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Research Article

Real Time Application of Smart Grid in Distribution Systems

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Abstract

In this paper presents real time application of smart grid in distributed systems. The smart grid, regarded as the next generation power grid, uses two-way flows of electricity and information to create a widely distributed automated energy delivery network. In this paper deals with supporting modernization of the electricity transmission and distribution networks to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve increased use of digital information and controls technology; dynamic optimization of grid operations and resources; deployment and integration of distributed resources and generation; development and incorporation of demand response, demand-side resources, and energy-efficient resources; development of 'smart' technologies for metering, communications and status, and distribution automation; integration of 'smart' appliances and consumer devices; deployment and integration of advanced electricity storage and peak-shaving technologies; provisions to consumers of timely information and control options and development of standards for communication and inter-operability." For the smart protection system, we explore various failure protection mechanisms which improve the reliability of the smart grid, and explore the security and privacy issues in the smart grid.

Keywords: Smart Meter; Advanced Metering Infrastructure; Wide Area Network; Wireless Communication; Supervisory Control; Data Acquisition.

Introduction

Established electric power systems, which have developed over the past 70 years, feed electrical power from large central generators up through generator transformers to a high voltage interconnected network, known as the transmission grid [1]. Each individual generator unit, whether powered by hydropower, nuclear power or fossil fuelled, is large with a rating of up to 1000 MW. The transmission grid is used to transport the electrical power, sometimes over considerable distances, and this power is then extracted and passed through a series of distribution transformers to final circuits for delivery to the end customers [2,3].

The part of the power system supplying energy (the large generating units and the transmission grid) has good communication links to ensure its effective operation, to enable market transactions, to maintain the security of the system, and to facilitate the integrated operation of the generators and the transmission circuits. This part of the power system has some automatic control systems though these may be limited to local, discrete functions to ensure predictable behaviour by the generators and the transmission network during major disturbances [4]. The distribution system, feeding load, is very extensive but is almost entirely passive with little communication and only limited local controls. Other than for the very largest loads (for example, in a steelworks or in aluminum smelters), there is no real-time monitoring of either the voltage being offered to a load or the current being drawn by it [5,6].

There is very little interaction between the loads and the power system other than the supply of load energy whenever it is demanded. The present revolution in communication systems, particularly stimulated by the internet, offers the possibility of much greater monitoring and control throughout the power system and hence more effective, flexible and lower cost operation.

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The Smart Grid is an opportunity to use new ICTs (Information and Communication Technologies) to revolutionize the electrical power system [7]. However, due to the huge size of the power system and the scale of investment that has been made in it over the years, any significant change will be expensive and requires careful justification. The consensus among climate scientists is clear that man-made greenhouse gases are leading to dangerous climate change. Hence ways of using energy more effectively and generating electricity without the production of CO_2 must be found. The effective management of loads and reduction of losses and wasted energy needs accurate information while the use of large amounts of renewable generation requires the integration of the load in the operation of the power system in order to help balance supply and demand [8].

Smart meters are an important element of the Smart Grid as they can provide information about the loads and hence the power flows throughout the network. Once all the parts of the power system are monitored, its state becomes observable and many possibilities for control emerge. In the UK, the anticipated future de-carbonised electrical power system is likely to rely on generation from a combination of renewables, nuclear generators and fossil-fuelled plants with carbon capture and storage [9] [10]. This combination of generation is difficult to manage as it consists of variable renewable generation and large nuclear and fossil generators with carbon capture and storage that, for technical and commercial reasons, will run mainly at constant output. It is hard to see how such a power system can be operated cost-effectively without the monitoring and control provided by a Smart Grid.

Implementation of Smart Grid

Components of the Smart Grid

Electricity Generation includes Electricity Transmission, Electricity Distribution, Communications and Operations and End-User Applications (Fig. 1).

Electricity Generation

The process of creating electricity from other forms of energy includes chemical combustion, nuclear fission, photovoltaics (solar), or kinetics (water and wind) (Fig. 2).

Fig. 1. Components of Smart Grid

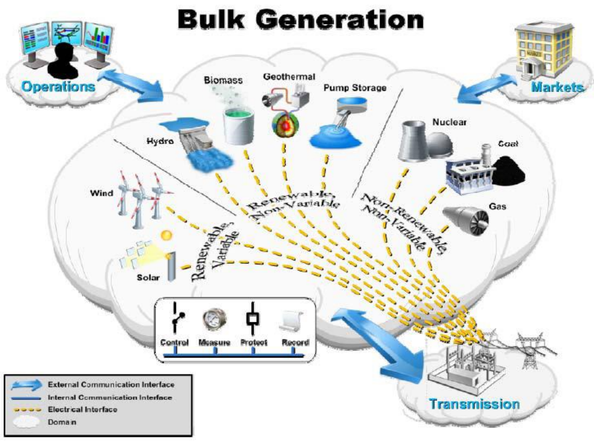

Fig. 2. Electricity Generation

Electricity Transmission

Bulk transfer of electrical energy from Generators to substations via overhead power lines or underground cables. Most activity in this component takes place in substations, whose operations are controlled by the Supervisory Control and Data Acquisition (SCADA) system (Fig. 3).

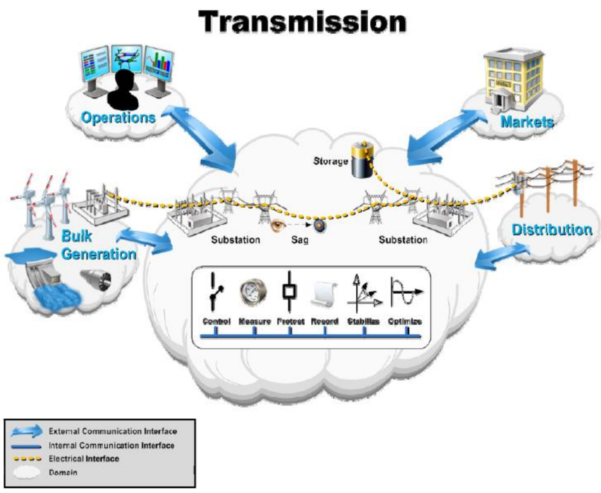

Fig. 3. Electricity Transmission

Electricity Distribution

The Distribution system carries electricity from the substation to the consumer's metering point. Infrastructure includes –Feeders, Power Lines, Transformers and change voltage from transmission levels to consumer use levels (Fig. 4).

Automation of Feeder Equipment: The automated system will communicate directly with smart meters.

Fault Detection: Utility companies will access personal information regarding electricity use in real time, without direct interface with the consumer.

Load Management: Utility may take control of systems within the home –i.e. air conditioner cycling off during times of peak demand.

Data Gathering and Storage: Utilities will now control many times more data points than they currently collect.

End-User Applications

Advanced Metering Infrastructure (AMI) - Tools to monitor and analyze energy usage by the consumer. Smart Meters are Data Management Software, Data Storage Devices, Smart Appliances and Home Area Networks (Fig. 5).

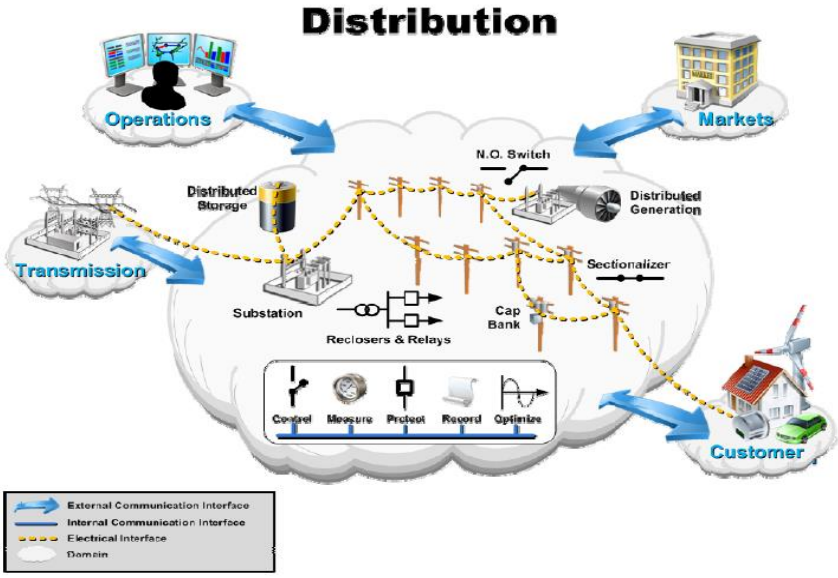

Fig. 4. Electricity Distribution

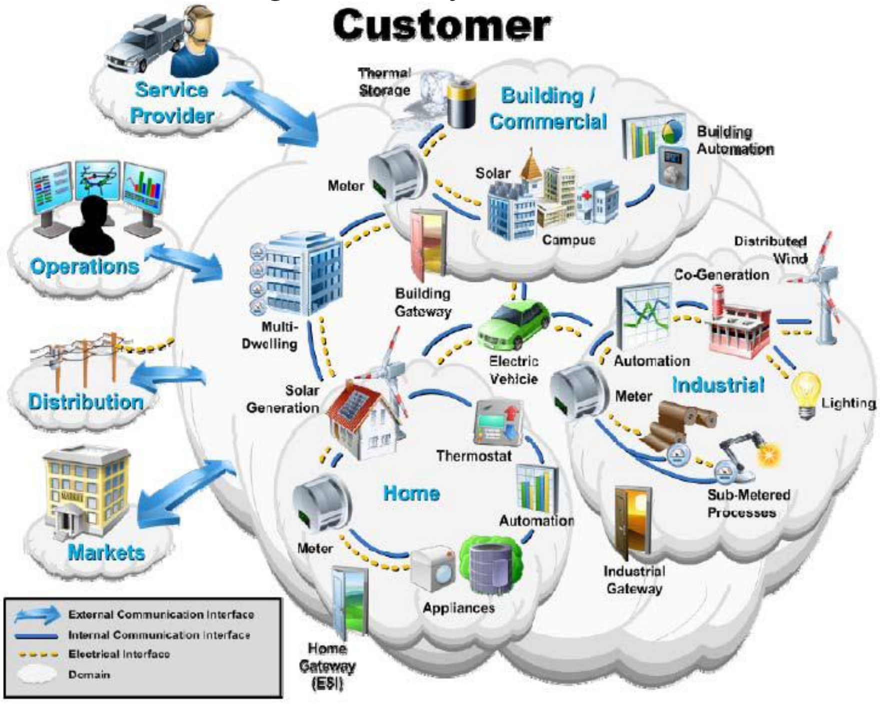

Fig. 5. End-User Applications

Smart Metering Information regarding energy use will be collected from the home and may be able to relay information about specific types of appliances being used at specific moments in time. Data will potentially be collected at very short (15 minutes or fewer) intervals. Load Signatures could potentially indicate when you are home and whether you are cooking, watching television, or using other electronic devices.

Smart Appliances

General Electric and Whirlpool plan to roll out "smart" appliances by 2010. Automatic shut-off during times of peak demand. Communicate with metering devices and other appliances (Fig. 6).

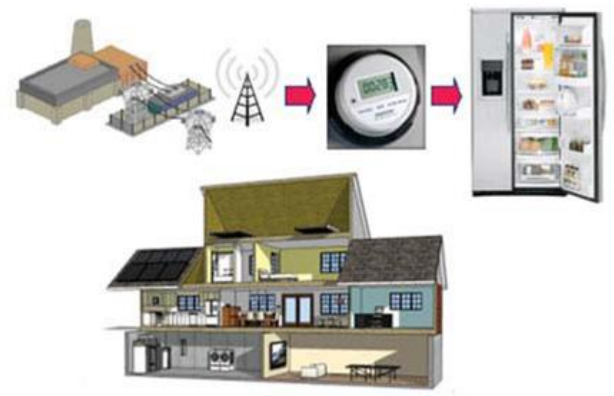

Fig. 6. Smart Appliances

Plug-In Electric Vehicles

Identify each vehicle at the location it charges and bill the proper account. Accommodate times of peak charging demand. Use batteries for storage and exchange power between the Grid and your vehicle (Fig. 7).

Fig. 7. Plug-In Electric Vehicles

Communications and Operations

The communication infrastructure of a power system typically consists of SCADA systems with dedicated communication channels to and from the System Control Centre and a Wide Area Network (WAN) (Fig. 8). Some long-established power utilities may have private telephone networks and other legacy communication systems. The SCADA systems connect all the major power system operational facilities, that is, the central generating stations, the transmission grid substations and the primary distribution substations to the System Control Centre (Fig. 9). The WAN is used for corporate business and market operations. These form the core communication networks of the traditional power system. However, in the Smart Grid, it is expected that these two elements of communication infrastructure will merge into a Utility WAN.

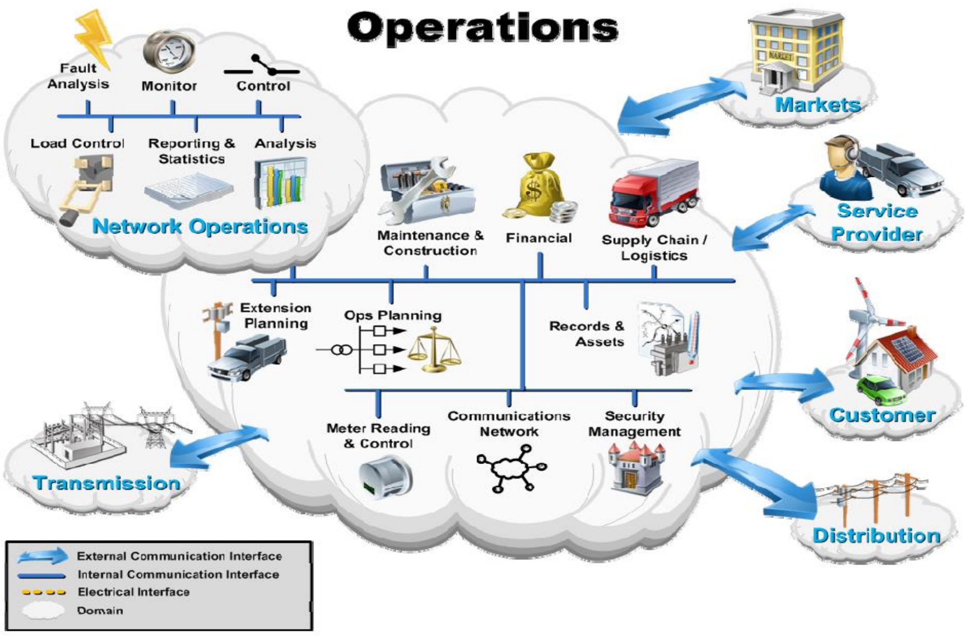

Fig. 8. Communications and Operations

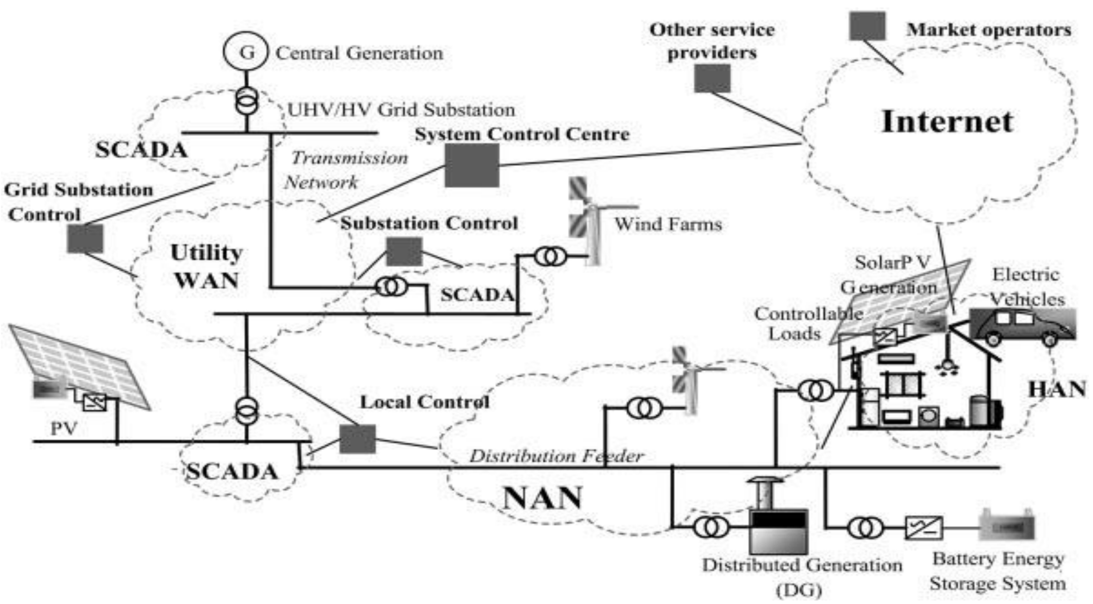

Fig. 9. SCADA with Communication Network

Modern electric power systems are supplied by large central generators that feed power into a high voltage interconnected transmission network. The power, often transmitted over long distances, is then passed down through a series of distribution transformers to final circuits for delivery to customers Operation of the generation and transmission systems is monitored and controlled by Supervisory Control and Data Acquisition (SCADA) systems (Fig. 10). These link the various elements through communication networks (for example, microwave and fibre optic circuits) and connect the transmission substations and generators to a manned control centre that maintains system security and facilitates integrated operation. In larger power systems, regional control centres serve an area, with communication links to adjacent area control centres. In addition to this central control, all the generators use automatic local governor and excitation control. Local controllers are also used in some transmission circuits for voltage control and power flow control, for example, using phase shifters (sometimes known as quadrature boosters). Traditionally, the distribution network has been passive with limited communication between elements. Some local automation functions are used such as on-load tap changers and shunt capacitors for voltage control and circuit breakers or auto-reclosers for fault management. These controllers operate with only local measurements and wide-area coordinated control is not used.

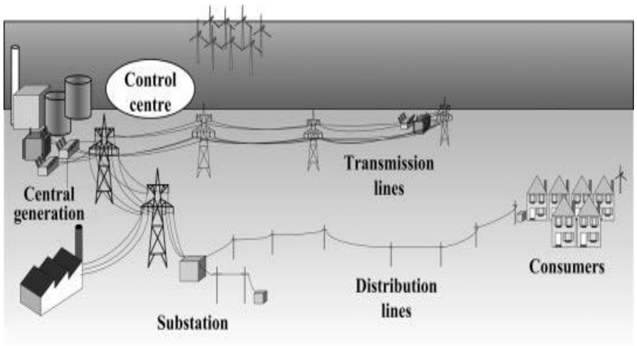

Fig. 10. Power Generation, Transmission Lines & Distributed Lines

Renewable Energy Generation

Renewable energy sources are being developed in many countries to reduce CO_2 emissions and provide sustainable electrical power. The balance of particular technologies and their scale changes from country to country. However, hydro, wind, biomass (solid biomass, bioliquids and biogas), tidal stream, and photovoltaic (PV) are common choices. Variable speed turbines are used for wind, small hydro and tidal power generation. These generally use AC–DC–AC power conversion where the turbine is arranged to rotate at optimum speed to extract the maximum power from the fluid flow or minimize mechanical loads on the turbine. The variable frequency power output from the generator is first converted to DC. A second converter is used to convert DC into 50/60 Hz AC. The output of a PV system is DC and therefore a DC–AC converter is essential for grid connection. Biomass technologies use a steam or gas turbine and a conventional generator. Reciprocating engines may be fuelled by biogas.

They generally use a synchronous generator connected to the grid directly. The power electronic interface between a renewable energy source and the grid can be used to control reactive power output and hence the network voltage as well as curtailing real power output, and so enable the generator to respond to the requirements of the grid.

Photovoltaic systems

Photovoltaic (PV) systems which convert solar power directly into electricity are being installed in increasing numbers in many countries, for example, Germany, Spain, the USA and Japan. Feed-in-tariffs, which provide guaranteed payment per unit of electricity (p/kWh) for renewable electricity generation, have been particularly important in stimulating the uptake of PV. The main elements of a grid-connected domestic PV system. It typically consists of: (1) a DC–DC converter for Maximum Power Point Tracking (MPPT) and to increase the voltage; (2) a single phase DC–AC inverter; (3) an output filter and sometimes a transformer; and (4) a controller (Fig. 11).

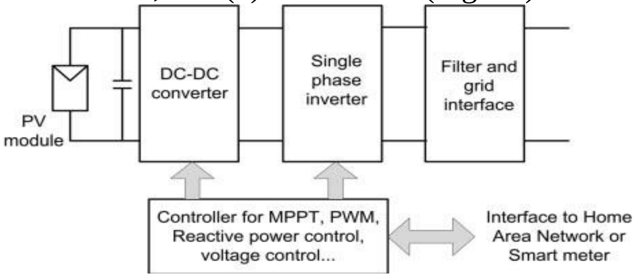

Fig. 11. Grid Connected PV System

Residential Perspective

Residential Perspective is described in Fig. 12.

Home Energy Manager Concept

Home Energy Management System is described in Fig. 13. HEM Characteristics are

1. Interoperable communications
2. Intuitive user Interface
3. Set-and-forget controls
4. Single interface for utility

Diverse Energy Sources

Diverse Energy Sources are described in Fig.14

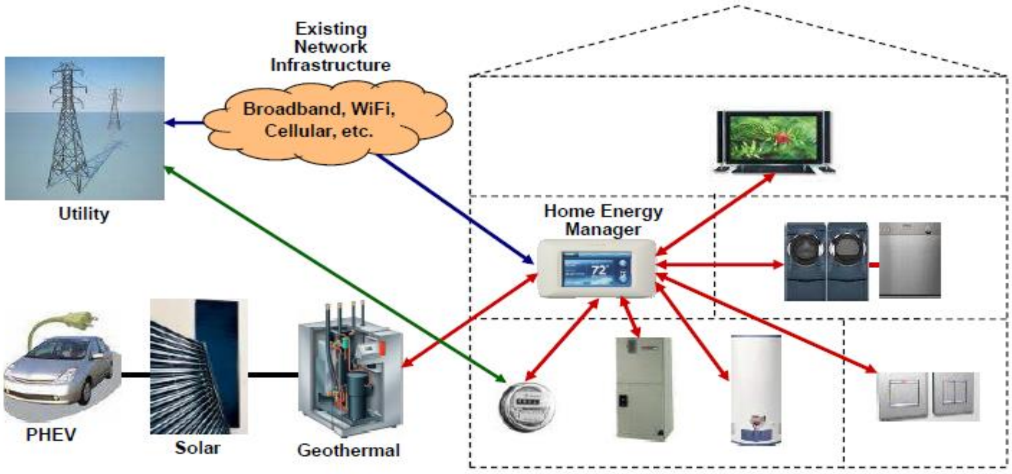

Fig. 12. Residential Perspective

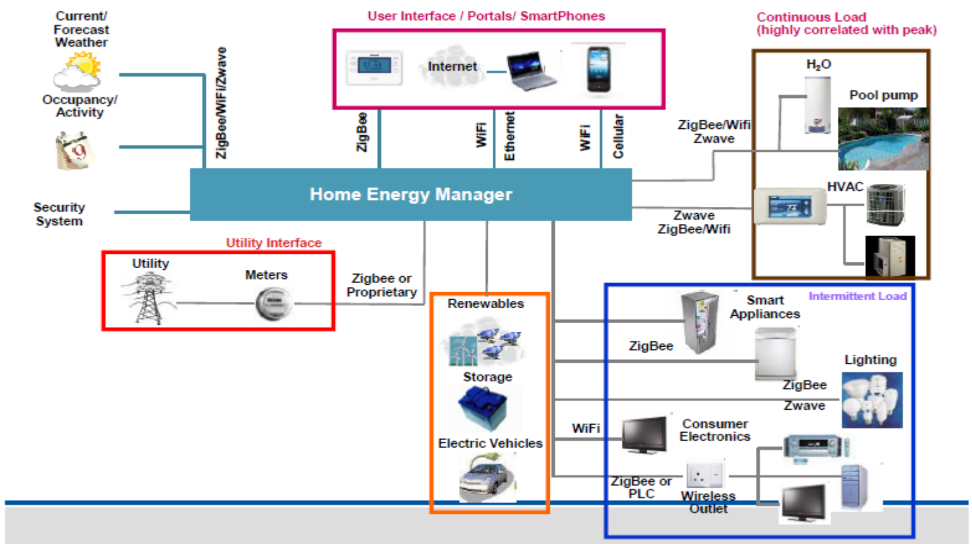

Fig. 13. Home Energy Management System

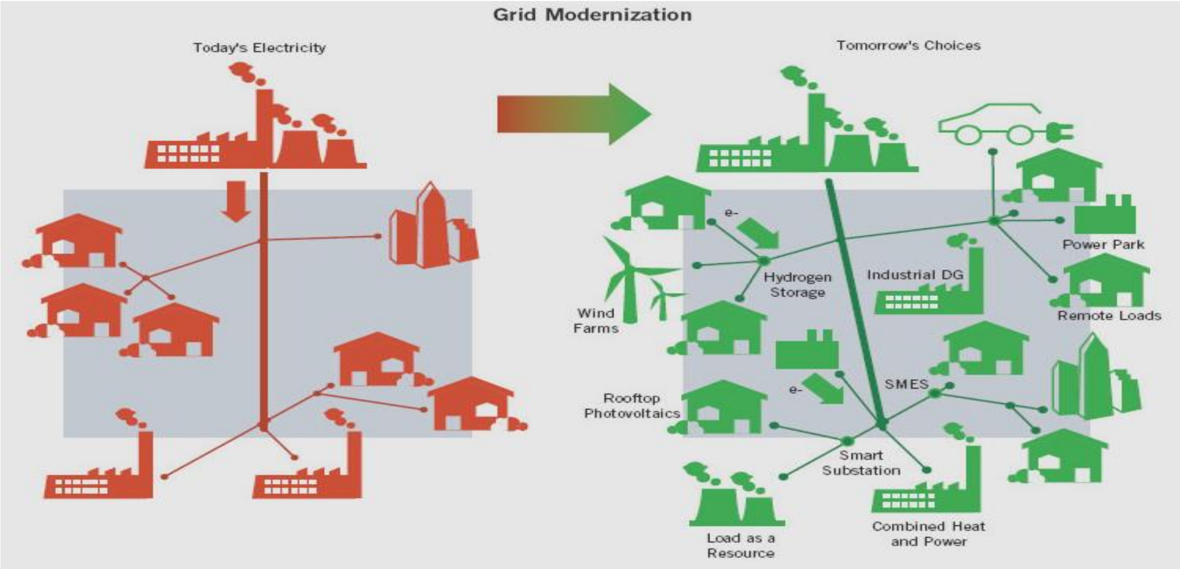

Fig. 14. Diverse Energy Sources

Conclusions

Smart Grid provides intelligent, advanced power control for the next century. Many new technologies involve for supporting sensing, controlling, human interfaces. Charging electricity cost is fundamental infrastructure can be implemented similar to stock market in smart grid. We believe that within the advanced infrastructure framework of Smart Grid, more and more new management services and applications would emerge and eventually revolutionize consumers' daily lives.

Conflict of interest

Authors declare there are no conflicts of interest.

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