Analysis of distributed smart grid system on the national grids

M. Mythreyee, Nalini Anandan
Department of Electrical and Electronics Engineering, Dr. M.G.R. Educational and Research Institute, Chennai, India

Article Info

Article history:

Received Mar 27, 2023
Revised Dec 8, 2023
Accepted Mar 20, 2024

Keywords:

National grid
Power sectors
Renewable energy sources
Smart grid
Smart meters

ABSTRACT

In the power industry, advanced techniques have furthered the development of the smart grid's power system and management. The world's third-largest country is India, which has a producer and consumer of electricity, is struggling with different power-related problems, as well as distribution losses, transmission, environmental concerns, and electricity theft. The energy sector is investigating innovative technologies to enhance grid efficiency, security, and sustainability to address power-related issues. Recently, smart grid technology has ascribed significance to the energy scenario; the term "smart grid" relates to electric electricity. The study aims to thoroughly evaluate how smart grid technologies might improve the reliability and efficiency of India's electrical system. This article examines the impact of smart grid technologies on national grids and makes some proposals to authorities for switching their traditional grid system to a smart grid system. The results indicate the yearly wind profile, comparative analysis of energy consumption, and cost analysis of the system. Smart grid integration is strengthened by the useful insights provided by the annual wind profile study, which reveals the region's renewable energy potential. Analysis of costs and energy consumption patterns show that switching to a smart grid system is financially feasible in the long term, and studies of impacts on utilization of resources show that it is beneficial.

Corresponding Author:

M. Mythreyee
Department of Electrical and Electronics Engineering, Dr. M.G.R. Educational and Research Institute
Maduravoyal, Chennai-600095, Tamilnadu, India
Email: mythreyee.phd@gmail.com

1. INTRODUCTION

One type of advanced technology that enables bidirectional is a smart grid system. However, it contains various other elements, including availability, efficacy, precision, controllability, adaptability, interoperability, sustainability measurability, excellence, dependability, sustainability, stability, scalability, and security. The Indian power system is organized into five regional grids for planning and operational purposes. The unification of regional grids, also hence the development of the national grid, was conceived in the early 1990s. Regional grid integration commenced with asynchronous high-voltage direct current (HVDC) back-to-back inter-regional lines that allowed for the restricted exchange of regulated power. It advanced to standard performance synchronous wires connecting the areas. The earliest inter-regional links were designed to ease the transfer of operational excess across regions. However, as the planning concept evolved from regional self-sufficiency to an inter-regional linkage, national foundation were planned in conjunction with generating projects that had benefited from beyond regional lines. This research aims to identify aspects that could act as drivers for the development of India's smart grid. The essential components of smart electricity networks are smart meters.

Meters used in combination with a management system may also monitor and control devices and appliances as needed by users. Survey questionnaires, interviews, and workshops were performed with notable academicians, researchers, and industry specialists working in the electricity sector to analyze the different components of the smart grid. One drawback of smart grid systems is their level of integration methods. To solve this, a strong smart grid network must be integrated, which in turn demands cooperation between renewable and non-renewable energy sources. Because of variations in technical design, integrating such many capabilities can be difficult. Figure 1 examines the impact of smart grid technologies on national grids and makes some proposals to authorities for switching their traditional grid system to a smart grid system. This work analyzes the implemented distributed network using renewable energy resources (RES) and national grids of India which consists of five regional grids like northern grid, southern grid, western grid, eastern grid, and northeastern grid. Finally, the comparative analysis of the implemented smart grid with the power grid is done.

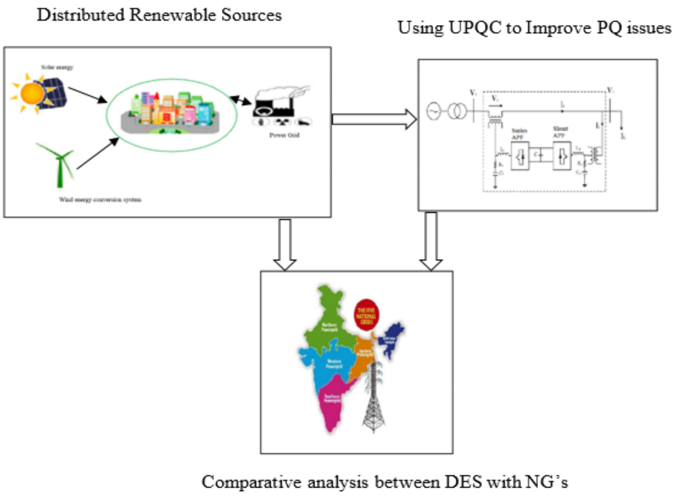

Figure 1. Schematic diagram of the research work

The energy operations have been encouraged to generate electricity on a large scale by alternative RES, such as solar and wind power, because of their many advantages, including the fact that they are pollution-free, accessible worldwide, and cost-free [1]. Thus, for smart city growth to be sustainable in the long run, grid incorporation of renewable energy sources is essential, taking into account all technical implications [2]. Connected energy consumers that exchange real-time data with a utility grid make form a power distribution network [3]. The process of solar energy conversion from light into electricity is temperature and irradiance dependent throughout the photovoltaic (PV) panel. A direct current (DC) electric source is created when the panel collects the photons [4]. Environmental variables and solar irradiation vary drastically over time, affecting the output current and voltage of the PV. One method of controlling PV modules is maximum power point tracking (MPPT), which tries to get the most power out of them by keeping their operational point feature at the highest possible output power [5]. To fix many problems with the perturb and observe (P&O) algorithm, this method employs other algorithms that utilize IC. In a situation where there are large fluctuations in radiation, IC aims to boost energy generation and monitor timings [6].

The wind power system is able to convert the energy that the wind blows into electricity. As the wind speed varies, so does the power it generates [7]. Bidirectional power flow, DC fault blocking, and voltage step-up and step-down levels are essential properties of a DC-DC converter [8], which is a crucial component in DC grid connection. In order to enhance the output voltage from the input voltage, the article implements the boost converter. Various control techniques are identified in which the PI controller is simple and efficient. This control technique is applied to generate pulse signals for the converter switches. The DC-DC boost converter is controlled using the PI-based MPPT approach [9] in the suggested renewable systems. A wide range of pulse width modulation (PWM) control approaches have been created in the last twenty years. Complex real-world problems in the field of engineering, management, economics, and politics have lately been tackled using metaheuristic algorithms. Genetic algorithm (GA) is a well-established metaheuristic algorithm that draws inspiration from the biological evolution process [10]. GA's primary components are the representation of chromosomes, fitness selection, and operators. The Chromosomes, which are also known as solution space points, are managed by genetic operators via regular population changes. A value received by the fitness function reaches every chromosome in the population. The biological basis for operators such as selection, mutation, and crossover is well-established [11]. Wind and solar energy are inherently unpredictable, and variable renewables provide electricity with unexpected rises and decreases hence storage devices are essential. A complete control system, the energy management system (EMS) [12] manages the efficient and flexible flow of energy between power sources, loads, and the utility grid. Compared to a standard energy meter, a smart meter [13] is an enhanced energy meter that detects a consumer's energy use and gives additional data to the utility provider. Securely transmitting data such as voltage, current, phase angle, and frequency, smart meters are able to read and display energy use in real-time [14]. The smart grid upgrades the current traditional grid so that it can communicate and collaborate with other systems. Intelligent grid connections between generators, users, and consumers may provide safe, efficient, and inexpensive power [15]. In this paper, the implementation of the proposed smart grid system is presented by hybrid renewable resources and a battery system in a distributed network. Efficient control techniques are applied to the DC-DC converters and inverters to provide better output response. Power quality monitoring (PQM) offers forecasted insights into power quality fluctuations via examining past data and patterns that enhances grid stability as well as allocation of resources [16], [17].

2. POWER SCENARIO IN INDIA

India is one of the world's fastest expanding economies. Globalization has beneficial of economy for every industry, involving the electrical sector. To meet the increased energy difficulties, the government implemented several organizational and operating modifications to the electricity industry [18]. The changes aimed to increase competition in various sectors, establish an independent regulatory commission, and establish a proper finance structure. Since independence, India's electricity industry has experienced significant improvement. The installed capacity in India was from 1,362 MW in 1947 to 399,497 MW in 2022, as shown in Figure 2.

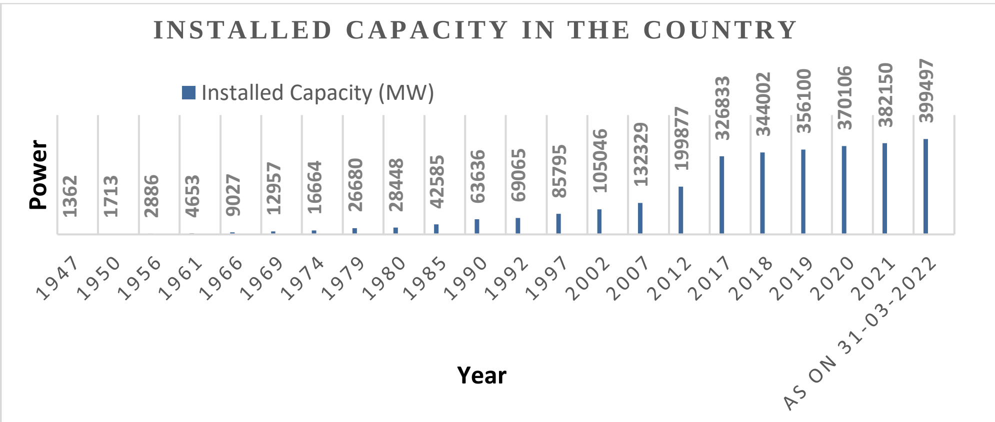

Figure 2. Growth of installed capacity in the country

The transmission network has evolved from a regional system focused on urban and industrial sectors to a national grid. Though, the power demand has always exceeded the supply. The significance of electricity as a major engine of growth is universally acknowledged. The Indian government has actively participated in the development of the power system through the establishment of several organizations such as National Hydro Electric Power Corporation (NHPC), National Thermal Power Corporation (NTPC), Power Grid Corporation Limited (PGCL), and State Electricity Boards (SEB).

2.1. Demand

2.1.1. Demand trend

In 2019-2020, service electricity accessibility was 1,284.44 billion KWh, a 6.5 billion kWh (0.5%) shortfall relative to requirements. The peak load met was 182,533 MW, which was 1,229 MW (0.6%) less than required. The Central Electricity Authority of India forecasted an excess energy is 2.7% and an excess peak is 9.1% for 2020-2021 in 2020 load generation balance report. Through regional transmission networks, power might be made available to just a few states that are expected to face shortages from those with surpluses. Generation of electricity in India has been less of a concern than power distribution since the calendar year 2015.

2.1.2. Demand drivers

Approximately 0.07% of Indian citizens (0.2 million) do not have access to electricity. The International Energy Agency estimates that India would add 600 GW to 1,200 GW of additional power generation capacity by 2050. Other drivers of India's electrical industry include the country's rapidly expanding economy, higher exports, improved infrastructure, and rising household incomes. So, per capita, electrical consumption is increasing [13], [19] as shown in Figure 3.

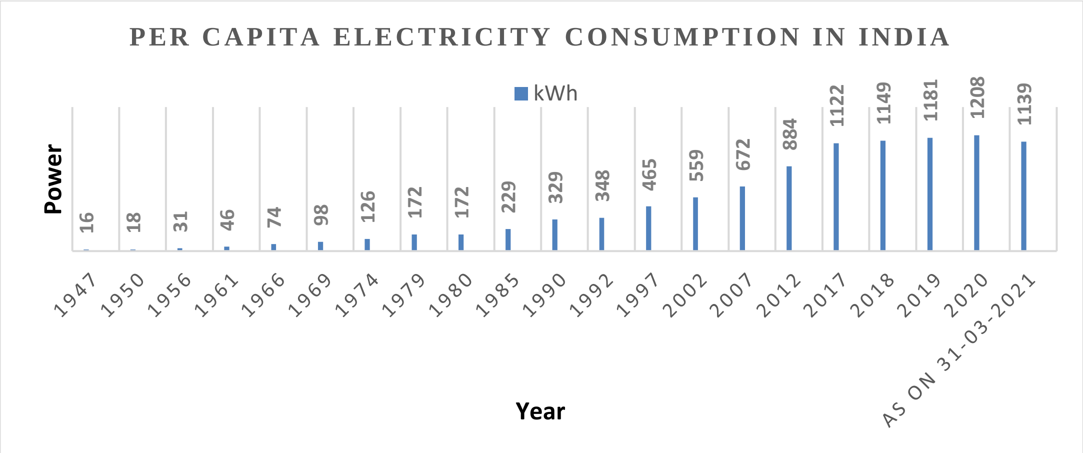

Figure 3. Per capita electricity consumption in India

Per capita consumption is each individual's annual use of goods and services, calculated by dividing the whole population's usage of goods and services. Figure 4 displays a countrywide grid's yearly monthly load utilization. It represents the maximum monthly load consumption. Because the energy value is higher between November and February, load usage rises during the winter season. In example, the highest load consumption of the year is 11,300 MW in December. This non-linearity in load demand may be accommodated by the smart grid technology.

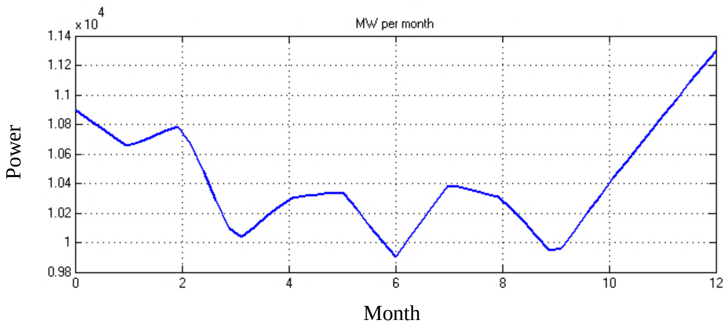

Figure 4. National grid’s maximum load consumption per month in the year 2020

2.2. Future projection

The aim of this work is to analyze a system’s efficiency and consistency of the grid by automatically reacting to interruptions of system. Grid power demand is expected to increase to 2,057-2,341 TWh by 2030, with coal contributing 1,090-1,779 TWh a considerable range depending on non-fossil penetration. Coal will continue to be a significant source, accounting for over half of the total generation. Net captive generation is expected to increase to 318-361 TWh, with coal accounting for two-thirds, down from more than 80% in 2017. Across scenarios, 260 GW of grid-based coal capacity suffices, with minor tweaks needed along the extreme situations to maintain under 60-75% PLF. According to the estimate, peak coal is unlikely to occur by 2030 unless 500 GW of solar and wind capacity are implemented with appropriate storage and alternatives.

3. RENEWABLE ENERGY RESOURCES DEVELOPMENT IN INDIA

India's power industry is among the most diversified in the world. Power generation sources range from commercial sources like hydro, coal, natural gas, lignite, nuclear power, and oil to viable non-conventional sources including wind, solar, agricultural, and household waste. The country's electricity demand has been fast expanding and is expected to develop more in the future years. The portfolio of installed generating capacity in India is growing in accordance with international trends. Renewable energy generation (RE) accounted for approximately 12% of total installed capacity, or 29.5 GW, in 2014. Figure 5 displays the RES development in India.

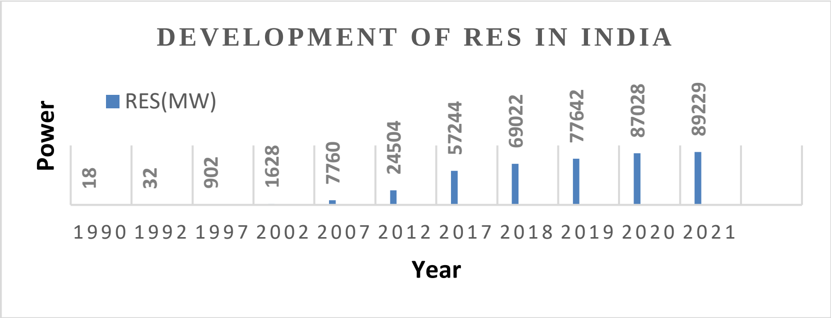

Figure 5. RES development in India

The "Green Energy Corridors" paper, published as part of India's twelfth Five Year Strategy, outlines a detailed grand plan for grid integration of large-scale renewable power increase. The master plan addresses intra- and inter-state transmission systems, as well as grid interconnection mitigation measures for variable and intermittent renewable energy sources, such as adaptable generation, renewable forecasting, the establishment of a Renewable Energy Management Center (REMC), and energy storage facilities, among other things. It also includes a long-term plan for large-scale renewable energy generation between 2030 and 2050.

3.1. Development of smart grid in India

The government of India approved smart grid pilot projects, which have the functionalities covered these projects are distributed generation (DG), outage management system (OMS), PQM, OMS, and advanced metering infrastructure (AMI). All 14 (states) projects involve the installation of Smart Meters to reduce distribution losses and increase reliability. The smart grid pilot projects in India are shown in Figure 6.

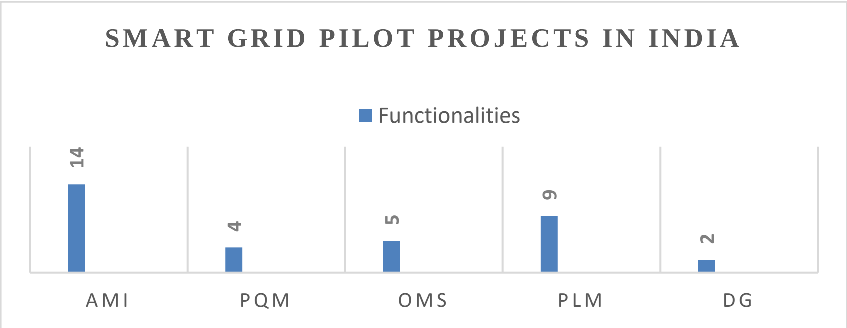

Figure 6. Smart grids pilot projects in India

3.2. Initiative power grid on smart grid

Power grid has taken the lead in adopting smart grid technologies throughout the entire value chain of power supply. A pilot smart grid is being established in the "distribution network" sector and is implemented through open cooperation with manufacturers. This article gives an example of smart grid implementation from our previous work. Various smart grid features have already been introduced as part of this work and are being gradually scaled up. Smart meters are currently legalized at the consumer level. The daily average load and temperature profile as measured by a smart meter deployed in a configured smart grid is illustrated in Figure 7.

This demonstrates the daily energy produced in the implemented smart grid. The upper wave and lower waveforms show that wind and solar energy sources are produced in the smart grid [20], [21].

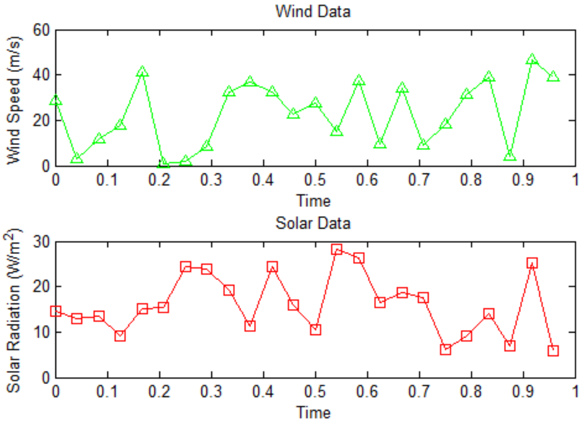

Figure 7. Daily average loading and temperature monitor

The graphs in Figures 8 and 9 illustrate the yearly profile of solar irradiance and wind speed (from January to December). The radiation profile predicts that the normal peak power production will occur between May and August. Wind energy output will be at its peak between July and October. The average daily sun global radiation level is 4.49 kWh/m^2 on an annual basis. At a height of 10 metres, the monthly average wind speed ranges from 1.86 to 6.41 m/s.

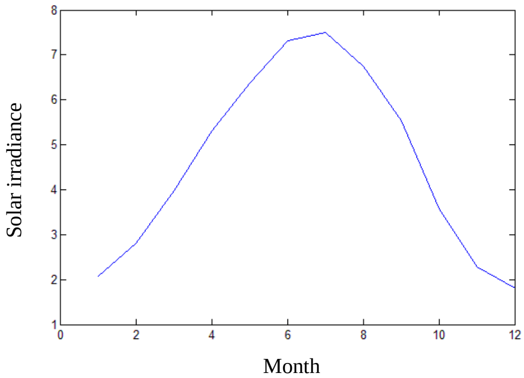

Figure 8. Yearly radiation profile in Kwh/m^2

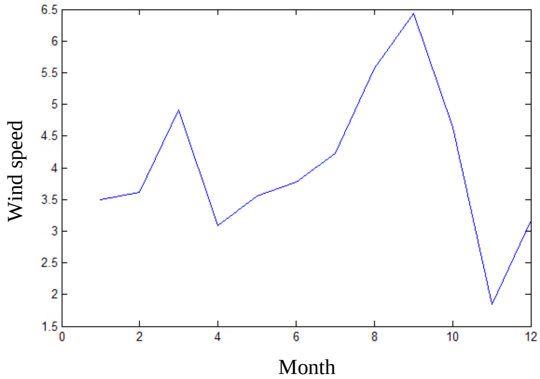

Figure 9. Yearly wind speed profile in m/s

Figure 10 displays a 6 kVAR power factor correction (PFC) solution for a smart grid deployment to assure quality supply to customers. As part of the power quality enhancement plan, the FACTS device includes automated PFC. Active power filters based on FACTS have also been used in reactive power compensation and smooth voltage. Table 1 illustrates typical monthly energy usage as well as hybrid wind and solar power generation on these users' properties with rooftop solar generating.

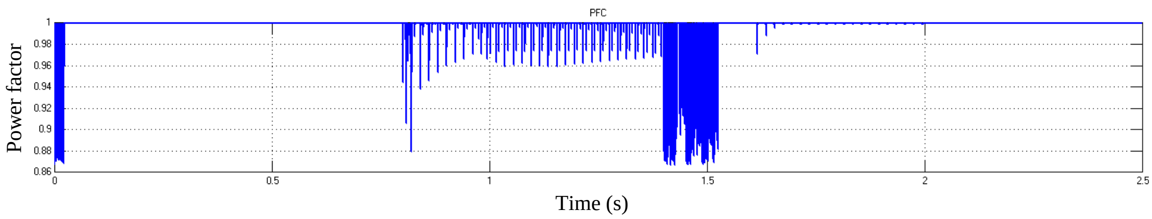

Figure 10. PFC for implemented smart grid

Table 1. Energy exchange scenario

Energy exchange	Micro grid
Total import from grid	1.6 MW
Total export from grid	250 KW
Net energy exchange with grid	1.35 MW

In India, a smart grid is still in its early stages. The Ministry of Power created the National Smart Grid Mission (NSGM), which plans also supervises smart grid project strategies and initiatives for smart grid development and deployment [22], [23]. India's power grid India's electrical grid system is geographically separated into five areas for better management: northern, southern, western, eastern, and northeastern. The Indian power system has been divided into two grids since August 2006: the integrated northern, southern, western, eastern and northeastern. Consequently, "One Nation, One Grid, One Frequency" is achieved. All conceivable methods are implemented to preserve the grid frequency between 49.90 and 50.05 Hz (hertz). The significance of one frequency: sustaining a steady electrical frequency is critical for various frequencies cannot coexist without causing device damage. This has significant consequences when it comes to delivering power on a national basis.

The National Grid capacity: the country currently has a total inter-regional transmission capacity of over 1,12,250 MW, which is expected to increase to around 1,18,740 MW by 2022. Merits of one nation, one grid:

– Matching demand-supply*:* synchronization of all regional grids will help in the optimum use of scarce natural resources by shifting power from resource-centric areas to load-centric regions.
– Development of electricity market*:* this will also pave the way for forming a thriving electricity market that would facilitate power trade across borders.

Smart grid continues to face hurdles in deployment. These obstacles are related to the adaptation of developing technology, socio-economic concerns, a lack of legislation, and a lack of resource awareness [24]. According to the 19th electric power survey (EPS) [25], a region-by-region overview of electrical energy requirements and peak electricity demand projections for the years 2020-2021 and 2021-2022 are available (vol-1) is described for the electricity demand over the regional grids, which is shown in Table 2.

Table 2. Regional summary

Regional	Electrical energy requirement (MU)		Peak electricity demand (MW)	
	2020-2021	2021-2022	2020-2021	2021-2022
Northern	443704	468196	69766	73770
Western	455250	481501	66847	71020
Southern	399047	420753	59581	62975
Eastern	162669	171228	26633	28048
North East	22083	23809	4170	4499
Andaman and Nicobar	446	475	91	97
Lakshadweep	59	62	11	11
All India total	1483257	1566023	213244	225751

The regional electrical energy need and peak electricity demand for 2020-2021 and 2021-2022 are depicted here. India's total electricity consumption in 2020-2021 and 2021-2022 is 1483257 MU and 1566023 MU, respectively. Furthermore, the peak demand in 2020-2021 is 213244 MW and 225751 MW. This indicates that as the demand develops, so does the necessity. The main purpose is to fulfill demand.

The category-by-category forecast depicts electrical energy consumption for 2020-2021 and 2021-2022, respectively. The category-wise forecast describes the electrical energy consumption for 2020-2021 and 2021-2022 as per the 19th EPS (vol-1). Figure 11 depicts the electrical energy consumption of the category-wise prediction, demonstrating that home electric energy consumption has been higher.

The conceptual model is discussed, providing a thorough and accurate grasp of the aims, design, possible advantages, and power grid concerns of various regional defenders and participants [26]–[29]. So, the optimal solution to reduce the electricity consumption from the grid is to install solar PV and wind energy in residential areas with the smart meter to make the system the smart grid, which is already shown in Table 1. The comparative analysis of the implemented smart grid with the power grid is analyzed. Whereas, per day consumption of the implemented smart grid is 1.6 MW, then the yearly consumption of the implemented smart grid is 1.6 MW*365days*6h, which is 4672 MWh shown in Figure 12.

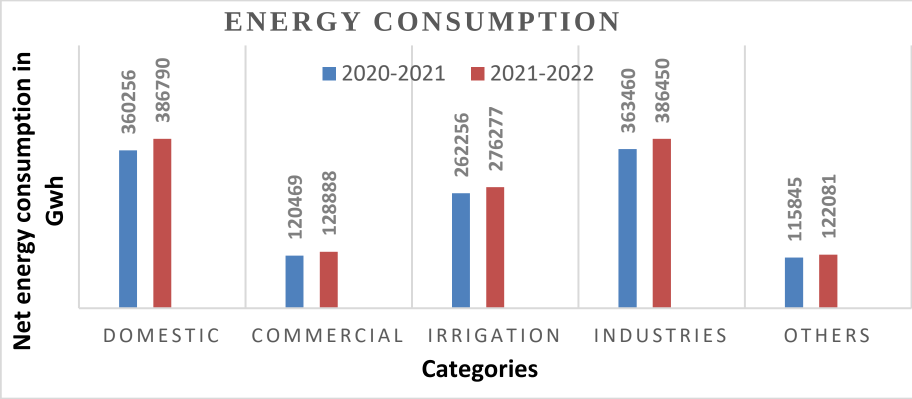

Figure 11. Electrical energy consumption (GWh)

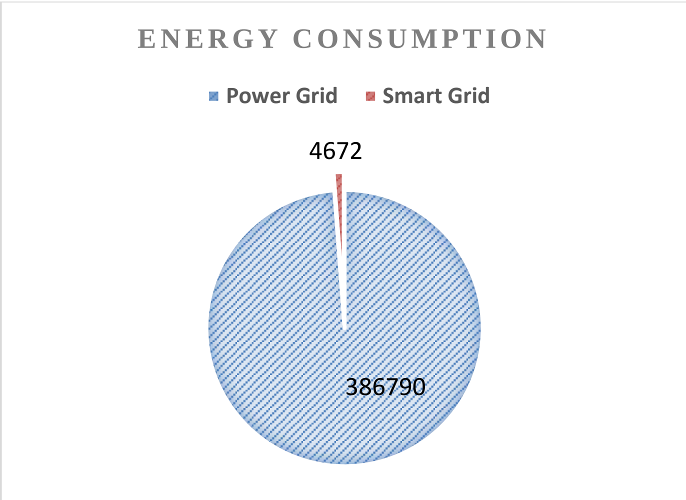

Figure 12. Comparative analysis of the energy consumption

This graph represents the comparative analysis of the energy consumption of the implemented smart grid with the power grid. Comparative analysis of the energy consumption is done with the national power grid to the smart grid.

3.3. Cost analysis of the research work

Here the implemented system cost analysis as in Table 3 is done by the mathematical expressions, which is for a day. A comprehensive examination of the economic variables related to the incorporation of renewable power sources, namely PV systems and wind power, is included as part of the cost analysis. Installing PV systems requires an initial investment in solar panels, inverters, and cabling. Costs associated with wind turbines, supporting infrastructure, and connecting to the grid are all part of the total cost of integrating wind energy systems.

To provide an extensive overview of the financial consequences, the research carefully calculates the lifespan costs of various renewable technologies, including maintenance, operating, and decommissioning costs. The study goes further into the function of batteries and other energy storage options as they relate to grid optimization. Battery technologies are also included in the cost analysis, along with initial expenditures, maintenance expenses, and the effect of battery life on the economics of the system overall. The financial feasibility of integrating PV systems, wind energy, and battery technologies into a smart grid may be better understood with the help of a thorough cost study.

Table 3. Cost analysis of the system

	Quantity	Value	Unit
PV system	Rated capacity	4	kW
	Total production	809	kWh
	PV penetration	17.31	%
	Operating hours	5.5	Hrs
	Capacity factor	10.83	%
	Cost of energy (COE)	0.106	$/kWh
Wind energy conversion system	Rated capacity	1	kW
	Total production	160	kWh
	PV penetration	3.4	%
	Operating hours	8	Hrs
	Capacity factor	1.3	%
	COE	0.117	$/kWh
Battery	Rated capacity	2	kW
	Total production	52.8	kWh
	PV penetration	11.3	%
	Operating hours	10	Hrs
	Capacity factor	1.1	%
	COE	0.1	$/kWh

4. CONCLUSION

In this paper, the current and future energy scenarios in India are explored in this research. The country's expanding economy has compelled it to raise its electricity capacity to 200 GW this year. Despite this increase in supplies, the country is still experiencing shortages. Enormous problems arise in providing universal access to electricity for families and increasing the dependability and quality of electricity supplies. This study proved the need to focus on soft challenges caused by human perceptions, environmental constraints, and technology improvements. Furthermore, this study raised awareness of the interconnectedness of smart grid stakeholders and the necessity to develop a collaborative solution that suits their particular needs; taking such measures because of the overlapping nature of the intricate and challenging circumstances is challenging for a single stakeholder to express their concerns. Stakeholders may differentiate between the actual occurrence and the ideal condition. Furthermore, this technique fostered a collaborative relationship between researchers and participants. As energy demand grows, more power generation at the centralized or distribution level will be required to meet the increased demand while maintaining power quality. However, there are several issues related to the efficient operation of electric grids that might result in significant power outages and even severe scarcity in the future. The most recent breakthroughs in renewable energy generation necessitate a method for optimum application.

REFERENCES

[1] I. Colak, R. Bayindir, and Ş. Sağıroğlu, "The effects of the smart grid system on the national grids," in *2020 8th International Conference on Smart Grid (icSmartGrid)*, Paris, France: IEEE, Jun. 2020, pp. 122–126, doi: 10.1109/icSmartGrid49881.2020.9144891.

[2] S. Kumar, B. Bhattacharyya, and V. K. Gupta, "Present and future energy scenario in India," *Journal of The Institution of Engineers (India): Series B*, vol. 95, no. 3, pp. 247–254, Sep. 2014, doi: 10.1007/s40031-014-0099-7.

[3] Archana, R. Shankar, and S. Singh, "Development of smart grid for the power sector in India," *Cleaner Energy Systems*, vol. 2, p. 100011, Jul. 2022, doi: 10.1016/j.cles.2022.100011.

[4] I. S. Jha, S. Sen, and R. Kumar, "Smart grid development in India — A case study," in *2014 Eighteenth National Power Systems Conference (NPSC)*, Guwahati, India: IEEE, Dec. 2014, pp. 1–6, doi: 10.1109/NPSC.2014.7103866.

[5] M. Madhavan and N. Anandan, "Genetic algorithm based smart grid system for distributed renewable energy sources," *Computer Systems Science and Engineering*, vol. 45, no. 1, pp. 819–837, 2023, doi: 10.32604/csse.2023.028525.

[6] M. Madhavan and N. Anandan, "Unified power quality control based microgrid for power quality enhancement using various controlling techniques," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 1, pp. 75–84, Jan. 2022, doi: 10.11591/ijeecs.v29.i1.pp75-84.

[7] A. Sharma, B. K. Saxena, and K. V. S. Rao, "Comparison of smart grid development in five developed countries with focus on smart grid implementations in India," in *2017 International Conference on Circuit, Power and Computing Technologies (ICCPCT)*, Kollam, India: IEEE, Apr. 2017, pp. 1–6, doi: 10.1109/ICCPCT.2017.8074195.

[8] R. Kappagantu and S. A. Daniel, "Challenges and issues of smart grid implementation: A case of Indian scenario," *Journal of Electrical Systems and Information Technology*, vol. 5, no. 3, pp. 453–467, Dec. 2018, doi: 10.1016/j.jesit.2018.01.002.

[9] D. K. Dubey, "Issues and challenges in electricity sector in India," *The Business & Management Review*, vol. 5, no. 4, pp. 29–30, 2015.

[10] B. K. Reddy, B. S. Reddy, P. Prakash, D. Vamshy, P. R. K. K. Reddy, and M. M. Alhaider, "Latest trends and their adoptions in electrical power systems – an industrial perspective," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 1, pp. 8–14, Jan. 2022, doi: 10.11591/ijeecs.v29.i1.pp8-14.

[11] O. S. Neffati *et al.*, "Migrating from traditional grid to smart grid in smart cities promoted in developing country," *Sustainable Energy Technologies and Assessments*, vol. 45, p. 101125, Jun. 2021, doi: 10.1016/j.seta.2021.101125.

[12] D. B. Avancini, J. J. P. C. Rodrigues, R. A. L. Rabêlo, A. K. Das, S. Kozlov, and P. Solic, "A new IoT-based smart energy meter for smart grids," *International Journal of Energy Research*, vol. 45, no. 1, pp. 189–202, Jan. 2021, doi: 10.1002/er.5177.

[13] S. R. Salkuti, "Challenges, issues and opportunities for the development of smart grid," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 10, no. 2, pp. 1179–1186, Apr. 2020, doi: 10.11591/ijece.v10i2.pp1179-1186.
[14] S. K. Rathor and D. Saxena, "Energy management system for smart grid: An overview and key issues," *International Journal of Energy Research*, vol. 44, no. 6, pp. 4067–4109, May 2020, doi: 10.1002/er.4883.
[15] I. Alotaibi, M. A. Abido, M. Khalid, and A. V. Savkin, "A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources," *Energies*, vol. 13, no. 23, p. 6269, Nov. 2020, doi: 10.3390/en13236269.
[16] T. Meenakshi, R. Ramani, A. Karthikeyan, N. S. Vanitha, and S. Murugan, "Power quality monitoring of a photovoltaic system through IoT," in *2023 International Conference on Sustainable Communication Networks and Application (ICSCNA)*, Theni, India: IEEE, Nov. 2023, pp. 413–418, doi: 10.1109/ICSCNA58489.2023.10370494.
[17] R. Raman, R. Jagtap, S. Muthumarilakshmi, M. Lalitha, G. Jethava, and S. Murugan, "Energy monitoring in solar-powered buildings using internet of things," in *2023 Second International Conference On Smart Technologies For Smart Nation (SmartTechCon)*, Singapore, Singapore: IEEE, Aug. 2023, pp. 318–322, doi: 10.1109/SmartTechCon57526.2023.10391826.
[18] G. Dileep, "A survey on smart grid technologies and applications," *Renewable Energy*, vol. 146, pp. 2589–2625, Feb. 2020, doi: 10.1016/j.renene.2019.08.092.
[19] T. Alladi, V. Chamola, J. J. P. C. Rodrigues, and S. A. Kozlov, "Blockchain in smart grids: A review on different use cases," *Sensors*, vol. 19, no. 22, p. 4862, Nov. 2019, doi: 10.3390/s19224862.
[20] K. R. Khan, M. Rahman, H. Masrur, and M. S. Alam, "Electric energy exchanges in interconnected regional utilities: A case study for a growing power system," *International Journal of Electrical Power & Energy Systems*, vol. 107, pp. 715–725, May 2019, doi: 10.1016/j.ijepes.2018.11.028.
[21] P. Kalita, S. Das, D. Das, P. Borgohain, A. Dewan, and R. K. Banik, "Feasibility study of installation of MW level grid connected solar photovoltaic power plant for northeastern region of India," *Sādhanā*, vol. 44, no. 9, p. 207, Sep. 2019, doi: 10.1007/s12046-019-1192-z.
[22] S. Bhattacharjee, "Literature review on renewable energy sources in north-eastern states of India," *National Journal of Environment and Scientific Research*, vol. 2, no. 8, pp. 11–16, Aug. 2021, doi: 10.53571/NJESR.2021.2.8.11-16.
[23] S. Buragohain, K. Mohanty, and P. Mahanta, "Experimental investigations of a 1 kW solar photovoltaic plant in standalone and grid mode at different loading conditions," *Sustainable Energy Technologies and Assessments*, vol. 41, p. 100796, Oct. 2020, doi: 10.1016/j.seta.2020.100796.
[24] R. Jabeur, Y. Boujoudar, M. Azeroual, A. Aljarbouh, and N. Ouaaline, "Microgrid energy management system for smart home using multi-agent system," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 2, pp. 1153–1160, Apr. 2022, doi: 10.11591/ijece.v12i2.pp1153-1160.
[25] M. Asaad, F. Ahmad, M. S. Alam, and M. Sarfraz, "Smart grid and Indian experience: A review," *Resources Policy*, vol. 74, p. 101499, Dec. 2021, doi: 10.1016/j.resourpol.2019.101499.
[26] M. Ourahou, W. Ayrir, B. El Hassouni, and A. Haddi, "Review on smart grid control and reliability in presence of renewable energies: Challenges and prospects," *Mathematics and Computers in Simulation*, vol. 167, pp. 19–31, Jan. 2020, doi: 10.1016/j.matcom.2018.11.009.
[27] A. Joseph and P. Balachandra, "Smart grid to energy internet: A systematic review of transitioning electricity systems," *IEEE Access*, vol. 8, pp. 215787–215805, 2020, doi: 10.1109/ACCESS.2020.3041031.
[28] M. Gomathinayagam and S. Balasubramanian, "Various demand side management techniques and its role in smart grid–the state of art," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 12, no. 1, pp. 150–156, Feb. 2022, doi: 10.11591/ijece.v12i1.pp150-156.
[29] R. Raman, P. R. Parvathy, P. Sapra, V. B. Sonule, and S. Murugan, "Robotic weed control and biodiversity preservation: IoT solutions for sustainable farming," in *2023 7th International Conference on Electronics, Communication and Aerospace Technology (ICECA)*, Coimbatore, India: IEEE, Nov. 2023, pp. 112–117, doi: 10.1109/ICECA58529.2023.10395531.

BIOGRAPHIES OF AUTHORS

Dr. M. Mythreyee completed B.E in Electrical and Electronics Engineering from Annamalai University, Annamalai Nagar, Chidambaram. M.Tech in Energy Engineering at Vellore Institute of Technology, Vellore, Tamil Nadu. She is presently pursuing research in monitoring and analysis of power quality in advanced distributed network of smart grids in the Department of Electrical and Electronics Engineering accredited Dr. M.G.R. Educational and Research Institute, deemed to be University with Graded Autonomous Status, Chennai, India. She can be contacted at email: m.mythreyee@gmail.com.

Dr. Nalini Anandan obtained her B.E and M.E from Annamalai University. She received her Ph.D. degree from Dr. M.G.R. Educational and Research Institute. Her specialization in PG is power systems. Her research interests include wide area monitoring and control, phasor measurement unit, power system simulation studies and optimization. She is presently working as Associate Professor of Electrical and Electronics Engineering Department at Dr. M.G.R. Educational and Research Institute, Chennai, Tamil Nadu, India. She can be contacted at email: Nalini.eee@drmgrdu.ac.in.