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From Smart Grids to an Energy Internet:

(A Review Paper on Key Features of an Energy Internet)

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Abstract:- **Invest in "Green" and Alternative Energy Sources by using the latest technology with digitalization is indeed a need of every country to survive. In future smart electric grids, large-scale deployment of distributed energy resources (DERs), renewable generation units such as wind turbine and photovoltaic generation are expected. To obtain reliability and security, every stakeholder of energy delivery has to cooperate and interact with each other. Of course future of Smart Grids is an Energy Internet. The new concept of an Energy Internet with its key features and architecture is presented in this research paper. Energy sustainability in future demands Energy Internet for efficient energy management with a higher degree of interactive flexibility from all the stakeholders.**

Keywords:- Energy Internet, Smart Grid, Future Grid , Distributed Energy Resources, Future Renewable Electric Energy Delivery and Management (FREEDM).

I. INTRODUCTION

According to Central Electricity Authority (CEA) of India, the total electricity generation from all sectors is 344Gw (Refer Table 1) [8] amongst which fossil fuel (thermal) based generation is 56.6%. This statistics shows that, we are still more dependent on fossil fuel (coal, natural gas, crude oil) based electricity generation. Due to this dependency our nation which is under developing stage face an issue of energy resource crisis and other serious issue is global warming i.e. greenhouse gas emission (CO_2). How to generate and use energy in a more efficient and a clean way becomes a necessity of every nation worldwide. So there is an urgent need to utilize, monitor and control renewable energy based electricity generation.

Table: 1 Total Electricity Generation from all sectors as on 31/05/18[8]

Thermal (MW)			**Nuclear (MW)**	**Renewable (MW)**	
Coal	Gas	Diesel		Hydro	Other Renewable
1,96,957 - (57.27%)	24,897- (7.23%)	837- (0.24%)	6,780- (1.97%)	45,293 - (13.20%)	69,022- (20.07%)
Total Thermal=2,22,691 MW			Total Nuclear= 6,780	Total Renewable=1,14,315	
Total Electricity Generation from all sector =3,43,786 MW=344GW					

As we know that modernization of conventional grid is a smart grid. As per National Institute of Standards and Technology (NIST), USA smart grid is: "A modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications". Even smart grid uses smart an intelligent network, there is still some limitations exist. To have more advancement in smart grid feature, Energy Internet has been proposed as a new paradigm which will perfect the smart grid in all-round manner, as demonstrated in Fig.1. The EI can be described as a new type of energy network in which the various energy networks such as power system network, natural gas network, cooling/heating system, storage devices, distributed energy generation, various distributed load etc. are connected. Energy Internet also uses many advanced technologies such as advanced monitoring and measurement, intelligent management, big data and data analytics, and information and communication. In this research paper, Energy Internet (EI) is proposed as one of the key solutions to mitigate the above problems.

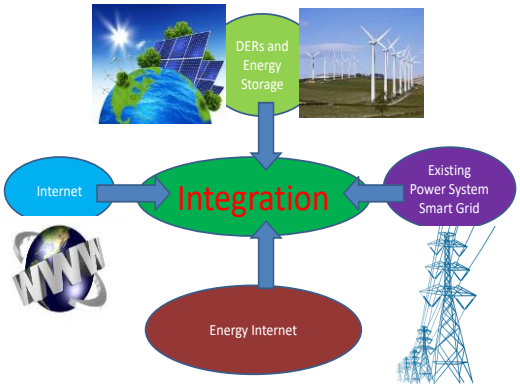

Fig.1 Vision of Energy Internet

II. CONCEPT OF ENERGY INTERNET [1,2,5,6]

EI integrates the internet with, energy generation, energy transmission, energy storage, energy consumption as well as energy trading in a competitive energy market. There is no perfect definition of an energy internet.

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As per the economist and energy visionary Jeremy Rifkin [9], "the energy internet is a vast network that efficiently supplies electricity to anyone anywhere. The digital age will allow such a system to be decentralized, efficient and reliable. The energy internet is really the internet brought to energy". Rifkin has written in his book "the third industrial revolution", he told that his book is about the new convergence of communication (internet) and energy. He also mentioned about collection of renewable energy by having solar ship, solar parks, offshore wind, and converting the entire building infrastructure with roof top solar. He has also discussed the intermittent issues with renewable energy. He proposed that, in an internet we are storing all media in a digital form and share it with others. The same can be implementing with distributed energy sources.

Some scholars believe that making a network of energy will change the conventional concept of an electric grid. Energy internet is based on concept of an internet which will change the traditional grid concept with reference to grid infrastructure, architecture, and control mechanism.

The energy internet will change the current electricity structure in the following ways:

- Energy Generation from conventional fossil energy sources toward environmental clean renewable energy sources, such as solar, wind, and other new energy sources as main energy,
- Consideration of electric vehicles as a major transportation option (distribution load) by using large-scale distributed energy resources (DERs) and energy storage systems (ESS),
- Use of Internet and Technology, providing wide-area for sharing energy in distribution systems [6].

Fig. 2 Towards Energy Internet

III. COMPARISON OF SMART GRID AND ENRGY INTERNET[6]

The comparisons of EI and smart grid are discussed here.

- EI integrates the technology use in distribution system such as smart meter, real-time monitoring of energy and control, whereas smart grid involves intelligent information and communication technology.
- Smart grid is always comes under regional systems while main focus of EI, supports the access of scattered large scale distributed energy systems.
- EI refers to energy sharing and exchanging information bidirectional, while smart grid refers one-way communication i.e. from top to bottom.
- EI is dominated by Internet (Web) whereas smart grid is dominated by communication systems.

Main focus of EI is energy utilization more efficiently considering distributed and scalable renewable energy resources. Instead of exploiting renewable energy itself, the key solution of energy crisis; which is still exists in many parts of the world including India, is energy internet which deals with efficient delivery and management of renewable energy sources at a larger scale. A lot of researches have been done since the EI concept proposed. In this paper, EI architecture, technical requirements, challenges to implement EI and solution to the problems associated with EI implementation is discussed.

IV. COMPARISON OF INFORMATION INTERNET AND ENRGY INTERNET[1]

A dictionary meaning of network is: "A group or system of interconnected people or things". In terms of computer systems a network is defined as; a connection of different computers, peripherals, servers, mainframes together by physical connections or wireless to share information/data. An example of a network is an 'internet' which connects millions of people worldwide to share information. Information internet connects different computers/servers while energy internet connects different forms of a power grid to share energy from excess to deficit. EI and information internet (worldwide web-www) have similar terms as well as differences with reference to network structure, function, different types of equipments, network protocol, security, and objective of service. For example in EI, there is a transmission of energy which creates a big loss in transmission lines. The transmission speed of information is much higher than the transmission of energy. Table 2 compares EI and information internet.

Table 2: Comparison of Information Internet with EI [1, 2]

Category of Comparison	Information Internet	Energy Internet
Transmission	Information	Energy (Electricity)
Transmission speed	High	High
Transmission loss	No losses	Loss Exist
Access	For all	For all
No. of nodes	Many	Many ex. Micro grids
Path for transmission	Communication Subnet	Transmission Lines i.e. Grid
Supply and Demand	As per Resource Subnet	As per generation and Demand of Electricity

V. ARCHITECHTUTE OF ENERGY INTERNET (FREEDM System)[4,6]

The FREEDM system is a new green energy delivery and management system which includes conventional power grid with large-scale distributed renewable energy sources and energy storage systems in order to encourage green-energy-based power industry.

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The FREEDM architecture is given in [6]. Several technologies are prime important which is shown in Fig. 3.

i. Plug-and-play interface, this allows distributed energy sources and energy storage devices to be inserted and to be removed at any time similar to a USB port in a computer.
ii. Intelligent energy management software, this will calculate the price as per availability of distributed energy generation and storage devices and also residential customers can trade excess energy.
iii. Internet equipment management, it ensures optimization of energy generation and load balance.
iv. Distributed grid intelligent software, it will work as a distribution level and balanced demand and renewable generation including energy storage at every node.
v. Solid state transformer, it replace conventional distribution transformer and it connect distributed generation and energy storage.
vi. Intelligent fault management, it will maintain stability between distribution grid and main grid.
vii. Smart metering and SCADA system, advanced metering is a core technology for EI. It provides predictability, observability and controllability in case of emergencies to an operator.

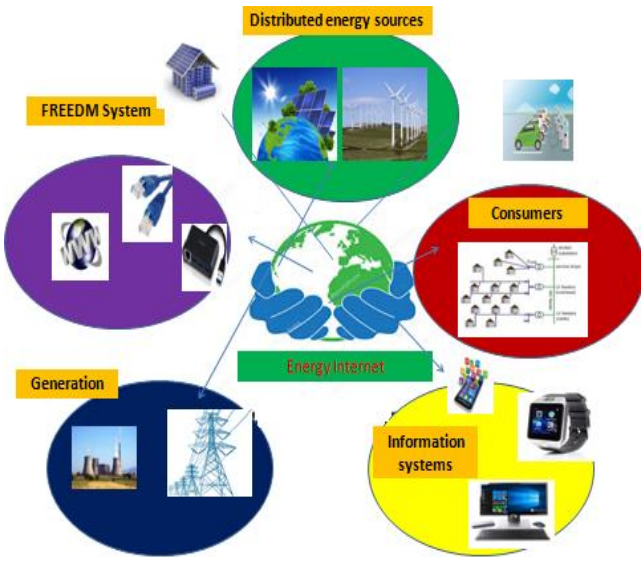

Fig. 3 Architecture of Energy Internet

VI. MOTIVATION/BENEFITS OF EI

- ✓ Enhanced customers experience towards energy utilization i.e. User centered
- ✓ Energy Conservation and Energy Efficiency
- ✓ Increased Openness
- ✓ Energy Market Revolution (new energy market evolve includes market competition)
- ✓ Active participation of Energy Consumer and Energy Prosumer

VII. CHALLENGES IN EI IMPLEMENTATION[6,7]

i. Complexity: EI is a complex system as it is networks of systems of systems. It incorporates distributed energy sources, communication systems, energy storage systems, energy utilization etc. to mitigate this proper modeling, design, and analysis is required.
i. Planning technology: EI composed of multiple systems. Therefore rigorous planning is required. It includes system architecture design, mythology, and development.
ii. Energy technology: Integration of generation, transmission, distribution, utilization as well as energy storages at a larger scale with energy efficiency itself is a challenge. Exploration of new energy technology demands intelligent network.
iii. Fast information and communication technology: It contains smart metering, artificial intelligence, high-performance computing, and high-speed communication network.
iv. Generation and demand management technology including energy storage and price signals: Real-time energy management and delivery optimizing all available resources is a main focus of EI. Acquisition of energy generation signals, energy demand signals, and price signals are the main goal of energy market management.
v. Energy security and Information network security: EI is a combination of energy signals as well as information signals. Cybersecurity is also a challenge for information internet, EI demands more research and innovation in these fields.
vi. Reliability: EI incorporates new energy technology which gives a priority to renewable energy sources which are intermittent in nature. Energy storage will be an emerging field of research in this direction. Energy storage provides new features to energy internet.

VIII. INDIAN SCENARIO

A developing country like India, the demand of electricity is higher and stills many households is not connected to the country's electricity grid. As per the latest report of November -2018, India has surplus power generation but does not have adequate infrastructure facility to supply electricity to every needy people. As per NFHS report,12 % households in various parts of the country are still not connected to country's grid amongst which Madhya Pradesh, Tripura, Maharashtra, Manipur, Haryana, Meghalaya, Rajasthan, and Arunachal Pradesh having 88 % connectivity to country's electrical grid[10]. Recently the Indian government has launched a "Power to All" scheme, under this scheme new infrastructure should be provided, so that every household and industries will get quality power. Also, India's transmission and distribution losses are highest in the world; in some states it is 10 to 20 % while in some other states, it is more than 40 % considering

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energy theft. Indian utilities face challenges such as high T & D losses, theft of electricity, failure of a distribution transformer, and rising power purchase costs. It is a serious national issue and India needs to invest in a modern and intelligent grid which is nothing but a smart grid. On the contrary, consumers also face power quality problems, failure of electricity and unsafe handling of electrical equipments-results in fire hazards. Even today consumer has to inform the utilities for failure of electricity in many parts of India!!!

India needs an electricity network with advanced sensors, and specialized technology including information and communication technology which convert a conventional grid into a smart grid which improves efficiency, reliability, safety and security to the personnel as well as to the electrical equipment. Through demand response and load management, smart grid can reduce the cost of electricity per unit. Undoubtedly, the smart grid is an "energy internet" of future. The participation and cooperation of all the stakeholders (GENCOs, TRANSCOs, DISCOs, policymakers and regulators, and consumers) is the only way to move towards the future grid. To realize an impact of a smart grid, the countries like India will take at least some more few years, when every household's energy meter will be controlled by an operator from utility's control room!!! In order to find a better solution of all the problems mentioned above, one has to move towards technology and without smart grid; India will fail to create a sustainable environment and ecosystem for Indian economy.

IX. ENERGY INTERNET AND ENERGY MARKET

In energy internet, all the energy- market participants want to maximize their interest through participation in the open market. Whenever the external energy price changes, system marginal cost fluctuates, so system operators will choose the option of energy storage. The greater the market price fluctuation, greater the use of energy storages. Using renewable energy as a main (primary) energy, it will create more and more uncertainties in the energy market transactions. So energy storage becomes an important consideration in open access based energy market mechanism. Also, collaborative planning and scheduling of renewable energy generation, as well as energy storage systems are two key challenges.

X. CONCLUSION AND FUTURE RESEARCH

To achieve efficient use of large-scale renewable energy, an energy internet is a key solution in a smart grid environment. The key motivation of energy internet is to create new business with new and improved technology which leads towards an industrial revolution in energy that what the Jeremy Rifkin told!! . It is evident that there are many advantages of EI implementation in smart grid scenario but one cannot refuse to accept certain complexities too! Proper planning of technologies including communication infrastructure can increase the reliability, efficiency, and security of an electricity market in the future.

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