (Lahore Electric Supply Company) losses Rs 2.35 billion, MEPCO(Multan Electric Power Company) losses Rs 0.28 billion, IESCO(Islamabad Electric Supply company) losses Rs3.66,SEPCO(Sukkur Electric Power Company) Rs 7.47 ,HESCO(Hyderabad Electric Supply Company) losses Rs 16.17 billion, PEPCO(Pakistan Electric power Company) and KESCO(Karachi Electric Supply Cooperation) losses about Rs 45 billion.

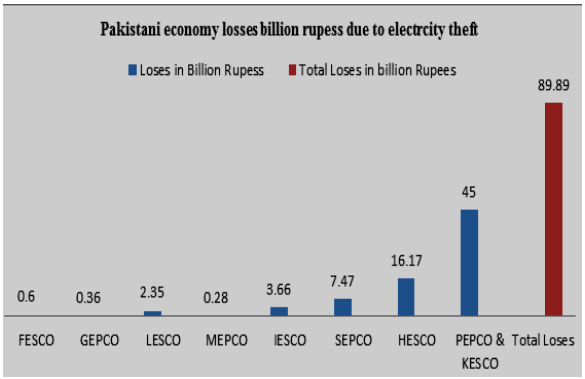

Figure 4. Annual power theft ratio at different power distribution companies in Pakistan

4.1 Theft Prevention

The different electric power distribution companies in Pakistan use electromechanical and digital energy meters to acquire the meter reading at the end of month and do not provide any antitheft mechanism for electricity. The electric meters are installed at the consumer premises and any one can tamperm meter readings or bypass the meter connection. Recently, smart metering system has been introduced in various cities of Pakistan as an anti-theft solution with support of USAID project.

4.2 Power Management

The existing traditional metering system does not have any mechanisms for power load managements and controlling illegal usage of energy. On the other side, ESP is also unable to monitor real time data transmission, energy usage patterns and tampering events. At that occasion SM with AMI is only solution for power managements. SM also support multiple techniques for energy saving and controlling theft events.

4.3 Automatic Meter Reading

Another main feature of AMI SM is sending energy consumption units automatically to ESP through wireless and wired technologies. In addition ESP do not needs the services of meter readers to visit the consumer premises where electricity meters are installed. SM systems also send various alerts to ESP when any tampering event is occurred and automatically trip the electricity. In Pakistan, USAID have intended to install more AMR meters in five different power distribution companies. The 29,000 old electricity meters has replaced by different DISCOs (Power Distribution Companies)[33].Theimplementation of SM will ensure the accurate billing and it is expected that it will reduce the illegal usage of electricity while decreasing commercial losses of power distributio companies. Table 4 shows total number of installed smart meters at various power distribution companies in Pakistan[34].

Table 4.Total smart meter in Pakistan

Cities	Electric power company	Installed smart meters	Total smart meters
Lahore	LECSO	17000	29000
Faisalabad	FESCO	4500	
Peshawar	PESCO	4500	

The basic AMI infrastructure is illustrated in Figure 5.

- Central system in power company, will remotely monitor and control the smart metering system and acquire the meter reading
- GSM (Global System for Mobile Communication) modem, will be used for sending and receiving commands
- GSM will provide the whole communication between SM and ESP.
- Remote metering system will send the meter reading automatically to power companies from the consumers premises with the assistance of GSM network
- User mobile phone will be used for receiving various alerts

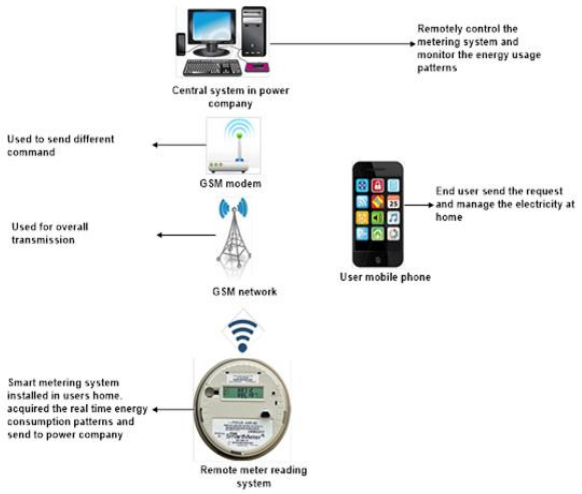

Figure 5.Basic AMI infrastructure

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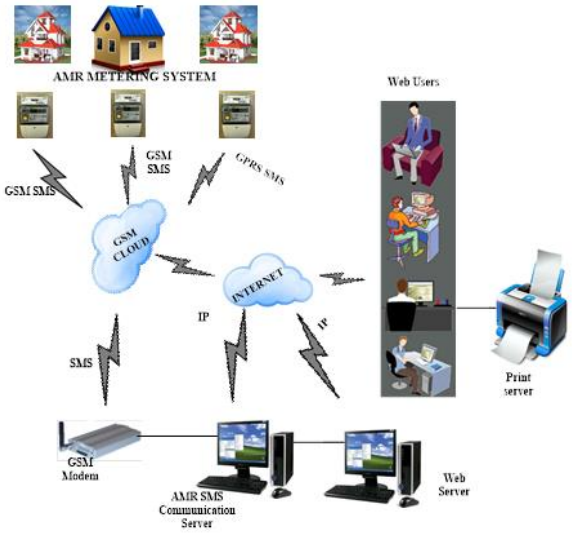

Figure 6.Different home environment with smart meters

5. SMART METERS IMPLEMENTATION CHALLENGES IN PAKISTAN

With the advance development in DCITN (Data Communication and Information Technology Networks), the power industry needs to install the intelligent system to monitor and control the power from generation side to consumer side. The power industry has installed SMs since last year to improve the quality control and manage of electricity. and Power Companies will face many challenges for installtion of SMs such as infrastructure cost issues, Installation complexities , acceptance issues, universal interface , network coverage problems, security issues, privacy issues, health issues and availability of SG station[35]. The figure 6. distinguishes the different environments used in various smart metering technologies which have different interface for acquiring the real time data from the remote site. Some homes are using the GSM based SM and some are based on GPRS and IP networks. AMR SMSs (Automatic Meter Reading, Short Message Service) communication, Web and Print servers are used at various levels for different purposes.

5.1 Infrastructure Cost Issues

In Pakistan, the poor infrastructure of electricity causes the technical and non-technical power losses which directly impact economy of the country. To mitigate the power losses and theft issues, it is essential to replace and update the poor infrastructure of power sector but it is a big and costly issues for the government. Recently the Government of Pakistan introduced SMs as antitheft solution, However; proposed SMs do not have good communication infrastructure to interact and energy consumptionreport to ESP on regular bases. According to the ESC.

5.2 Installation Complexities

The new communication network and its installation is another challenge in Pakistan .It will need more and serious efforts for the deployments of latest technology, SG stations, technical personel and trained staff.

5.3 Acceptance Issues

The adaptation of new technology in home premises is another issue for electric power distribution companies. Without consumer acceptance and awareness about the new technology, the ESP will not be able to install the SM technology.It will be focused on the consumer awareness, satisfaction, acceptance and participation level about SM technology.

5.4 Universal Interface

In other countries where already smart metering technologies have been installed faced the universal interfacing issues. SM is based on different technologies such as GSM, GPRS, SMS, 3G, Bluetooth, ZigBee, IP, WI-FI and PLC.

5.5 Network Coverage

Smart metering technologies have two way communication mechanisms between remote side and power supply companies. Hence these smart systems need wide area coverage networks unlike the small range networks.

5.6 Smart Meter Security

SM technology used advance AMI with wireless technologies for the real time data transmission. Secure communication between remote SM and power companies will the be essential challenge[36]. Once the attacker can duplicate a meter, they have potential threats to smart system software and hardware. There are many types of threats that can be used for stealing and manipulating SM data such as replace actual meter with fake, recalibrate meters speed access, observe and hack transmission medium, steal the software and physically break the meter for code modification[37].

5.7 Privacy Issues

The privacy issues are more essential aspect to the future deployment of SM technology[38].SM is used to acquire the real time data information and send it to power companies. When any third party accessesthe consumer's information without any agreement then it can easily access and analyze consumers private household appliance information. Many people do not like to share their private information to others. Therefore the ESP will ensure to provide trust level security to its consumers privacy[38].

5.8 Health Issues

SM with AMI infrastructure use radio frequency to send the real time electricity data from home premises to the ESP. They are operated in 900MHz and 1800 MHz frequency bands and due to millions of SMs huge amount of microwave radiation emissions may have direct effect on the health of peoples. According to the World Health Organization's International Agency for Research on Cancer (IARC) these microwave radiation have adverse effects on health such as brain tumours, cancer ,heart problems, and neurological diseases[39,40,41].

6. CONCLUSION

The infrastructure of electricity in Pakistan is traditional and timeworn due to outdated electricity network equipment and transmission lines Furthermore the Pakistan economy losses is $89.89 billion dollar per year due to theft and unmanaged electricity infrastructure. However, in recent years the Government of Pakistan took some concert actions to minimize electricity theft and overcome the line losses which were based on manual approaches. The Government decided to install android base smart meters and GSM based smart meters in

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various localities of Pakistan.Governament of pakistan amied to provide an anti-theft solution mechanism and manage the electricity at consumers level. once needed infrastructure is deployed. Recently smart metering technology was introduced and 29000 smart meters were installed in various cities of Pakistan. But still the government owned power distribution companies will face more obstacles for the implementation and installation of these system such as need considerable budget for the improve and update existing poor electricity infrastructure, replacement of transmission lines and gird stations to minimize the electricity losses. This review paper indicates some serious problems during the installation of smart meters in various vicinities throughout the country. However to overcome the non- technical losses of electricity and to overcome the strange shortfall ,installation and maintenances of smart meters would be reason able solution for government and as well as citizens. These smart meters have real time data transmission mechanisms for electricity suppliers and also real time billing for consumers.

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