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A Smart Grid Demand Side Management Framework Based on Advanced Metering Infrastructure

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Abstract The demand side management has gained considerable prospects and encounters due to the coming in of the Smart Grid. It is also anticipated that the advanced metering infrastructure will enhance the demand side management establishments. This paper discusses the proposed demand side management archetypal that relies on the advanced metering infrastructure for the smart grid. The archetypal has the following components; a collaborative or two-way communication grid, a metering infrastructure and submission software on the user's end and regulator side correspondingly. We present and discuss the inter-associations for the various minor components that make up the archetypal. In the proposed work, the terminal consumer circulated power resources are taken into account. This archetypal is meant to improve the communication between the power end user and the supply side. It is assumed that it will enhance power distribution and serve as a bench mark to the smart distribution system load management.

Keywords: *advanced metering infrastructure, demand side management, distributed energy resource, smart grid*

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1. Introduction

It is documented that the Demand Side Management (DSM) phenomenon was established by the Electric Power Research as a notion of sequences of several activities that are performed by the government so as to enhance the social well-being and also cut down on the power industry [1]. The DSM has been conventionally viewed as a means of reducing peak power demand so that utilities can delay building further capacity. In fact, by plummeting the overall load on a power grid, DSM has numerous favorable effects, including mitigating electrical system emergencies, reducing the number of power outages and increasing system reliability [2].

DSM is applied in different countries for a variety of reasons, such as environmental concerns, transmission and distribution deficiencies, or peak load problems. Looking at DSM programs in the global context, it is clear that each country has its own reasons for implementing DSM or not, whether it is utility regulator enforced, or driven by pressures from trade unions or consumers [3,4]. Conventionally, the plan and structure of power transmission and distribution grids were determined by an overall design philosophy established to enhance large-scale generation technologies. In this case when a single circuit is disconnected from the grid, the network will continue to function [5]. When a disconnection occurs as a result of, say, short circuit, the other circuits that take over the load of the faulty line should not turn out to be overloaded. The implication of this is that, given usual operating standards, on peak-load circumstances, circuits in the interconnected transmission grid are generally loaded below 50 percent [6].

The Smart Grid (SG) viewed as a promising and viable concept copping with the ever rising energy demand and environmental anxieties [7]. As the major component and structural aim of the SG, intelligent interrelation includes two-way communication of information and energy, to inspire power consumers to actively participate in the network usage style, like adjusting their energy usage patterns in regard to real-time tariffs and also to attain the plug and play network connection; and do away with the conventional power usages. Therefore, DSM innovation is another crucial component of the SG. Based on the traditional functions, the SG-DSM has new contents, like automation demand response, smart consume sequence, remote energy efficiency monitor control, energy-efficiency power generation, etc. [8]. The DSM and SG will complement each other. The DSM like the typical smart meters, the control and communication systems as well as other load monitoring technologies have a role to play in the near future's success in the execution of the SM [9]. The operation and development of the independent system operator (ISO) / regional transmission organization (RTO), power generation companies, system integrators, IT companies require DSM as well [10].

The South African electrical utility, ESKOM, currently focuses its DSM initiatives on controlling electrical load between the hours of 18:00 and 20:00 each day, which is the utility's peak demand period. A unique set of reasons for implementing DSM also exists in South Africa. ESKOM, generates one half of the continent of Africa's total electrical output [11] with South Africa consuming more than 80 percent of the ESKOM generated load [12].

The route to making DSM and SG more effective is to fully and animatedly integrate consumers, their loads, and data relating to their usage into the operation of the network [13]. As an important constituent of the SG, the advanced metering infrastructure (AMI), as well as the advanced metering, communication and control method, will assist in realizing the interaction of consumers and power establishments. In this work, a demand side management model is proposed so as to provide the requirements of the smart grid.

2. Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) is the totality of systems and networks for measuring, collecting, storing, analyzing, and using energy usage data [14].

At the start, automated meter reading (AMR) innovations were developed in order to minimize on the manual costs and advance the accuracy of meter readings. With the development of the understanding of the benefits of two-way interactions between system operators, consumers and their loads and resources, AMI was implemented to replace the AMR. It should be understood that AMI does not operate in isolation as a technology, but rather an integral of many innovations like, smart metering, home area networks, integrated communications, data management applications and standardized software interfaces.

As illustrated in Figure 1, an AMI system includes several communication networks, acknowledged according to their territorial scope. The two- way communications, advanced sensors, and distributed computing constitute the AMI and enhance it to provide both consumers and system utility operators the data or information that enables them to make logical that lead to improved service delivery like, reliability and safety of power delivery, and usage [15]. AMI also comprises of home network systems that encompass; communicating thermostats and other in-home controls, smart meters, communication networks from the meters to local data concentrators, back-haul communications networks to corporate data centers, meter data management systems (MDMS) and, lastly, data integration into existing and new software application platforms [16].

AMI is the green energy solution to improve energy management efficiency through offering real time consumption data administered by power utilities to the customer. As two-way power line communication (PLC) infrastructure between customer and power utilities through smart meter. AMI is the core technology to realize the Smart Grid.

2.1. System Function

- Measurement of energy demand and consumption data
- In-home display related to electric consumption
- Integrated metering (electricity, water, gas and caloric value)
- Monitoring of transformer load and electric leakage of customer's house.

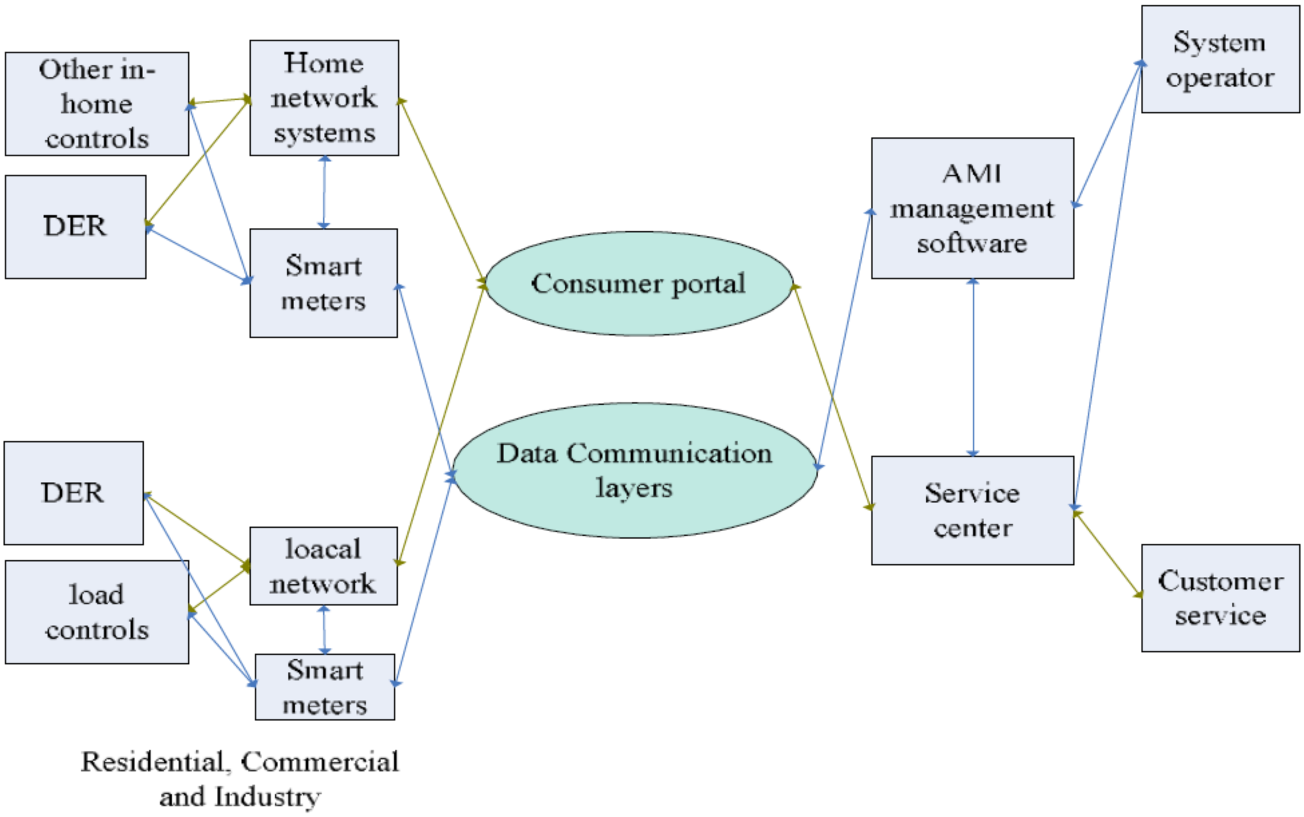

Figure 1. Composition of an AMI system (Sui et al., 2011)

3. The Demand Side Management Framework Based On Ami

The Demand-Side Management frameworks are designed to optimally control the electric resources of consumers via distinctive design, shown in Figure 2, which comprises of the components below:

- Local generators: local energy plants (e.g., photovoltaic (PV) plants) that generate electric energy that can be either used locally or injected into the grid.
- Smart devices: electric appliances that are able to monitor themselves, thus providing data, such as their energy consumption, and that can be remotely controlled [17].
- Sensors: used to monitor several data of interest, such as the user's position within the house, temperature and light [18]. Moreover, in the case of traditional devices, power meter sensors [19] can be used to monitor and control these appliances.
- Energy storage systems: are storage devices that allow the DSM system to be flexible in managing electric resources.
- Energy management unit (EMU): exchanges information with the other elements of the system and manages the electric resources of users based on an intelligent DSM mechanism. Specifically, this mechanism has to define the schedule of appliances, the operating plan of ESSs and the demand and supply profiles (i.e., when to buy and inject energy into the grid). In the case of multi-user architectures, all of the EMUs of users are connected to a central server, which coordinates the consumers.

Smart grids lead new elements to power network, such as distributed generation and storage devices, smart building, and electric vehicles charging station. The DSM in smart grid should take those plenty of plug and play distributed energy source (DER) and electric charging stations into account, the electric charging stations not only charge pure electric vehicles (PEV), and parallel hybrid electric vehicle (PHEV), but also work as energy storage devices to improve the power quality of distribution network, and adjust the distribution system load curve.

In Figure 2, the smart grid DSM framework is presented, which includes the load management units, the data collecting frame, communication infrastructure and the controllable load and DER, including wind generation, power distribution units power and many others.

DSM is comprised of two components: energy efficiency (EE) and demand response (DR). With the information provided by AMI, marketing system, load sensing entities and distribution units, the advanced control strategy and the appropriate economic incentives can be made by the utility, including load monitors, orderly consuming, and price policy. Among them, those economic incentives will be transferred back to the consuming management system at each terminal consumer, who will adjust their electric consuming schedule economically [13]. The two-way interaction between terminal consumers and the utility will achieve energy conservation and improve consumer service. In Figure 3 the general outline for the information flow in the proposed DSM framework is described. However in Figure 4, a comprehensive flow is described.

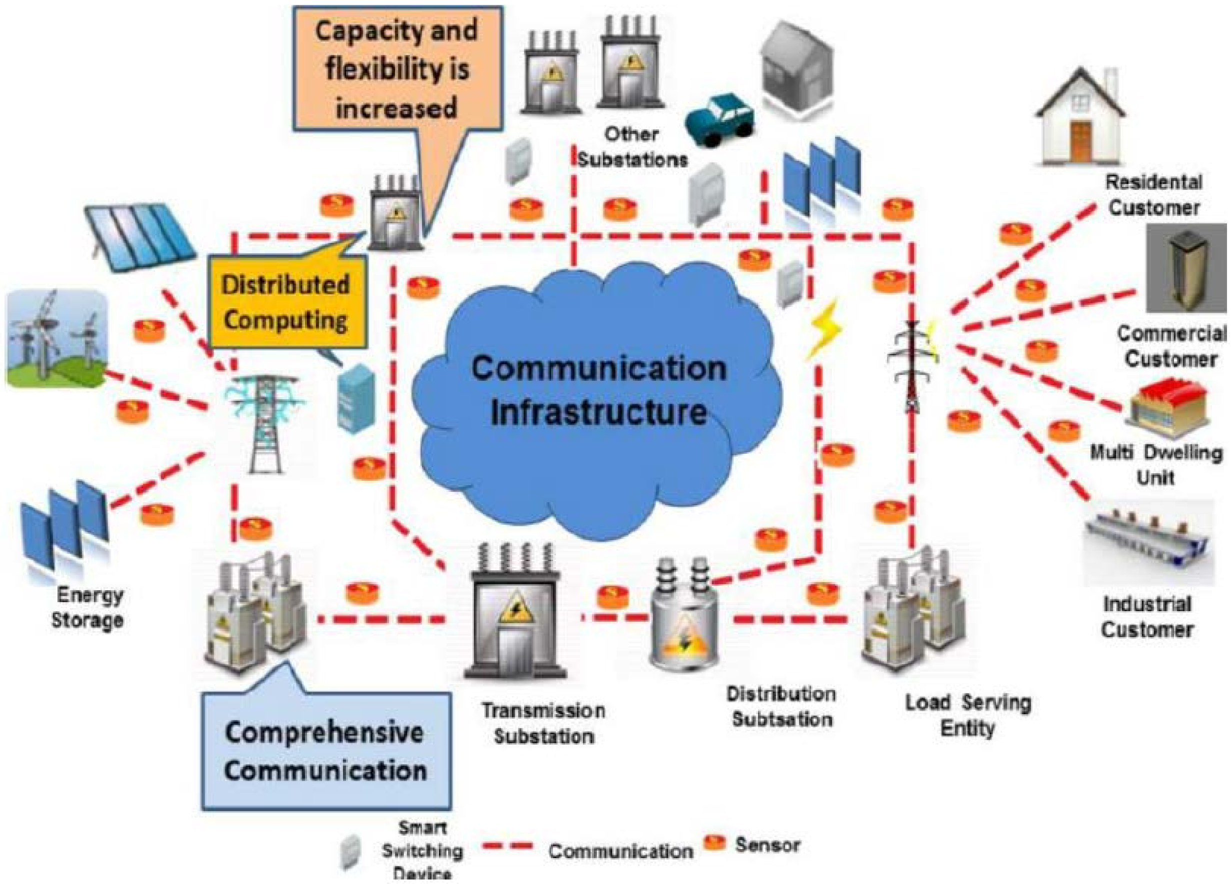

Figure 2. Composition of the DSM framework for smart grid

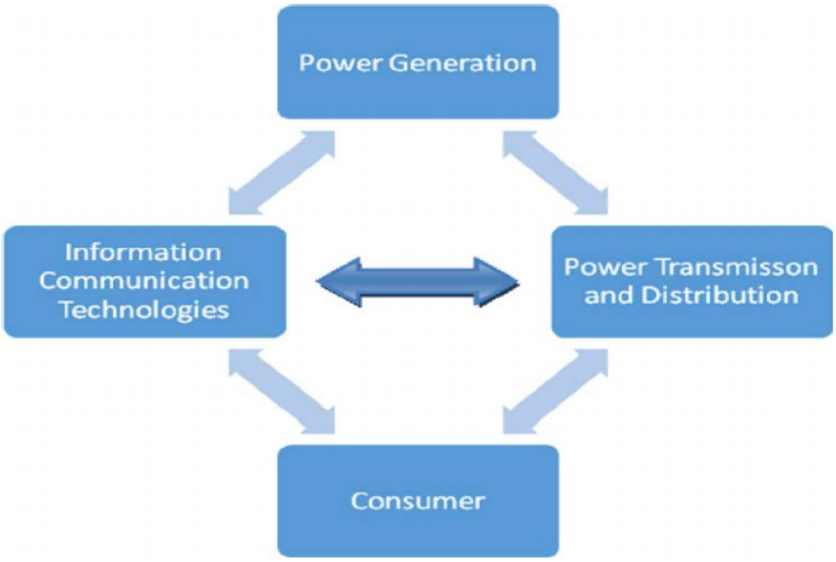

Figure 3. Information flow of DSM with other management system

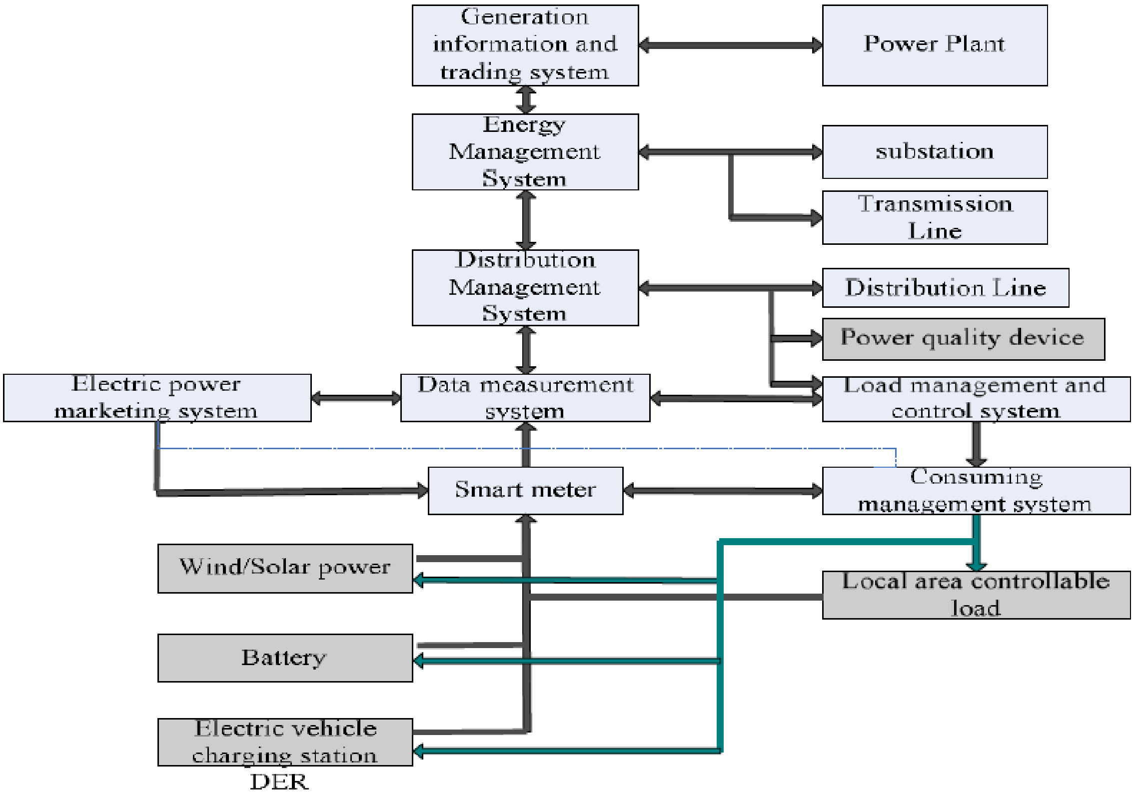

Figure 4. Detailed Information flow of DSM with other management units

Information obtained from the localized load management units and the DER using the smart meters, will be relayed to the power marketing unit, distribution units and the consumption management unit sequentially. This is essentially the uplink data. The power marketing unit analyzes the load features or attributes, the electricity consumption and abnormal usage, this is aimed at managing the whole situation of the power market. Collaborating with the generation information and weather forecasting units, the load monitoring unit can inform of the likely load demand and power price for the near future, which will be released to the consumer's management unit. This is the down link data.

The consumer management unit gives suggestions for planning to arrange the work time of controllable load and also insert their DER into the power structure. The two-way communication and demand response lead to energy efficiency together.

4. AMI at the Demand Side

AMI is considered as a smaller part of smart grid programmes which provides a two-way communication between the utility and the consumers (industries, households and commercial). AMI is thus the main component of a smart grid that interlinks metering data management systems (MDMS) with smart meters in consumers' premises. This interlinking is achieved through communication networks and the communication networks are thus the enabling core of smart grids and energy management systems. They provide a two-way combined communication between the utility management and sensing devices, grid self-healing capability devices and demand side management (DSM) systems. There are several kinds of communication type between smart meters and loads, for example, RS-485 bus and Zigbee network. The DER device is under the monitor and control of smart meters and consuming management system, also. The consuming management system connects with the utility load management & control system and marketing system through internet, receives such information as price adjustment, incentive policy, energy saving project and so on.

5. Software in Utility

The automated software upgrade utility enables a product supplier or software vendor to remotely upgrade the firmware on any of its products, such as automatic data collection ("ADC") device platforms, regardless of product type or product characteristics. The upgrade utility may reside at remote sites, such as the product owner's place of business, and periodically query the product provider for firmware upgrades.. Usually, these software packages include AMI data collecting system, marketing system, load forecasting system and distribution management system, these systems can not only work independently, but also work corporately for energy efficiency and demand response functions.

1) *Real-time price and incentive price*

The real-time pricing is the most important aspect of customer billing. The rules for dispatch and pricing in real-time affect everything that comes before. Forward markets provide hedging and scheduling activities, but the forward markets look ahead to what will happen in real-time. If efficient prices do not appear in association with the actual dispatch, this inevitably creates incentives to either "lean-on" the rest of the system, when prices are too low, or self-schedule to avoid providing flexibility for economic dispatch, when penalties are too high. This applies to short-term scheduling of generation and fuel supply [20].

The incentive problems for real-time pricing in DSM have been compounded by scheduling and operating problems during severe cold weather which result in part from depressed real-time prices and the inability to schedule and pay for gas supplies at the short-term constrained prices. This has produced a wide array of programs that treat many of the costs in uplift rather than fixing the underlying real-time prices that should rise to incent all market resources to be available, including those that need to schedule gas. As stated by [21] "…real-time prices often do not fully reflect the cost of satisfying demand and maintaining reliability during tight market conditions, particularly when fast-start resources or demand response resources are deployed in the real-time market."

2) *Energy efficiency monitor and diagnose*

Energy information management is the next issue raised in the energy management matrix which is a component of the DSM, and it is especially important as a component of any effective energy management strategy. The energy used by any business varies as production processes, volumes, and inputs vary.In that respect the goal of the DSM is to measure energy efficiency. Energy efficiency diagnostic testing collects the key energy-consuming user or key equipment (including lighting, motors, fans, pumps, air compressors, etc.) data through modern technology of sensing and communicating, compares the setting thresholds or similar user data to analyze the user energy consumption and provide authentic test reports, recommendations for energy users, to achieve energy efficiency market potential analysis.

3) *Smart power consumption and stage load*

Information and communication technology are the important support technology to effective energy distribution and consumption. Intelligent power use is increasingly benefiting homes and office buildings. Sensors direct lights to dim or turn on and off, and to increase or decrease ventilation, depending on the presence of people in the space. Energy networks may include features such as software that analyzes power usage by individual areas, applications and equipment. Such programs help to determine whether equipment needs to be replaced, either because inefficient operation makes it costly, or because it is critical and must not fail. An energy network is also essential if the building generates electricity via solar or wind energy harvesting Smart power consumption includes the establishment and optimization of the orderly power consumption strategy and auxiliary program, issue automatically and feedback [22].

4) *Distributed energy resources DER integration*

Distributed energy resources (DER) refers to a variety of small, grid-connected devices that generate, store or manipulate the consumption of energy. The power grid is in the early stages of transforming from a centralized generation design to a system that utilizes these decentralized DER systems. Renewable energy sources, such as wind and photovoltaic generation, have emerged as mainstream energy resources in many areas, with their intermittency and distributed nature representing a new set of challenges for the power grid The integration of plenty of DER will contribute to ease power shortage and improve load curves. Therefore DER should be considered in DSM, their integration will change the power flow direction. The interaction between DER and utility is very important to keep the system stability. The consumers who have DER send the energy back to network on the suitable situation, more often, when there is high electricity price. As soon as the consumer load management system receives a price higher than its setting value, it will control the DER to integrate into the power system, or the consumer takes part in the demand side bidding (DSB) program. The development of DSB will lead more benefit to consumers and flexible system operation [13].

Two-way Communication

A two-way communications infrastructure that can network one or more parts of the smart grid via secure, high speed, high bandwidth connections. This infrastructure system serves as the backbone of the customer systems, AMI, distribution, and transmission smart grid systems.

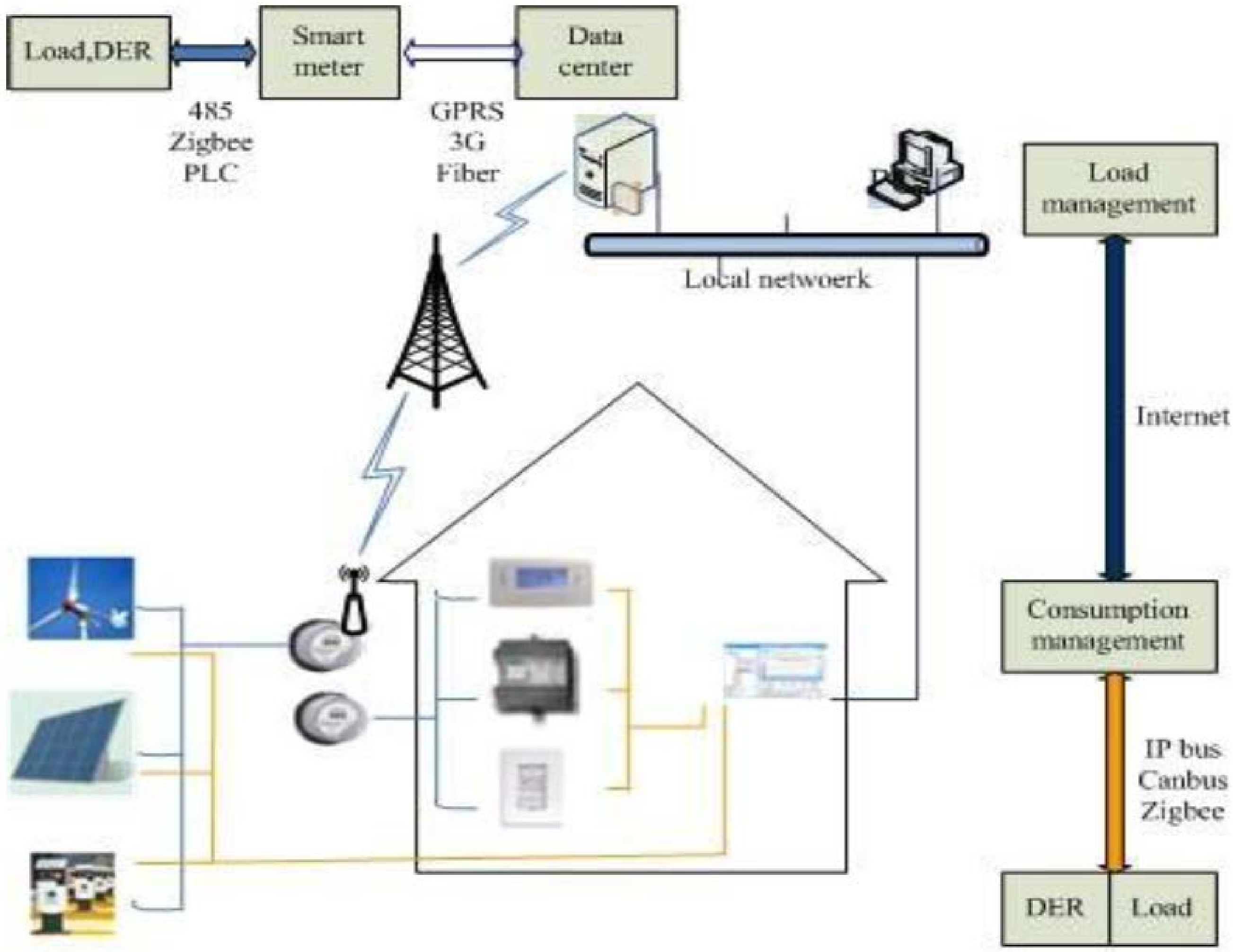

Figure 5. The communication grid in DSM framework

In the DSM model, the two-way communication is the foundation of all functions. As shown in Figure 5, several types are applied in the DSM communication network. The data collection adopts wireless and fiber communication. RS-485, ZigBee and power line carrier (PLC) are used between load applicants and smart meters often, from smart meters to data center at utility, the communication ways maybe private fiber networks, public communication networks (GPRS/CDMA), private wireless networks [23].

The utility unit, data center is connected to other application software by local network. Utility load management system utilizes public TCP/IP networks to communicate with consumer. Some other technologies, such as radio or cell phone communications are also possible in areas where the Internet access is not possible or too expensive to install. In local area, the control of load or DER is conducted through CAN-bus, IP- bus or ZigBee.

6. Conclusion

Traditionally, the vision of enhancing the efficiency of system operation and the existing investment in the generation and transmission of electricity has been the key driver for introducing DSM programmes. Again, commitment to market-based operation and deregulation of the electricity industry places consumers of electricity in the center of the decision-making process concerning the operation and future development of the system. Clearly, development of DSM will support this general trend and provide choice to consumers regarding usage of electricity and preventing cross-subsidies among consumers. However, DSM has not yet been fully integrated into the operation of electricity markets.

The AMI is related to DSM and demand response, provides the data and information. The development of smart grid brings advanced measurement technology; demand side management will grow quickly. In this research, an AMI based DSM framework is presented. The configuration of AMI and its means of communication are described firstly; data flow among DSM subsystems and the upper management systems is discussed. The functions of DSM are described in detail, particularly the integration of the terminal consumer DER is considered in the model. The proposed framework will increase the interaction of consumers with the utility, provide an important basis to the smart distribution system load management and adjustment, and distribution markets, enhances the energy efficiency both of the utility and consumers.

References

[1] Dehnavi, E. and Abdi, H., 2016. Optimal pricing in time of use demand response by integrating with dynamic economic dispatch problem. *Energy*, *109*, pp.1086-1094.

[2] Siano, P. and Sarno, D., 2016. Assessing the benefits of residential demand response in a real time distribution energy market. *Applied Energy*, *161*, pp.533-551.

[3] Boyle S., 1996. DSM progress and lessons in the global context. Energy Policy 24(4):345-59.

[4] Khondaker, A.N., Hasan, M.A., Rahman, S.M., Malik, K., Shafiullah, M. and Muhyedeen, M.A., 2016. Greenhouse gas emissions from energy sector in the United Arab Emirates–An overview. *Renewable and Sustainable Energy Reviews*, *59*, pp.1317-1325.

[5] Jayantilal, A and Strbac, G., 1999. Load control services in management of power system security costs IEE Proceedings: Generation Transmission Distribution, 146 (2) 269-275.

[6] Ayón, X., Gruber, J.K., Hayes, B.P., Usaola, J. and Prodanović, M., 2017. An optimal day-ahead load scheduling approach based on the flexibility of aggregate demands. *Applied Energy*, *198*, pp.1-11.

[7] Lu, M., Liu, S., Liu, P. and Li, Q., 2016, July. Design and Implementation of Power Information Visualization Platform Based on Smart Meter. In *Information Science and Control Engineering (ICISCE), 2016 3rd International Conference on* (pp. 297-301).

[8] Bui, V.H., Kim, H.M. and Song, N.O., 2015. Applying demand response based on TOU and EDRP to optimal microgrid operation. *Int. J. Smart Home*, *9*, pp.41-50.

[9] RAZAK, A.H.N.B.A., 2017. Malaysian residential housing for the smart grid: identifying optimization attributes for design and energy performance improvements. *How to face the scientific communication today. International challenge and digital technology impact on research outputs dissemination*, *42*, p.109.

[10] Malik, F.H., Ali, M. and Lehtonen, M., 2014. Intelligent Agent-Based Architecture for Demand Side Management Considering Space Heating and Electric Vehicle Load. *Engineering*, *6*(11), p.670.

[11] Aljanabi, H., 2012. A Trade-Off between Supply-Side and Demand-Side Management for Urban Water Resources. In *World Environmental and Water Resources Congress 2012: Crossing Boundaries* (pp. 2700-2706).

[12] Rankin, R. and Rousseau, P.G., 2008. Demand side management in South Africa at industrial residence water heating systems using in line water heating methodology. *Energy conversion and management*, *49*(1), pp.62-74.

[13] Sui, H, Ying Sun, Y. and Lee, W-J., 2011. A Demand Side Management Model Based on Advanced Metering Infrastructure, IEEE conference Weihai, Shandong, 6-9 July 2011.

[14] Wenpeng, L., 2009. Advanced metering infrastructure. *Southern Power System Technology*, *3*(2), pp.6-10.

[15] Betsy Loeff, 2008. "AMI Anatomy: Core Technologies in Advanced Metering". Ultrimetrics Newsletter (Automatic Meter Reading Association). http://www.utilimetrics.org/newsletter/index.cfm?fuseaction.

[16] Bodnar, T., Dering, M.L., Tucker, C. and Hopkinson, K.M., 2016. Using Large-Scale Social Media Networks as a Scalable Sensing System for Modeling Real-Time Energy Utilization Patterns. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*.

[17] Lui, T.J.; Stirling, W.; Marcy, H.O., 2010. Get smart. IEEE Power Energy Mag., 8, 66-78.

[18] Nguyen, T.A.; Aiello, M., 2013. Energy intelligent buildings based on user activity: A survey. Energy Build, 56, 244-257.

[19] Lanzisera, S.; Dawson-Haggerty, S.; Cheung, H.; Taneja, J.; Culler, D.; Brown, R., 2013. Methods for detailed energy data collection of miscellaneous and electronic loads in a commercial office building. Build. Environ. 2013, 65, 170-177.

[20] Egerer, J., Weibezahn, J. and Hermann, H., 2016. Two price zones for the German electricity market—Market implications and distributional effects. *Energy Economics*, *59*, pp.365-381.

[21] Hogan, W.W., 2015. Electricity markets and the clean power plan. *The Electricity Journal*, *28*(9), pp.9-32.

[22] Ali, M.J., Moungla, H., Younis, M. and Mehaoua, A., 2017. IoT-enabled Channel Selection Approach for WBANs. *arXiv preprint arXiv:1703.09508*.

[23] Parvez, I., Sarwat, A.I., Wei, L. and Sundararajan, A., 2016. Securing Metering Infrastructure of Smart Grid: A Machine Learning and Localization Based Key Management Approach. *Energies*, *9*(9), p.691.