*International Journal of Scientific Research and Engineering Development-– Volume 5 Issue 2, Mar-Apr 2022*

*Available at www.ijsred.com*

RESEARCH ARTICLE OPEN ACCESS

# A Comprehensive Study on Internet of Energy: Concept, Usages and Challenges in Smart Environment

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## Abstract:

Internet of Energy (IoE) is a futuristic evolution of the power system, transforming energy production, supply and consumption. The transformation is required to meet the high demands in the future. The concept of IoE is regarded as a sub-sector of Internet of Things (IoT). This paper includes a basic architecture of IoE, compare and contrast between Internet and energy networks and services, prime technologies, supply side and demand side analysis and main issues in IoE. This study has tried to isolate and describe various sides and parameters of Internet of Energy (IoE), which can help the reader to grab basic knowledge of Internet of Energy.

*Keywords* **— Internet of Energy (IoE), Internet of Things (IoT), Electric Vehicles (EVs), Renewable Energy Sources (RES), Machine Learning (ML)**

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## I. INTRODUCTION

The term IoE had been coined by Jeremy Rifkin in his book "Third Industrial Revolution" and it is referred to the internet-style solution of electricity based on bidirectional information and power flow. It represents a shift of today's grid system to a more efficient, reliable, flexible, and sustainable energy network[1].The term Internet of Energy (IoE) is related to the up-gradation and automation of the electrical infrastructure. With the help of IoE, energy production can move more efficiently and in a cleaner fashion. The term IoE is closely related to the Internet of Technology (IoT). IoE is basically the use of IoT in various energy systems[2]. Figure 1 shows IoT in smart power systems.

## II. MORE ABOUT IoE

IOE is a part of IOT including a network of sensors having numerous smart grid applications, including distributed storage, demand-side energy management, and renewable energy integration, etc[3].

*Energy demand Problem*: The demand for energy is increasing everyday and so implementing IoE, these demands can be efficiently managed[4].It is assumed that IoT can add about $14 trillion to the global economy by 2030 and the market for digital devices that makes IoE possible is assumed to grow by $89.4 billion by 2030[3].

  

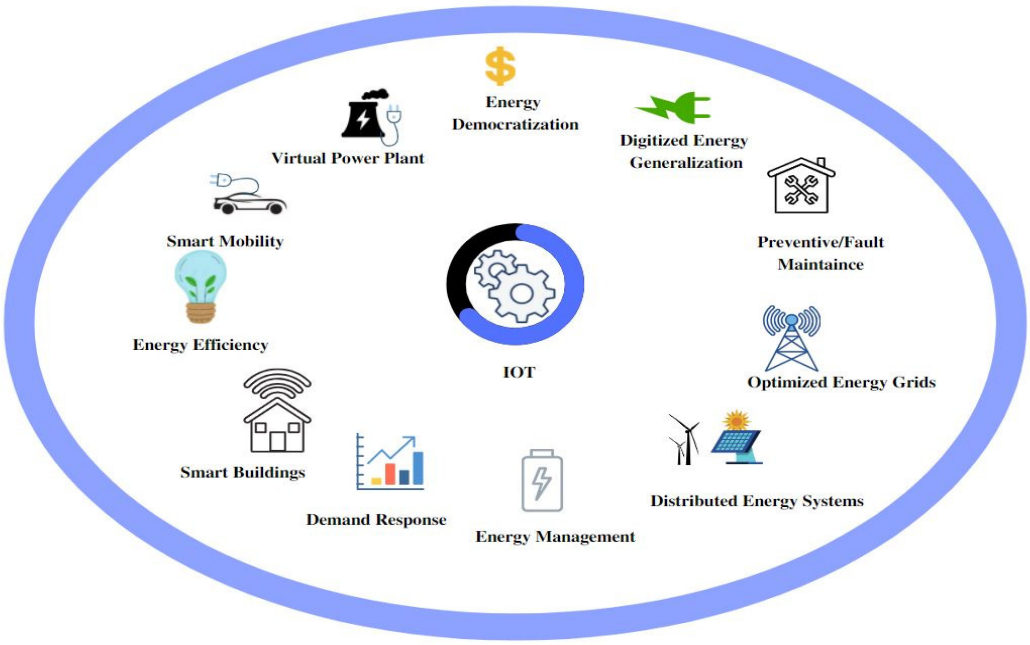


*Fig.1 various parts of an integrated smart energy system[9]*

*IoE examples:*

*General electric*: This company is combining big data, ML concepts, and IoT to build an IoE system. The benefits the company has received are a 5% reduction in downtime and a 25% reduction in maintenance and operation costs[5].

*Marriott Hotels*: This place has developed an IoE by attaching a switching unit to the air-con on the roof. The implementation of the system caused a savings of £7000,000 a year[5].

## III. INTERNET AND IoE

The structure and functionality of IoE and the internet are quite similar. The below-mentioned figure 2 gives a diagrammatic representation of similarities between IoE and the Internet[1].

## IV. PRIME TECHNOLOGIES IN IoE

### *A. Energy router:*

This is responsible for communication among a large number of distributed sources and loads. Its functions include processing information, dispatching electricity, and converting voltage. Its role includes improving the efficiency, safety, and reliability of the power system.

### *B. Energy Storage devices*

These key elements make the grid efficient. It is responsible for reliable supply, greater quality of energy, stable grid operation, and reliable supply. The energy storage system is a boon to the grid at a time when there is stress on the supply and demand.

### *C. Distributed Renewable Energy sources*

IoE includes the interconnectedness of various renewable energy resources, which makes energy clean and green. There are various renewable energy sources present like wind, solar, hydroelectric, etc. Out of which solar and wind are the most preferred options available.

### *D. Plug-and-play interface*

  

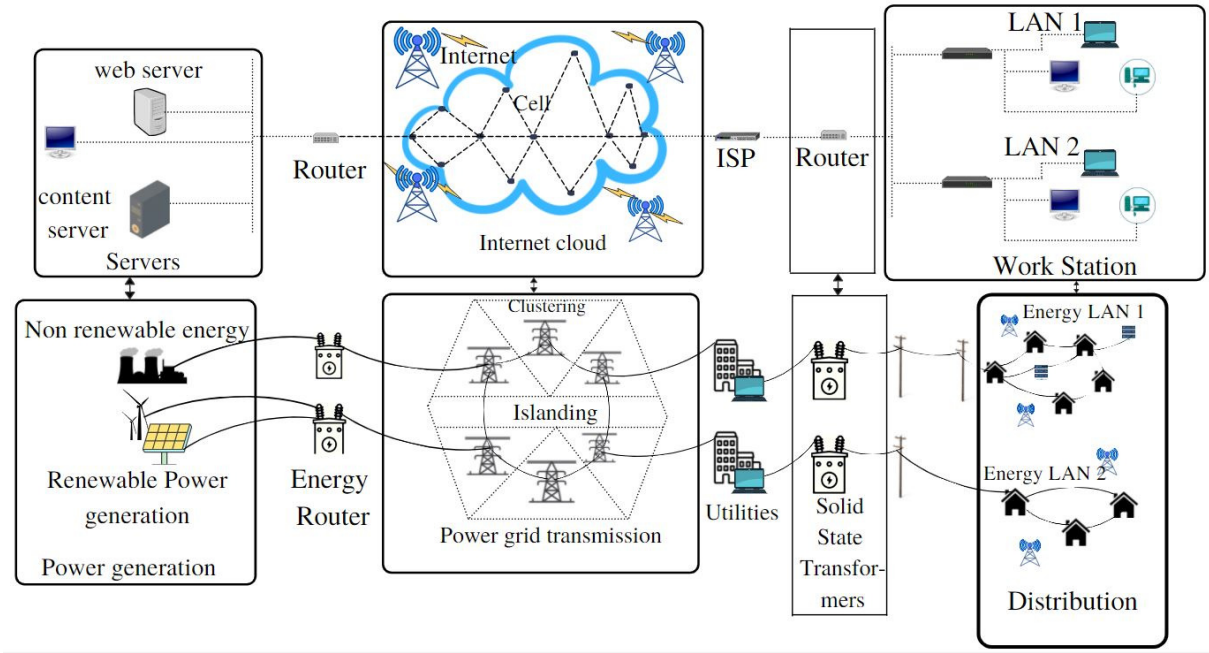


*Fig. 2 Similarity between Internet and IoE*

The plug-and-play interface of IoE allows it to connect with various renewable energy resources, loads, and storage systems making it more flexible for usage. It also forges an easier connection among various storages and distributed generations[1].

## V. ARCHITECTURE OF INTERNET OF ENERGY

IoE is responsible for energy exchange among a variety of loads and sources which includes distributed energy storage, plug-in electric vehicles, energy sources, prosumers, etc. With the help of the internet, energy network is being monitored. The general principle being followed here is the energy being directed from source(s) to load(s) which is similar to routing of information on internet[1]. Figure 3 gives a view idea of Architecture of IoE.

## VI. IOE and the POWER SYSTEMS

With the help of IoE technologies, producers and manufacturers can reduce inefficiencies in an already existing infrastructure. With updates in the electrical architecture, there is an ease in the flow of energy that can result in maximizing its potential.

### A. *IoE by the supply-side*

1) ***Renewable energy:*** The excessive use of fossil fuels has resulted in the emission of large amounts of pollutants causing harm to both the environment and people. The rapid degradation of fossil fuels means that we need to make haste and find an alternative for our energy needs. Solar and Wind for power generation is the need of the hour. But large scale utilization of RES with the existing technologies is difficult thus resulting in IoE and RES being inseparable. The main advantage of using IoE is it allows central monitoring of all the assets.
2) ***Energy storage technologies:*** Energy storage technologies play a major role in making the grid flexible and ensuring a reliable operation. The energy storage technologies are mainly used for three main operations: bulk-energy time-shifting, frequency regulation in small-scale, frequency stability in large-scale, and power reliability.
3) ***Thermal power plants:*** The functioning of Thermal power plants give resilience and reliability to power systems. The implementation of an Internet-based controlling system (IoT) on various elements of a conventional thermal power

  

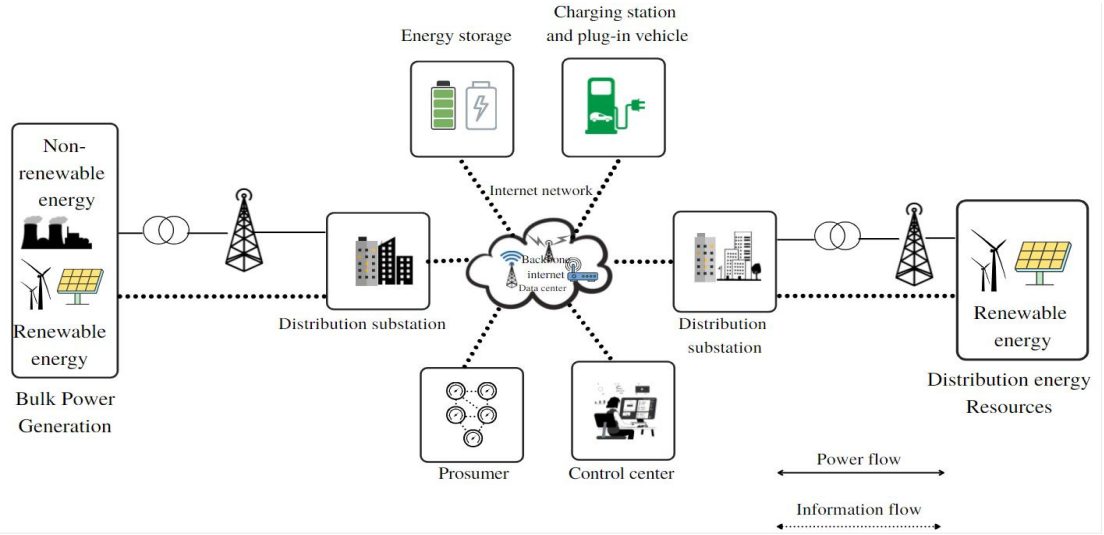


*Fig. 3 Architecture of IoE*

plant can result in efficient improvement of the existing grid system.

**4)** ***Power system operation and protection:*** In the future of power grid system, IoE will play an important role in the integration of various power sources that might cause a threat to grid security. It provides the grid operator a better monitor and control of the grid, making the system more reliable and secure[6].

**B)** ***IoE by the Demand-side***

**1)** ***Microgrids:*** With the integration of IoE with Microgrids, the data that corresponds to the micro sources can be shared with the main grid's operator. This practice can result in a more comprehensive probabilistic scheduling which would benefit the power system. In addition to that, it also provides mitigation from risk and better management of the whole system.

**2)** ***Demand response:*** The use of the internet has made the DR attractive and user friendly. This has allowed the user to manage the consumption with the help of tracking the information for its internal loads. It has also allowed the remote control of equipments using IoE.

**3)** ***Plug-in electric vehicle integration:*** With the ever-growing trends in electric vehicles, it is expected that EVs are going to be a major wave in the transport system . The rise in the use of EVs will have a significant effect on the grid systems. There are certain kinds of EVs that are capable of exchanging power with the grid. This is known as V2G (Vehicle to grid) capability. In case of emergency, it allows an operator to stop charging of V2Gs or promote V2Gs for power delivery.

**4)** ***Residential consumption management:*** The end-users mainly consist of residents, and they tend to use power at off-peak periods. IoE infrastructure is capable of having a robust EMS with the help of smart homes and buildings. It comes with a prerequisite that the users must be equipped with AMIs[6].

## VII. ISSUES AND CHALLENGES IN IoE

### *A. Technical challenges:*

The construction of IoE is an intricate task. It includes the integration and interaction of various power sources, energy storage units, transmission regulations, converters, sensors and regulators. Decentralized controlling and monitoring of energy management adds more complexity to the system..

### *B. Privacy and security issues:*

IoE uses the internet for its operation thus becoming a vulnerable target for attack. In recent years there have been some serious cyberattacks, resulting in huge financial and confidentiality losses.

  

### *C. Business model challenge:*

All the existing business models are based on existing centralized grid systems. The implementation of IoE requires a business model which allows the decentralization of the market and allows for peer-to-peer-based energy exchange[1].

### *D. Data management:*

In IoE, mammoth quantity of data is generated. For data storage cloud services are required which are accessed and managed by third-party auditors. Trusting these auditors can lead to threat of individual personal information and violate the privacy of the users. Also the use of centralized control can lead to a single point of failure. Hence IoE requires proper evaluation and authentication of data.

### *E. P2P energy trading:*

It plays an important role in IoE. This process includes trading among power grids, renewable energy sources, smart homes and buildings, electric vehicles, etc. Although it is a key element for the success of IoE, the process may face some security and privacy issues[7].

## VIII. CONCLUSION

In the recent years a lot of revolutionary advancements have been achieved in the field of Information and Communication Technologies. Now the power systems are moving more towards a carbon-free method of power generation and the RES is getting wide spread recognition and implementation. This scenario has resulted in the emergence of a new concept, Internet of Energy(IoE), which in other words is the application of IoT in Power Systems[6].In the coming days, controlling and monitoring of power systems will depend on the internet leading to IoE[1].

In this paper, an in-depth discussion on the supply-side and demand-side of IoE has been provided. Key technologies that play a major role in IoE have been highlighted. Basic architecture and issues faced by IoE have also been provided.

The integration of Internet technologies in power systems can bring an immense amount of benefits for all the sectors. It can also guarantee the development of the energy sector in terms of social, economic, and environmental sustainability[6].

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