COMMUNICATION-COMPUTING-CONTROL (3C) SYSTEM FOR PROMOTING DEMAND SIDE MANAGEMENT (DSM)

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***ABSTRACT*: Today, the demand side management (DSM) is an integral part of resource planning or least cost planning. The resources are developed in such a way as to minimize present and future costs. DSM techniques have been implemented in many developed countries successfully. However, the implementation of DSM has been limited due to lack of Information, Poor Power Quality, Reliability, Tariff, Small Scale Sector and Unavailability of Efficient Equipment in developing countries etc. The implementation of pricing and billing schemes is one of the objectives of smart grid. In this paper, we focus on various techniques for promoting DSM with integrated of Communication-Computing- Control (3C) system under the area of ICT (Information and Communication Technology) to consumers at electricity market and increasing energy efficiency in Smart Grid / Modern Grid.**

***Keywords:* DSM: Demand Response (DR) – Dynamic Pricing – Advanced Metering Infrastructure (AMI) - Smart Meter – Communications network – Home Area Network (HAN) - MDMS**

1. INTRODUCTION:

As per IEA (International Energy Agent), the next generation of the power grid, the vision of the smart grid has been proposed to fully upgrade the energy generation, transmission, distribution, and consumption. Information and Communication Technologies (ICTs) are being used in typical electric grid to enhance it into a Smart Grid (SG) / Modern Grid (MG). Currently, ICT services are included to intelligent and autonomous controllers, advanced software for data management, and two-way communications between power utilities and consumers [1, 7]. The objectives of SG / MGT are, to enhance the stability in stressed period and to reduce the electricity cost from consumer side. In order to achieve these goals, the Demand Side Management (DSM) is an important tool which can be used to ensure power systems' stability and reliability in the context of environmental concern. A Hierarchal model of DSM in smart grid is shown in figure 1.

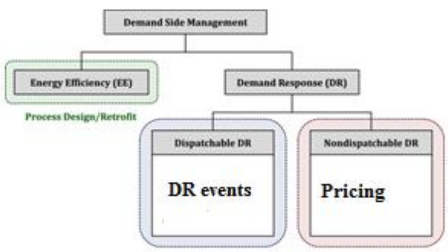

Figure. 1. Hierarchal Model of DSM

1.1Demand Response (DR):

It is a subset of DSM with energy-efficiency and energy-conservation programs. According to DOE (Department of Energy-USA),"Changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at a time of high wholesale market prices or when system reliability is jeopardized"[3].

In recent years, there has been an extensive research effort on the DR for electricity cost savings, reducing peak to average ratio and enhancing grid stability while maintaining user comfort. The objectives of DR are to reduce consumer energy bills, peak to average power ratio and carbon emissions. The energy management concept can be divided into three categories i.e. Residential, Commercial and Industrial energy management system. The Demand Response (DR) is generally performed in the Residential sector instead of Commercial and Industrial sectors. The advancement in communication technology revolutionized the power system [1].Two way communications between consumer and utility suppliers are essential for the implementation of energy management strategy is shown in figure 2. The main purpose of communication is monitoring, protection, optimization, automation and integration.

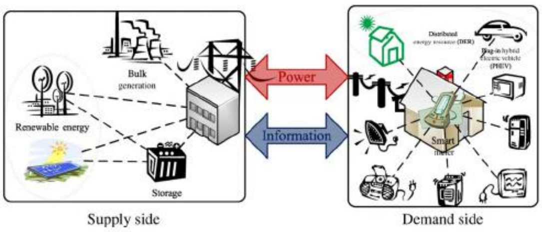

Figure 2. Abstract picture of DR

1.2 Smart Grid / Modern Grid:

The introduction of smart metering and availability of bidirectional communications are two main technical drivers for incorporating demand response into Smart Grid / Modern Grid [5]. A variety of communication standards and technologies coexist in different communication networks of the smart grid. Home Area Networks / Neighbor Are Network / Business Area Networks/Industrial Area Networks (HANs / NANs / BANs / IANs) are deployed. This technology will make the power system more reliable, efficiency of the electricity market, and lead to mutual financial benefits for both the power utility and all users; this will reduce the generating emissions and alleviate the environmental impacts, by enabling a more efficient utilization of current grid capacity with Advanced Metering Infrastructure [8]. The AMI provides an essential link between the grid, consumers and their loads, and generation and storage resources [14]. Such a link is a fundamental requirement of a Smart Grid / Modern Grid is shown in figure 3.

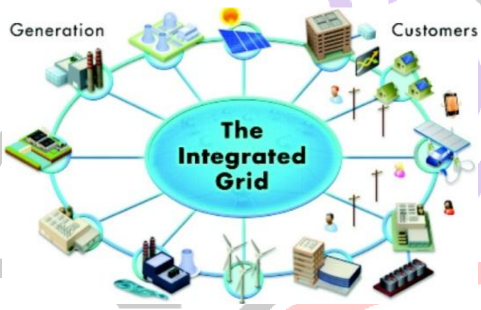

Figure 3.Integrated Grid

In the smart grid development process, there are three main drivers (Figure 4) in the world in order to reduce the power losses and power theft [13, 15].

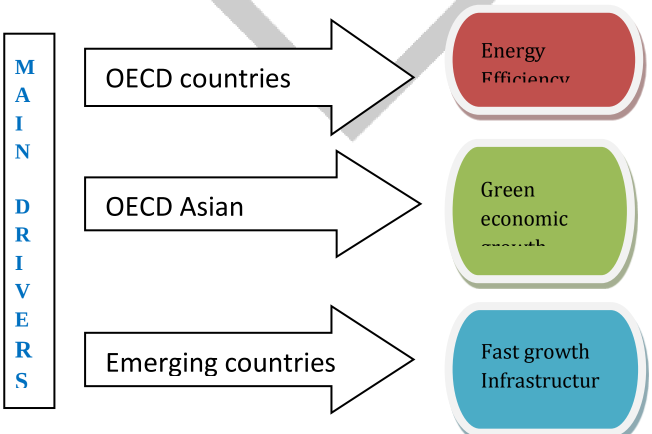

Figure 4: Smart Grid Technology with Countries

1.3 Dynamic Pricing Schemes:

Normally, Demand Response Program (DRP) can be divided into two categories:

1. Incentive based Program
2. Pricing based program.

These programs are able to shape the users' electricity load profiles to improve the reliability and efficiency of the grid. Price-based program provides users with different electricity prices at different times. Based on such information, users will naturally use less electricity when electricity prices are high, and thus reduce the demand at peak hours. In other words, this program indirectly induces users to dynamically change their energy usage patterns according to the variance of electricity prices, instead of directly controlling their loads [3].

***A. Peak Time Rebate* (*PTR*):** This pricing model is designed to shift the cost or demand peak.
B.Time of Use (ToU): When users consume energy at different time intervals of a day, or different seasons of a year, they are charged at different electricity prices.

The consumers willing to enroll to ToU tariffs are typically medium to small consumers. The communication system required for ToU tariffs can usually be a one-way system where the retailer or the utility sends the tariff signals to the consumers and the consumers are just equipped with a multi-rate meter.
C. Real-Time Pricing (RTP): This tariff is also referred to as dynamic pricing, where the electricity price usually varies at different time intervals of a day (in each 15 min or each hour). RTP is usually released on an hour-ahead or day-ahead (DAP) basis.
D. Critical peak pricing (CPP): Critical peak pricing (CPP) is a combination of ToU and RTP pricing systems. The basic rate structure is ToU, but under specified trigger conditions, the normal peak price can be replaced by a much higher CPP price. CPP is employed only for a limited number of hours or days per year, in order to guarantee reliability for system or balance demand with supply.
E. Inclining Block Rate (IBR): This tariff is designed with two-level rate structures (lower and higher blocks), such that the more electricity a user consumes, the more he/she pays per kWh. In other words, the electricity price per energy consumption will climb up to a larger value if the user's hourly/daily/monthly energy consumption exceeds a certain threshold. IBR incentivizes users to distribute their loads among different times of a day to avoid higher rates, helping reduce the grid's peak-to-average ratio (PAR). This tariff has been widely adopted by many power utilities since the 1980s, such as Pacific Gas and Electric, Southern California Electric in USA, and Canada [6].

The above pricing schemes are used to control the load in a smart grid in order to improve the DSM under ICTs scheme. DSM can be optimally utilized maximize the monetary benefits for both the utility and the consumer by optimal utilization of distribution generation.

1.4 Five Phases of Pricing:

Depending on each country's situation, this process may involve as five phases of pricing scheme. In the DSM platform, the successful implementation of pricing reform requires a time-phased approach so that neither confusion nor alarm is created in the energy marketplace. Such an approach also helps manage the expectations of the various players in the market. These phases are depicted in figure 5[4].

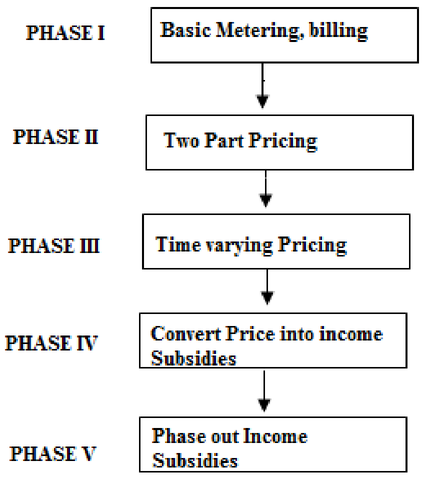

Figure 5. Five Phase Pricing

2. ADVANCED METERING INFRASTRUCTURE (AMI):

At present, Advanced Metering Infrastructure (AMI) which is backbone of DSM system. The AMI is a technique incorporated by smart meter. This helps to reduce the monetary expense charged to customers in the real time pricing scenario.

In the AMI, customer side devices and communication networks are important tools. AMI interface transfers data and signal in both directions. Meter Data Management Systems (MDMS) collect and analyze data from all customers. A major benefit of AMI is its facilitation of DR and innovative energy tariffs. A figure 6 shows the AMI technologies and how they interface. AMI provides a very "intelligent" step toward modernizing the entire power system [8, 9].

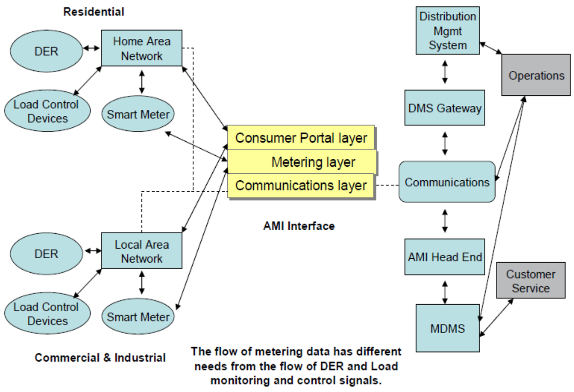

Figure 6. Overview of AMI

3. Smart Meter:

A smart meter is a modified or upgraded version of the conventional energy meter. It records utilization of electric energy in short intervals of time and sends the relevant details to the utility unit for scrutinizing and billing purpose. A bidirectional communication between meter and the central system is provided by smart meter [5, 7].

Generally, Smart meter is a green meter. Because it enables the demand response that can lead to emissions and carbon reductions. It gives greater energy efficiency to consumers [10]. A model of Smart Meter is shown in figure 7.

Figure 7. Smart Meter

Conventional electromechanical meters are used to serve as recording of the total energy consumed over a period of time – typically a month. Smart meters are solid state programmable devices that perform many more functions, including most or all of the following:

- Time-based pricing.
- Consumption data for consumer and utility.
- Net metering.
- Loss of power (and restoration) notification.
- Remote ON /OFF operations.
- Load limiting for "bad pay" or demand response purposes.
- Power quality monitoring.
- Tamper and energy theft detection.
- Communications with other intelligent devices in the home.

According to the DoE-USA, the smart meters have been installed highly in USA among the organization for Economic Co-operation and Development (OECD) countries. The other OECD and Emerging countries are expounding the installation process still. The given figure 8 shows the smart meter installed in the world market.

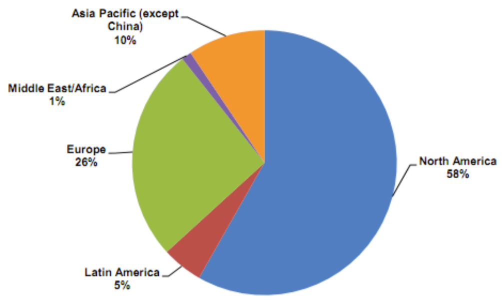

Figure 8. Smart Meter utility: World Market

As per USA energy board, the smart meters are installed 89% in the residential part. The commercial and industries are taken the installation capacity 10% and 1% respectively (Figure 9). Most of the countries are utilized the smart meter and the communication networks for promoting DSM. In this way, the goal of energy efficiency and reduction of prices can be achieved by 2021 (Table 1) [9, 10].

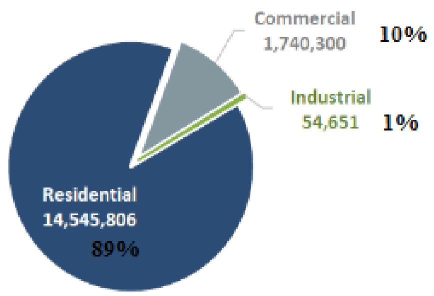

Figure 9. Smart Meter Utility: USA

Table 1: Smart Meters installed across the world

Country	Installed Capacity (Million)	
USA	71 (2016)	90 (2020)
UK	54 (2015)	70 (2020)
Italy	37 (2017)	50 (2020)
Japan	27 (2016)	55 (2020)
India	6 (2017)	130 (2021)
Australia	2.8 (2016)	-

4. COMMUNICATIONS INFRASTRUCTURE:

In the AMI technology, the communication infrastructure has open bi-directional communication level, yet be highly secure. Also, it has the potential to act as the foundation for a multitude of modern grid functions beyond AMI. The function of the network is used to collect the data from the local meters and transmit to the central point of the system [11, 12]. Currently, we have various communication media in the power sector as follows:

- Power Line Carrier (PLC)
- Broadband over power lines (BPL)
- Copper or optical fiber
- Wireless (Radio frequency), either centralized or a distributed mesh
- Internet
- Combinations of the above.

In future, the smart grid applications and consumer utilization should be considered based on the bandwidth of communication system. A general model of communication structure for DR can be taken as shown in figure 10.

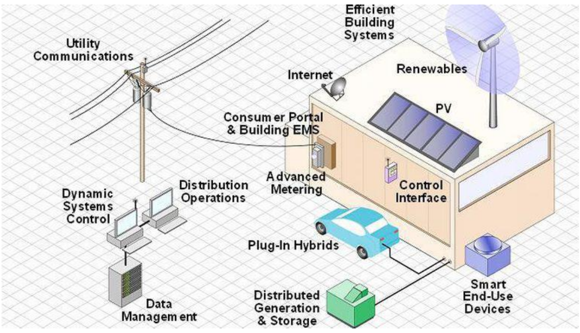

Figure 10.Communication Architecture for DR

5. HOME AREA NETWORK (HAN):

In residential part, HAN is used to interface with two major ports (smart meters and controllable electrical devices). Its energy management functions may include:
•Consumer knows the energy consuming and billing.
• Price signals based on consumer-entered preferences.
• Fix points that limit utility or local control actions to consumer.
• Load controlling without consumer involvement.
• Consumer over-ride capability.

The HAN/customer portal gives a smart interface to the market by going about as the buyer's "operator". It can likewise bolster new esteem included administrations, for example, security observing. A HAN might be executed in various courses, with the purchaser entryway situated in any of a few conceivable gadgets including the meter itself, the area authority, a remain solitary utility-provided passage or even inside client provided gear.

In view of two-way interchanges, smart metering could accumulate definite data of client’s power utilization designs and give programmed control to family unit apparatuses, which frames the home vitality administration framework.

At every family unit, an Energy Consumption scheduler (ECS) installed in the smart meter, whose part is to control the ON/OFF switch and working method of every machine as illustrated in figure11. The power cost gave by the power utility and the client's vitality requests are trading by means of HAN. The Smart meter goes about as a controller that arranges all apparatuses to fulfill the client's need. After request reaction, the smart meter will send ON/OFF control orders with indicated working modes to all machines, as per the subsequent energy consumption plan [2, 13].

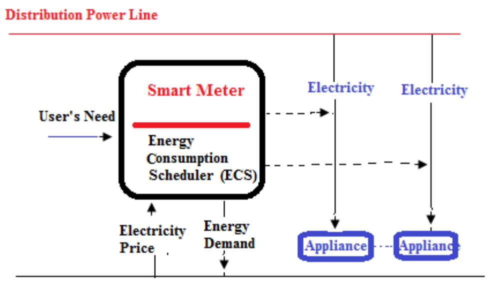

Figure 11: HAN with ECS

6. METER DATA MANAGEMENT SYSTEM (MDMS):

A MDMS is a database with analytical tools that enable interaction with other information systems such as the following:

• Consumer Information System (CIS), billing systems, and the utility website
• Outage Management System (OMS)
• Enterprise Resource Planning (ERP) power quality management and load forecasting systems.

• Mobile Workforce Management (MWM).
• Geographic Information System (GIS).
• Transformer Load Management (TLM).

One of the essential elements of a MDMS is to perform validation, editing and estimation (VEE) on the AMI information to guarantee that notwithstanding disturbances in the correspondences arrange or at client premises, the information streaming to the frameworks depicted above is finished and accurate [11].

The overall structure of 3C technology for promoting DSM is shown in figure 12.

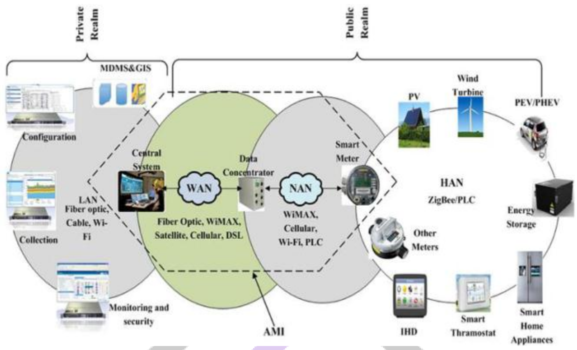

Figure 12: Overview of 3C system in DSM

7. CONCLUSION:

In this paper, we have presented a current technology schemes under ICT in the domain of DR – pricing options and energy efficiency in Smart Grid / Modern Grid. The maximum electricity cost saving can be achieved by using Communication, Computing and control (3C) system in Pricing / Tariff sectors of DSM. Communications are critical to the accuracy and optimality of demand response, and hence at the core of realization and performance of the smart grid. Advanced metering infrastructures enable the power utility and smart meters at users ‘premises to exchange information such as power demand and electricity price.

Without smart meters, the communications and information management systems that connect them, the cost savings and demand-reducing impacts and benefits from AMI and customer systems cannot be realized.

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