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Renewable Energy Sources Based Grid Integration: An Introspective Analysis

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To foster sustainable, low-emission development, renewable energy is the best solution for electricity supply, however solar and wind energy are more variable and uncertain than conventional sources. The demand of electricity can be compensated by involving these into power system planning and operations. Grid integration is the efficient ways to deliver variable renewable energy to the grid. Renewable energy is increasing in popularity worldwide. Since renewable energy is intermittent, the integration of renewable energy resources into the power grid infrastructure is a challenging task because the requirements for a power-electronic interface are not just the renewable energy source itself but also its effect on the operation of the power structure, particularly if an intermittent power source is used. This paper discusses the definition, challenges and possible solutions of Renewable Energy Sources (RES) based network incorporation into the energy system. The history of RES with its environmental implications and implementation is also being addressed with a study for primary use of RES and of non- RES in India.

Keywords: Renewable energy sources, power grid, wind technology, grid integration.

1 INTRODUCTION

Many countries have been driven to make numerous forecasts of large-scale integration of renewable power sources in their grids because of the growing concern for ozone layer depletion and climate variation [1-2]. ZQAS it is well

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established, the fossil energy resources of the earth such as coal, gas and petroleum are limited. Through every day, global use of these commodities rises. Renewable energy would have to meet rising energy needs in this dreadful situation. Renewable energy is clean because it has no emission or unwanted environmental damage by-products. Renewable energy is used primarily in the conversion of electricity. After several countries began to look solutions for using clean energy and renewable energy efficiently; high oil prices caused an energy crisis in 1973 [3]. The solution to this severe environmental issue is the use of safe, long-term environmentally friendly renewable energy. Therefore, many countries have already launched research into developing new technology to use renewable, clean, wind, solar, geothermal, biomass, and tidal energy sources. Wind energy is one of the most effective sources of energy for producing electricity that satisfies the global energy needs[4].

Technologies to reduce greenhouse gas emissions and global warming are clearly needed. The electricity generation of fossil fuels is an important contributor to greenhouse gases, but it cannot easily change the current infrastructure because the investment and intellectual efforts in the last 100 years are responsible. Despite the accessibility of renewable energy resources, it is not clear how technological obstacles can be overcome in their widening adoption, since such infrastructure, human behaviour and behaviours may require radically different approaches. The transformative path that is required in partnership with existing infrastructure promotes the production of renewable energy resources. The most promising path to remote electricity generation and/or elimination of fossil-fuel power dependence is the idea of the integrated power integrated network for renewable energy[5]. Because of decline in fossil fuels and rise in related ecological problems, the use of (RES) is growing considerably. Since most energy sources of renewable energy are irregular in nature, incorporation of RES in the power grid system is therefore challenging[6]. Such developments have contributed too many problems both technologically and non-technically.

This paper isfocused on(a) renewable resources;(b) power grid along with its transformation such as conventional, smart and intelligent; (c)grid integration especially RES based along with technical and non-technical issues and challenges and their possible solutions. Alsogrid integration statics in India are analysed.

2 RENEWABLE ENERGY SOURCES

Electricity industry in all respects, not only physically, but also socially, economically, commercially, and institutionally, has been changed radically. In many of the main concepts that have led electric power programs over the last few years [7-10], electric power utilities metcertain of the biggest development, processes and maintenance problems that they have ever encountered. A variety of new market and business models are being developed along with new technology available to a wider range of energy distribution providers, energy traders and the other players [11-15]. An integral part of this transformation is renewable energy. In the last 20 years, 145 countries have enacted renewable funding programs; production costs have decreased significantly, and clean energy expenditure has risen to $270 billion annually[16].

Fuels are used as carbon sources. Fuel is combusted into equipment to achieve acceleration (for example in a car) or heat (for example in a house heating system). When fuels are used to produce energy, heat or motion rotates and produces power for regular use in households and industries. Carbon sources may be categorized as non-renewable and renewable energy sources. The Planet lacks and will deplete non-renewable energy such as fossil fuels and radioactive energy. The most used form of energy in modern times was such commodities. Sources that regenerate as easily, as consumed, are continually available, such as wind, water, solar, and geothermal electricity. Others are refilled per growing season such as bio fuels from food crops and other plants. Renewable sources became more common in the early part of the 21st century with non-renewable sources beginning to decline.

3 POWER GRID

The power grid was built over a century ago into one of the most intricate networks in the history of man. As demand is mounting, the existing energy grids are rising into a huge system of numerous integrated national networks, owned and regulated at all heights and hierarchies by Power Company. The cross-area transmission work and more time contribute to weak co-ordination and inefficient power supply because of the dense focus, management and service of numerous power companies. There are still some problems ahead for the modern power grid in today's world. Different types of emerging technology such as the electric charging systems, the deployment of solar energy, smart meters, etc., are being implemented in the energy market with growing demand and usage groups, which all work against the complexity of modern electricity supply. In order for utilities to efficiently produce power, quicker power regeneration, and more stable costs, among others, increasing day by day reliance on electricity and the growing need for power quality.

3.1 Conventional Power Grid

The traditional power grid is made of separate processes such as energy generation, transmission and distribution. Generation involves electricity generation from renewable sources (such as wind and water) and non-renewable energy sources (carbon).

TABLE 1
Energy resources classification

Category	Properties	Type	
		Conventional	*Non- conventional*
Based on traditional use	Example	Coal, Wood, etc.	Wind energy, Sun energy, Nuclear energy, etc.
		Renewable (RES)	*Non-Renewable (Non-RES)*
Based on long-term availability	Technology /Type	Solar energy, Wind power, Geothermal energy, Hydropower, Bio energy	Fossil fuels, Coal, Oil, Natural Gas Nuclear energy
	Conventional use	Power generation, Heating, Transportation, Off-grid energy services, etc	Transportation, Household use, Power generation, Mechanical applications, etc.
	Recent application	Photovoltaic (PV), Heat generation, Electric generator, Mechanical applications, Cooking, etc.	Cooking and another household application, Power generation, Heating, Mechanical applications, etc.

The power grid is a network of transmission poles, transformers and related devices used in the regional delivery of resources. In other words, it can be described as an interconnected electricity supply network for suppliers. It consists of power generation plants, high-voltage transmission lines that convey electricity from remote sources to demand centres, and distribution lines that link consumers.

Primary task performed in conventional power grid is consisting of three major fragments:

- Electric power plant generation.
- Electric power transmission.
- Electric power distribution

3.2 Smart Grid

Smart Grid is a computer-based monitoring and management system used by the modern electric grid. The key goal of the plan is to boost transmission and delivery network stability, safety, productivity, and economics. In order to control the output, transmission and delivery of power[17], Smart Grid employs analog and digital information.

The 'grid' refers to the systems which transmit electricity to its consumers from the plant it is manufactured. 'Smart grid' means the grid computerization, i.e. The Smart Grid is the infrastructure of automation that helps the utilities, in collaboration with customers, to change and monitor all appliances from a central location. The transition to a Smart Grid represents a shift in the broader market model and partnership between all stakeholders, energy providers, regulatory authorities and customers. It permits two-way connectivity between utilities and companies, the key extension of information from the traditional grid to the intelligent system. With intelligent electronic equipment (SMEs) which can provide more accurate information and bilateral connectivity, Smart Grid will improve and broaden its current functionality.

Smart Grid's two-way digital communication and plug and play technologies help reduce human interventions, leading to significant power savings. The entire process will be controlled by an integrated distributed energy network of Smart Grid. From the smart grid debate, it is known as the intelligent grid[18]:

Further convergence, monitoring, optimization and control of networks have been acknowledged to support achieve integrated connectivity, efficiency, self-healing, and reliability of the Smart Grid. In Fig.01, the main functional elements to be included in the Smart Grid architecture are outlined. Accessibility and sensor quality measurements are a feature of power system control. Poor or weak communications, bad communication, sensor failure can, however, lead to controllers of power system failure and thus to extreme possibilities.

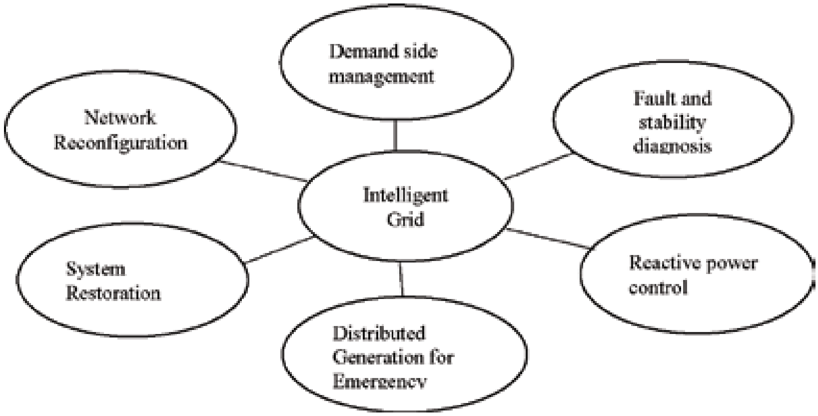

FIGURE 1
Smart Grid intelligent automation function.

In order to increase its security and reliability, default tolerant technology will be required in a smart grid and advanced control methods will carry out real-time predictions using computer intelligence methods [19]. The following guidelines for transformation may be drawn up after review of the function and possibilities of smart grids [20].

- Self-healing and intelligent surveillance:Smart Grid guarantees the consistent and stable delivery of electricity.
- Reliable data transfer: More quick energy restoration after power disruptions
- Better power disruption fault tolerance: The power disturbance that may cause harm is minimized by voltage and overvoltage.
- Reduction in service operations and management costs and in the end lower energy costs for consumers: yes, the cost of implementing the smart grid is very high, but this is more stable and reliable, which in turn would minimize the maintenance costs for customers.
- Reduced peak demand, which would also lead to lower power rates: because consumers are allowed to limit their peak loads by smart pricing, this reduces peak demand.
- Enhanced incorporation of massive energy systems: the use of the energy generation by renewable energy resources allows the transition of the power system with the use of intelligent grid technologies. The network will be built to promote a renewable technology future.
- Greater deployment of power generating technologies, including green energy projects, for customers: it helps to reduce the pressure on grids.

4 RELATED WORK OF GRID INTEGRATION BASED ON (RES)

The growing understanding of environmental issues has led to focused initiatives on the integration of green energy sources. Because of global power generation remains dependent on fossil fuels, the purpose of the project is to satisfy world demand for local, renewable energy resources, like solar photovoltaics, for both off-grid and grid groups [21-24]. Subsidisations and lucrative feed-in tariffs (FiT) are implemented in numerousdeveloped nations which have led to wind turbines or solar photovoltaic (PV) large-scale grid interconnections[25-27]. Simultaneously, a great deal of study was undertaken to integrate this renewable technology into the network and to develop intelligent grids and techniques for energy management in secure grids [27-29]. A smart grid is usually an extension to a current power network, providing coordination and monitoring between the customer and the utility in real time. It helps producers and customers to maximize power demand depending on the system's market expectations and environmental and technological chal-

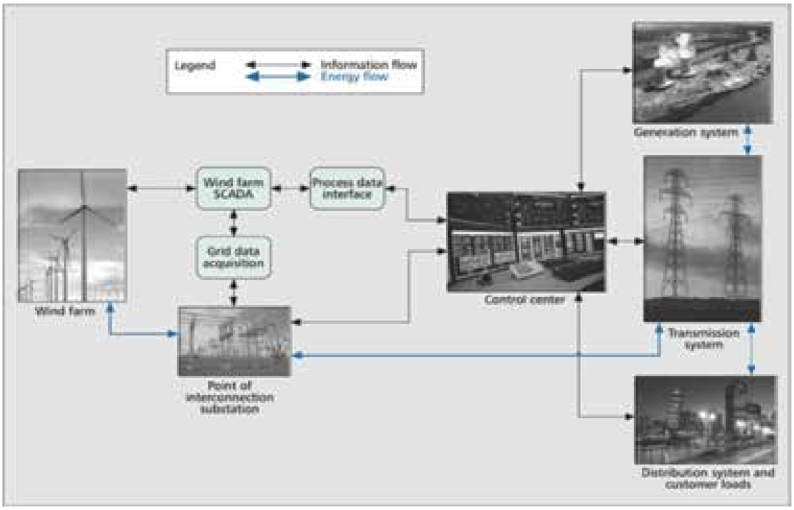

FIGURE 2
Example of Grid integration in wind farm [31].

lenges. The intelligent grid uses IT automations to communicate the energyre-quests of the load level to the making station through either electricity line connection or separate wired / wireless technology [30]. Fig.02 shows a high-level scheme of grid integration of wind farm.

Effective management of high demand is a fundamental motivation for building a smart grid. The main necessity is the existence of a reliable grid that can continuously supply electricity to the loads. This is not the case in Asian, African and Latin American developing countries, where demand for electricity has risen sharply, in order to maintain economic growth[32]. These countries often rely largely on fossil fuels to meet their energy requirements. However, the electricity needs of consumers in these countries are not fully met, given the different factors such as rapid economic growth, fluctuating crude oil prices, global meteorological impacts, political uncertainty, and so on[33]. The disparity between energy demand and supply is called the' electricity shortfall.

The power shortage is not constant and over time fluctuates. For example, seasonal variations affect it and are generally higher in summers as demand rises mostly because of air conditioning loads. This imbalance between large demand and supply is called a high energy deficit. Many countries in South Asia (where 25 percent of the world's population lives) are not self-sufficient to meet their peak demand for electricity and this peak electricity shortage could be very important. For instance, in Nepal the recording peak deficit stands at~53 percent, in Pakistan~32 percent and in Bangladesh and India~10 percent[34-35]. The grid integration challenge encompasses many elements. Main among them is the idea of resilience of a power system , in terms of integrating intermittent wind and solar energy in particular, and more broadly in terms of how all elements of a power system, on both supply and demand sides, should operate together to ensure reliability ("keep the lights on") while minimizing cost. Another key element is the architecture of electricity markets themselves, in ways that facilitate grid integration, thus maintaining the most economically efficient service. A further aspect is the preparation and upgrading of transmission grids to balance geographical patterns of renewable energy resources and power demand. One final function is the redesign of delivery networks to enable network convergence and versatility in their planning and operation. Many of these elements are discussed in this article. The field of facets of green energy incorporation into the energy market is wide-ranging and increasingly increasing. In the last few years alarmingly, an immense amount has been written. Much literature is technological and designed, but the transition to higher renewable energy shares is primarily concerned with policy, economies, structures, legislation, economic and business models.

Renewable sources of energy are sporadic in nature and incorporating renewable energy supplies into the electricity grid is also a daunting challenge. The incorporation of different renewable sources of energy in particular wind energy model and solar PV is a major challenge and issue. Furthermore, these problems are generally graded and defined as technological and non-technical.

4.1 Technical Issues and challenges

- Power fluctuation
  - Seasonal or long-time power fluctuations
  - Short time power fluctuations
- Power quality
  - Voltage and Frequency fluctuation
  - Harmonic
- Protection issues
- Storage
- Islanding
- Optimal settlement of RES

4.2 Non- Technical Issues

- Minimumaccessibility of transmission link to accommodate RES
- Lack of technical skilled manpower
- RES automations are excepted from the competition by providing them precedence to transmit which dissuade the installation of another power plant for standby perseverance.

4.3 Possible Solutions

The transition to greener energy resources has been driven by RES like wind, solar, thermal etc. New approaches for process and controlling of the electricity grid are needed to support or even increase the energy supply reliability and superiority due to the increasing number of RES and distributed generators. In the light of the above, researchers have proposed some of the possible solutions.

- Electronic energy technology plays an important role in distributing and integration RES in the grid and is widely used and rapidly expanded with the more integrated grid-based applications. Power electronics has evolved rapidly over the last few years, primarily because of two factors. The first is to develop fast semiconductor switches that can switch fast and handle high power. The second factor is that computer controllers can implement advanced and complex control algorithms in real time. Together, these influences led to the development of economical and versatile converters.
- RES intermittent power generation can be regulated by electricity generation from the distribution of RES in small units to larger geographical areas rather than from large units concentrating in a single area. For example, the power output of the big solar photovoltaic system with a rating of tens of megawatts can be modified by the local phenomenon in five to ten minutes, as cloud transitions, etc. Due to local problems only small unit power may impact not the overall output power, the fluctuation in total output may be decreased.
- If irrigation requires for powered and load is supplied by conventional grid at night or off-peak load time. Instead of storing power to use later, which increases cost of the overall system, power generated by solar PV during day time can allows us to use that power for irrigation.

5 GRID INTEGRATION IN INDIA

The country's increasing energy deficit and intensified focus on developing renewable energy sources, especially nuclear, solar and wind have largely influenced India's energy policy [36]. In 2017, India obtained 63% total energy autonomy [37-38]. India's primary power consumption fell 2.3% in 2019, making it the third highest in the world behind China and the United States with a 5.8% share. India energy statics in 2019 is shown in Fig.03 [39].

5.1 Power Grid in India

India has a very strong power market. It is split into five different parts. They are the North, the West, the East, the North-East and the South. These areas are well-connected between north, west, east, and north-east. It aims to

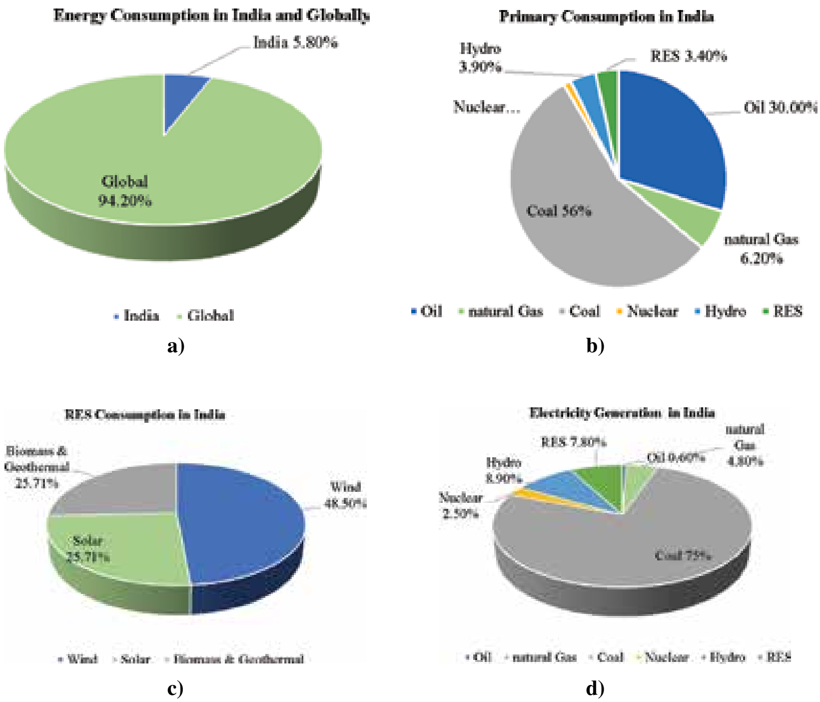

FIGURE 3
India energy statics in 2019; a) Energy consumption in India and global; b) Primary consumption in India; c) RES consumption in India; d) Electricity generation in India [39].

enhance the transmission network so that inter-State and inter-regional connections can be established, and that national grid capacity can be increased on time so as to ensure the best possible use of unequal power delivery

India was the third-largest electricity maker before last year. The estimates for the products used are biomass (59%), hydro (17%), renewables (12%) and natural gasses (9%), nuclear gasses (2%) and oil (1%), according to last year's statistical results. A "Natural Energy Corridor" will be built by the power grid for the incorporation of more renewable energies to reduce the reliance on coal and oil.

5.2 Smart Grid

The power grid of India is one of the world's highest and most complicated grids. Therefore, India has opted to introduce Smart Grid. No specified smart grid standard and guidelines existed in India until the 1990s. But the Indian power market is slowly developing smart grid policies and regulatory structures. The aim is to foster smart grid infrastructure creation and deployment to encourage transitions in terms of stability, health, quality and cost efficiency[40].

In many parts of India, good solar irradiation conditions will make a major contribution to meet the electricity demand of the country by mixing photovoltaic (PV) and concentrated solar power (CSP) capacity. Because of the size of the Indian market, an Indian equipment industry for solar PV and CSP and for T&D equipment should be developed. The government also provides support to produce solar energy in the form of incentives for different solar applications, and it has set a target to contribute 7 % of the total power generation in India by 2022. The capacity for network connectivity for wind power generation in all countries with Himalayan / N-E and A&N islands, measured at 49,130 MW with two% of land available in possible areas. India ranks fifth in the world behind USA, Germany, China and Spain in grid wind power systems.

India finds Smart Grid to be a full electricity network, combined with electricity and ICT. The Smart Grid Initiatives have been developed by the Ministry of Power (MoP) to build the Smart Grid in the process. [41] In order to aid Mop in planning a roadmap for creating smart grid in India, MoP has set up India Smart Grid Forum (ISGF) and India Smart Grid Task Force (ISGTF). In the pilot programs, the core functionalities are:

- Generation of delivery
- Enhancing service output
- Automated Metering Infrastructure(AMI) deployment
- Monitoring of the correct loss
- Clean energy incorporation
- Micro grids are installed
- Effective Peak Load Protection

6 CONCLUSION

The incorporation of renewable energy supplies in the grid is powered by the electronic energy system. A power electronic interface for the highest expected turbine rating should be established, the energy conversion, transmission and reactive power control optimized, distortion minimised, high efficiency achieved over a wide power range at low cost, and the failure of a subsystem part with high reliability and tolerance should be achieved. In this paper, the common and future trends for renewable energy systems have been described with issues, challenges and feasible solution in the aspect of grid integration and this paper analysed grids and recent energy consumption in India. In future, this introspective study can be extended to Artificial Intelligence (AI) based grid integration for RES sources to achieve dynamic scalability and managing damping factor.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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