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STUDY CONFIGURATION OF A HYBRID RENEWABLE ENERGY SYSTEM

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ABSTRACT

Energy storage systems may also make it possible for the use of electricity to account for a sizeable portion of the total energy consumption of a society while only requiring the installation of a minimal amount of fundamental infrastructure, such as transformers, lines, and cables, among other things. Energy storage devices may be able to control the fluctuation of power output with the help of a method that has been suggested. This could serve as an affordable addition to the upgrading of traditional networks. This kind of strategy, which assists distributed energy resources (DERs) in becoming more widely used, is an important step towards the transition of the energy sector into one that is one that is more ecologically and socially acceptable. Using a hybrid energy system as a strategy to generate electricity and feed it into the utility grid is possible for even relatively small users.

Keyword: Energy, grid, DERs, infrastructure, consumption

INTRODUCTION

To ensure that clients always have access to energy, separate power generating stations must be built and placed into operation. Therefore, the combination of a number of power generating plants will result in the formation of a subsystem that generates electrical energy from primary energy. A combination of an electric generator and a primary mover is the most fundamental kind of generating station. When the prime mover turns the generator, electric current is produced. This process is made possible by the input received from the primary power supply. India's power generation capacity (source-wise) has been shown with the help of pie-chart in the following fig.1..

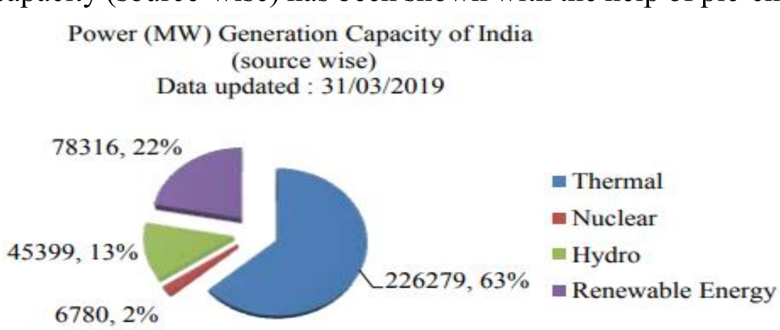


Figure 1. Power generation capacity in MW

Electrical Energy Derived from More Traditional Sources

Electro-mechanical generators, which are primarily driven by heat-based engines and fuelled by chemical or nuclear fuel combustion, produce electricity at the power plants. Frequently used traditional techniques are

Hydro

Thermal (e.g., coal, oil, gas)

Nuclear

Hydro and thermal generators are the two primary types of non-renewable energy sources that are utilised to produce electricity.

A. Hydro

In order to generate electricity, hydroelectric power plants make advantage of the latent energy that may be extracted from water when it is at a high level. The power comes from the energy that is created by the falling water.

B. Thermal

The bulk of the energy that is produced on the planet comes from thermal power plants. These kind of power plants make use of the heat produced by the combustion of fossil fuels, such as coal, oil, gas, or any other such fuel, to power boilers that generate steam under conditions of high pressure and temperature. After that, the steam is put to use to operate steam turbines and generators, which ultimately results in the production of energy. Coal is the dominant source of energy since it accounts for about half of the world's total energy supply for commercial use.

C. Nuclear

Nuclear power is required since there is an almost continuous need for electricity, hence it is essential. Coal, oil, and gas are examples of fossil fuels that are swiftly depleting and becoming very difficult to find. Another source of energy must be discovered in order to fulfil the world's anticipated energy requirements and bring supply and demand into equilibrium. This is necessary in order to fulfil the world's growing need for energy..

Power Derived from Renewable Sources of Energy

Producing electricity from non-conventional energy sources (also known as NCES) has become more important in the present climate. These sorts of sources can end up being quite significant for the long-term expansion of the electrical sector and the protection of energy supplies. These non-conventional energy sources, such as wind, solar, and small and micro-hydroelectric dams, have the potential to fulfil all of humanity's energy needs for an extremely extended period of time. In addition to this, they have the ability to fulfil the need for energy all across the globe. These are some possible clean and green energy sources that might be used as a backup plan, despite the fact that their power generation is sporadic and their availability is spread out.

The concept that underpins solar energy

The sun is a large orb that is made up of an endless supply of gases that are heated. The temperature of the solar disc's surface seems to be 5762 Kelvin as seen from Earth's vantage point. The sun's electromagnetic radiation imparts heat energy onto the planet. The phrase "solar constant" describes the rate at which radiation from the sun reaches the upper atmosphere. It is the amount of heat energy that is received by a region that is perpendicular to the path that the sun takes across the sky in a given amount of time at the average distance that the earth is from the sun. Solar radiation has a constant power output of 1353 watts per square metre.

Solar energy is naturally replenishable, there is an abundance of it, and it is good for the environment. It is known as solar radiation when it is seen on the surface of the earth. On a day with clear skies and plenty of sunshine, its measurement hovers around 0.1 kW/m2 all day long. The quantity of solar energy that is continuously received by the earth is around 178 billion MW, which is over 10,000 times more than the amount of energy that the earth requires. The daily global radiation value is 5 kWh / sq. metre / day, with sunshine hours per year ranging between 2300 and 3000. Solar radiation may be converted into usable power by using photovoltaic cells. Because most home appliances operate on AC, you will always require an inverter to convert the DC that is produced by PV cells, which produce DC.

Fig.2 demonstrates the block diagram of solar PV generation system connected with utility grid.

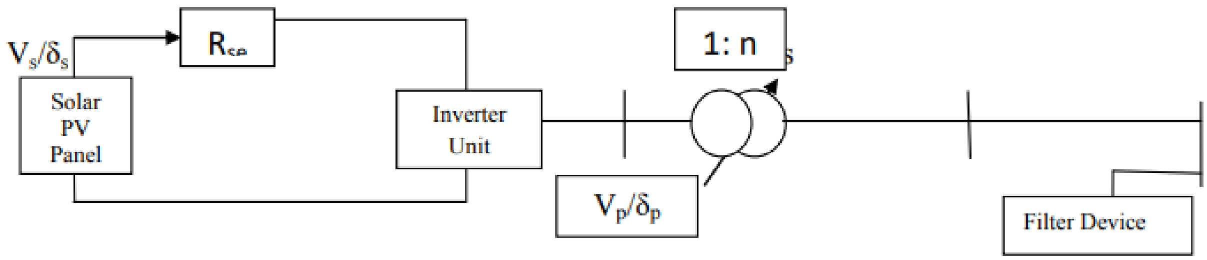


Figure 1 Grid-Connected/ Off-Grid Solar Arrangement

Conceptualization of Wind Energy

Wind power is the most practicable kind of renewable energy in terms of both its usage and its potential for commercialization. The estimated power of wind flowing above the surface of the earth is 1.6 x 107 MW, which is far higher than the amount of energy that is currently being used globally. Wind energy accounts for around one percent of the world's total energy consumption at the moment, and the installed capacity of wind power plants is always being expanded.

There are a great deal of critical problems to be faced in relation to the functioning and influence on modern electrical systems as well as their integrated operation:

Low density of available energy :Unpredictable and erratic production of energy

Ability of wind generation to not be sent

The traditional high voltage network system is reportedly seeing a rise in the amount of electrical power generated by turbines, as shown by recent trends. Separate electrical equipment and switchgear systems are established in order to ensure that the electrical network is operated correctly and to prevent any malfunctions from occurring. It is necessary to include scattered generator connection in the event that the grid becomes isolated or weakened, as well as at wind power plants that have considerable installed capacity. In order to enhance the penetration of wind energy generators (WEG), it is required to put them at a mass size that is less than their capacity. The following table illustrates the growth in generating capacity from January 2018 to March 2019; the month range covered is provided.

SYSTEM FOR STORING

It is necessary to encourage the expansion of renewable energy sources and make them more broadly accessible. The generation of electricity has to be extended and connected in order to achieve the goal of regulating the volatility in output. Because storage systems contribute to grid stability, continuous supply, and greater energy security, they should be included into the expansion of renewable energy sources. This is because storage systems contribute to the continuous supply of energy. The arrangement of the energy storage helps in rectifying the expected inconsistencies between the demand and the production of electricity. During off-peak hours, the storage system may manage demand peaks, while during high load hours, it might trade excess capacity back to the utility.

The energy storage system not only offers sufficient power backup for emergency situations, but it also has the potential to lessen the intermittent character of the electricity that is generated by renewable energy sources. There are several choices for energy storage:

- Hydraulic storage pumped
- tiny turbines
- Electric Cars
- Batteries
- Flywheel storage

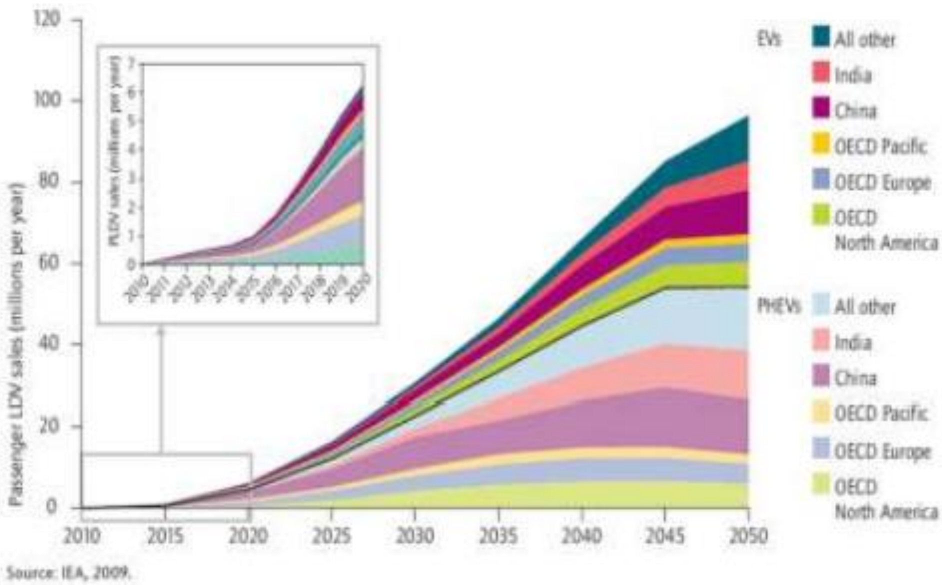


Figure 2 Distribution of Electric Vehicles

The techniques for storing energy that were discussed before are nonsensical, despite the fact that they are highly effective. It seems that the proportion of households using electric cars is growing at the present time. The batteries in the automobiles store any surplus energy that is generated during off-peak load hours. This energy may either be utilised to satisfy local load demands or sent back into the grid. The hybrid energy system will promote user engagement in the functioning of the grid while at the same time minimising the strain placed on existing power sources. Charging batteries using solar and wind power would not only save money but will also reduce the quantity of greenhouse gases that are produced by transportation.

THE TRANSMISSION AND DISTRIBUTION OF ELECTRICITY

Centralised power plants that rely on fossil fuels are often located in remote places and generate electricity, which is then delivered to users via a network of transmission and distribution lines. A significant amount of energy is lost as a consequence in the networks that are utilised for distribution and transmission. Energy supply and demand on an electric grid are required to be in appropriate balance at all times, regardless of the conditions. When renewable technologies are used on a larger scale as a substitute for traditional forms of energy production and when there is a greater need for energy storage, the issue becomes one that is of greater significance. The use of certain control algorithms in hybrid energy systems may make it possible to preserve both the power quality and the dependability of these systems. It is necessary to put the proposed method into action in order to ascertain the location of distributed energy resources (DER) integration and the capabilities associated with it.

CONSTRAINTS IMPOSED BY THE ELECTRICAL POWER SYSTEM

The gap between supply and demand is continually widening as rising living standards push higher overall levels of life. The demand-supply balance is a significant challenge for the engineers who work for electric utility companies. It may be possible to achieve this goal by using electric equipment that are both energy-efficient and contribute to the decrease of consumption. Using alternate forms of energy to generate more power near to the area of greatest demand is maybe yet another significant strategy.

To be able to meet the demand for energy, the infrastructure of the power system has to be improved. The locations of the many green energy sources are scattered across the landscape. Distributed energy resources (DERs) need to be included into distribution networks in order for there to be a reduction in the quantity of electricity that is produced from conventional sources. Integration of DERs with distribution networks is not permitted on the system that is currently in place. The existing circumstance allows for the possibility of electricity to be transferred in both directions between the dispersed generators. The integration of DERs has an effect on a variety of aspects of the distribution network, including the losses, the power quality, the emissions of greenhouse gases, and the tuning of various components of the power system. The intermittent nature of power output from distributed energy resources (DERs) has to be compensated for via the use of electrical energy storage devices. The connected load continues to sometimes diverge, on a somewhat smaller scale, from the usual value that was previously calculated. The sum of the load and any related losses is equivalent to the amount of electricity that can be generated by DERs as output.

LITERATURE REVIEW

Le et al. (2016) proposed a method for regulating voltage that makes use of DG. They presented a modeling technique that may inject electricity from DG in the most effective and efficient manner feasible by using the voltage control methodology. Using the Load Tap Changing (LTC) transformer technique, Dai and Baghzouz (2017) evaluated the fluctuation in voltage regulation produced by DG. It was discovered that in the lack of appropriate controls for the LTC transformer, there might possibly be some transient voltage fluctuations. Certain academics have suggested control models in an effort to increase the effectiveness of the DG operation. Kashem and Ledwich (2014) provided an overview of the operation and control mechanism of DG installation in distribution networks. In order to raise the voltage across the distribution network, the authors of this article made use of a DG control model. When a large number of DGs were running, it was discovered that there were certain issues with the network, and it was proposed that design criteria be met by displaying analytical approaches and potential solutions (Kashem and Ledwich, 2015).

Dai and Baghzouz (2017) provided an easy-to-use analytical approach that estimates the voltage profile of the radial distribution system upon deployment of distributed generation (DG) with particular active and reactive power production. This technique was developed to estimate the voltage profile of the radial distribution system. Kim and Kim (2021) have examined the ways in which voltage control may be coordinated to facilitate the establishment of distributed generation inside a distribution network system. It is possible for there to be some variation in the power factor and losses of the distribution system while DGs are being installed. A select group of academics discussed how the infusion of DG electricity into the network system has the potential to reduce losses. Borges and Falcao (2014) also used the power summing approach to decrease losses when using DGs.

Barker and Mello (2020) offered a short description of how DG installation influences feeder losses, but they did not undertake a full study. Borges and Falcao (2014) also used the power summation method to lower losses when using DGs.

(IWEO, 2019) The Indian Wind Energy Outlook Report of 2019 states that the installed capacity from renewable sources is 13.2 gigawatts. From 41.3 MW in 1992 to 13065.78 MW by December 2010, the installed capacity has increased dramatically (IWEO, 2020). Wind power now has a capacity of 48,561 megawatts (MW). The construction and installation of 14,158,00 MW worth of commercial projects has been completed as of March 2018. India is now ranked fifth in the world in terms of the amount of wind generating capacity that has been built. This study provides information on the state of wind energy throughout the country, as well as the legal framework for forecasting wind power demand, including prices and growth rates, benefits, and energy efficiency. IWEO (2019) emphasized grid stability, which is a basic problem that must be addressed prior to integrating an existing grid with any new system. The variable nature of wind power highlights the need of developing interconnection standards in order to maintain a sustainable grid even in the presence of parameter volatility. This should be done so that the quality of the electricity is not adversely affected.

According to a research that was conducted by the OECD in 2015, the adoption of the idea of grid integration in recent years was precipitated by the increasing penetration of wind power in several nations. Both the intermittent nature of wind power and the unpredictability of electrical grids provide significant challenges for its widespread implementation in the future.

Xie et al. (2021) investigated one of the most significant operational challenges that must be overcome by a power system in order to allow the integration of large-scale wind generation. In addition to that, they discussed the influence that wind has on things like unit commitment, economic dispatch, autonomous generation management, and frequency stability. According to the findings of study carried out by Martinez et al. (2014), power error vector management as well as active and reactive power reference reduction may be used as viable solutions during voltage dips in order to facilitate low voltage ride through. The compatibility of wind turbines with DFIG for the new grid operator rules that necessitate ride through operations was another aspect that was investigated in this research.

Khorrami (2018) developed a system that enables integration by means of load management, control over energy usage, and management of renewable energy sources. He also presented this technology during his discussion of the challenges that a cyber-controlled smart grid must overcome. Additionally, it was suggested that people who consume energy should be given the tools necessary to live more sustainably, that distributed generation systems should be created in which people who use energy also generate energy, and that FACTS could be utilized to control smart switches. The works of Smith et al. (2017), Parsons et al. (2016), and Demeo et al. (2015) give updates and summaries of many of the significant subjects on the present state of knowledge about the problems associated with the integration of wind energy into utility systems.

The influence of wind generation was proven by a comparison of system dynamic performance with and without the integration of wind, and it was determined that real operating experience would be required to properly appreciate the impact of wind on the system. The findings of the research conducted by Matias et al. (2016) provided helpful evidence for the need to evaluate, update, and restructure the existing structures of the electricity market in order to make room for a significant penetration of wind power and to underline the necessity of making use of the advantages afforded by wind energy. Sorensen et al. (2020) reported on main power quality concerns and collected data on reactive power, voltage imbalance, current imbalance, frequency range harmonics, interharmonic distortion, and voltage fluctuations within the framework of a joint study between Denmark and India.

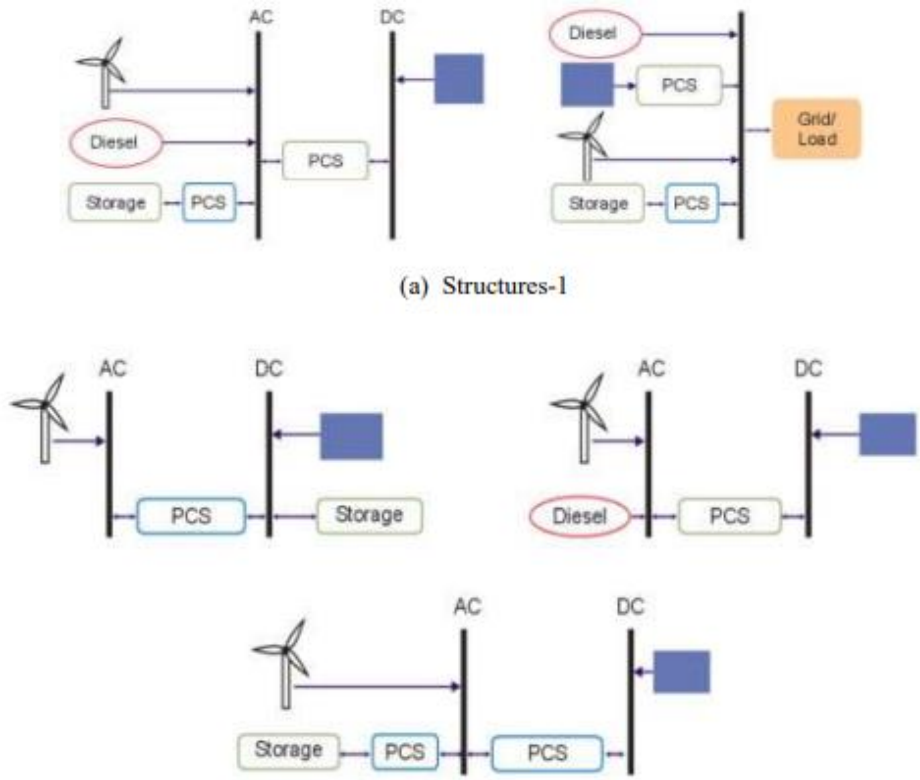
RESEARCH METHO

the constraints imposed by concerns, the entire technical potential of RES is only partially fulfilled. Due to the fact that RES are dispersed throughout a large number of different areas, there is an initial restriction placed on the process of scaling up to the most economically feasible locations. Due to geographical limits, the majority of renewable energy sources, such as some kinds of saltwater, biomass energy, geothermal energy, and solar energy, have a restricted supply. The electric utility industry is constantly being reshaped and regulated, with both market forces and regulatory frameworks playing a role. The fact that the entry of DGs into the open market has been made possible at a more mature pace as a result of government regulations and public policies is a well-established fact. The operation of power-generating equipment that is connected to the distribution systems network being investigated as part of the distributed generation initiative.

Analysis

It is recommended to use the energy that is produced by RESs at the same site where the energy is produced in order to receive the maximum amount of energy that can be obtained while also having the least amount of an effect as possible on the functioning of the electric grid. When combined with other types of renewable energy, energy systems powered by the sun and the wind have the greatest potential to improve the state of the environment on a worldwide scale.

A hybrid energy system is comprised of the many various forms of renewable energy that may be used in a certain place, the required load, and the costs involved with the installation, operation, and maintenance of the system. One strategy for mitigating the effects of the energy source's intermittent nature is to combine the output of many sources of energy, such as wind, solar photovoltaic, diesel generators, and storage devices. Another strategy is to use a combination of these sources. On the other hand, a hybrid energy system that is connected to the grid could find that the upkeep of the system is best handled by a mix of solar photovoltaic cells and wind power. A hybrid energy system that simply makes use of solar and wind power will not be able to provide a consistent supply of electricity over the course of a lengthy period of time.



(a) Structures-1

(b) Structures-2

Figure Possible example of a hybrid structure

THE OPTIMIZATION GOALS

The creation of hybrid energy systems has a number of primary goals, the most important of which are to achieve higher reliability, lower energy costs, and better efficiencies. It is necessary to ensure that all energy storage systems, solar photovoltaic (PV) systems, wind generators, diesel generators, and other types of generators are running at maximum efficiency.

A multi-objective optimization that takes into consideration LCC, LPSP, and EE as a function of environmental concern and life cycle cost is the basis for the approach that is recommended for the construction of hybrid energy systems. This method is based on a multi-objective optimization. A fuzzy logic approach was used to solve the optimization problem, and the major objective was to maximize the levelized cost of energy (LCE) while maintaining a high reliability index (LPSP). This problem was successfully addressed. This strategy is an alternative to the optimization that is based on the "worst-month scenario," and it takes into consideration the total cost of ownership as well as the degree to which the system can run independently.

The energy expected not supplied (EENS) metric and the dependability index were used in order to do an analysis on the long-term viability of the suggested hybrid energy systems. We studied how effectively defined objectives may be realized by the design of hybrid energy systems while taking into account the restrictions of uncertainty by using a methodology based on trade-offs and risks. Comparisons have been made between the fuzzy logic-based optimization approach and a computer software known as HOMER. In the event that the system is powered by a non-renewable energy source, the optimal size must still be capable of delivering the load at a cost that is as low as possible to run.

It is very necessary to use an appropriate optimization technique in order to build a hybrid energy system that is reliable, efficient, has optimal capacity, and is cost-effective. An suitable optimization strategy may be used to ascertain the optimal capacity and working conditions of the hybrid energy systems that have been presented. However, the optimal scale of a hybrid energy system is contingent not only on the penetration of distributed energy resources at a particular location, but also on the solar radiation, wind speed, load pattern, and generation pattern, as well as the optimization methodologies that have been used.

SYSTEM DETAILS

The city of Kota, which is located in the southern portion of the Indian state of Rajasthan, was chosen to serve as the integration site since it is positioned on the left side of the river. Location on the map: 25 degrees 18 minutes north and 75 degrees 83 minutes east. There are around 318 square kilometers included, which is approximately comparable to 3.63 percent of Rajasthan. It is situated at an elevation of about 271 meters (889 feet) above the level of the sea. In this region, which is characterized by a semiarid climate, high temperatures are to be expected throughout the whole year.

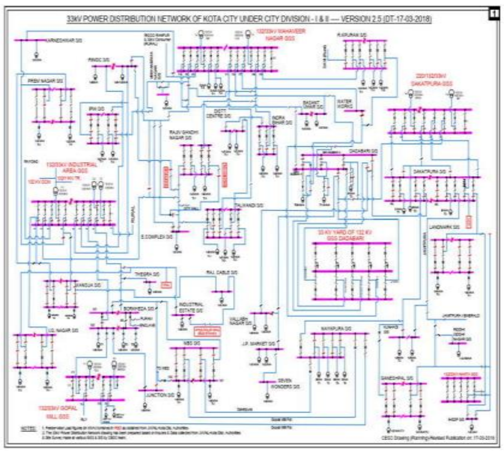


Figure A 33kV power distribution network's line diagram

Indian Standard 69 Bus Branch Parameters: Radial Distribution Network

The values of each bus's resistance (R) and reactance (X) are detailed in Table 4.2 below.

Table1 : Each bus's resistance (R) and reactance (X)

Branch Number	From bus	To bus	R (ohm)	X (ohm)
1	I	2	0.0004	0.0018
2	2	3	0.0005	0.0012
3	3	4	0.0005	0.0012
4	4	5	0.0015	0.0036
5	5	6	0.0251	0.0294
6	6	7	0.366	0.1864
7	7	8	0.3811	0.1941
8	8	9	0.0922	0.047
9	5	10	0.0493	0.0251
10	10	11	0.819	0.2707

11	11	12	0.1872	0.0619
12	6	13	0.7114	0.2351
13	13	14	1.03	0.34
14	14	15	1.044	0.345
15	7	16	1.058	0.3496
16	16	17	0.1966	0.065
17	17	21	0.3744	0.1238
18	16	22	0.0047	0.0016
19	22	23	0.3276	0.1083
20	17	18	0.2106	0.069
21	18	19	0.3416	0.1129
22	19	20	0.014	0.0046
23	3	24	0.1591	0.0526
24	3	25	0.3463	0.1145
25	25	26	0.7488	0.2475
26	26	27	n 1089	0.1021
27	27	28	0.1732	0.0572
28	28	29	0.0044	0.0108
29	29	30	0.064	0.1565
30	30	31	0.3978	0.1315
31	31	32	0.0702	0.0232
32	32	33	0.351	0.116
33	25	34	0.839	0.2816
34	34	35	1.708	0.5646
35	35	36	1.474	0.4873
36	36	37	0.0044	0.0108
37	36	38	0.064	0.1565
38	34	39	0.1053	0.123
39	39	40	0.0304	0.0355
40	25	41	0.0018	0.0021
41	41	42	0.7283	0.8509
42	42	43	0.31	0.3623
43	25	44	0.041	0.0478
44	44	45	0.0092	0.0116
45	45	46	0.1089	0.1373
46	46	47	0.0009	0.0012
47	45	48	0.0034	0.0084
48	48	49	0.0851	0.2083
49	48	50	0.2898	0.7091

50	3	51	0.0822	0.2011
51	51	52	0.0928	0.0473
52	52	53	0.3319	0 1114
53	53	54	0.174	0.0886
54	54	55	0.203	0.1034
55	3	56	0.2842	0.1447
56	56	57	0.2813	0.1433
57	57	58	1.59	0.5337
58	51	56	0.7837	0.263
59	56	59	0.3042	0.1006
60	59	60	0.3861	0.1172
61	60	61	0.5075	0.2585
62	61	62	0.0974	0.0496
63	62	63	0.145	0.0738
64	61	64	0.7105	0.3619
65	64	65	1.041	0.5302
66	65	66	0.2012	0.0611
67	66	67	0.0047	0.0014
68	65	68	0.7394	0.2444
69	68	69	0.0047	0.0016

Radial Distribution Network Nodes of Indian Standard 69 bus with Connected Load

The bus-by-bus load figures are included in Table 4.3 for your reference.

Table 2 : Every bus's actual and reactive power

Bus No	Real Power at Load (kW)	Reactive Power at Load (kVAr)
1	0	0
2	0	0
3	0	0
4	20	15
5	0	0
6	0	0
7	0	0
8	32	24
9	20	15
10	40	30
11	82.4	61.8
12	80	60
13	80	60

14	80	60
15	252	189
16	0	0
17	0	0
18	50.4	37.8
19	80	60
20	160	120
21	32	24
22	20	15
23	20	15
24	80	60
25	0	0
26	20	15
27	80	60
28	80	60
29	8.8	6.6
30	32	24
31	80	60
32	20	15
33	50.4	37.8
34	0	0
35	20	15
36	20	15
37	20	15
38	20	15
39	80	60
40	80	60
41	80	60
42	0	0
43	160	120
44	80	60

45	0	0
46	20	15
47	32	24
48	0	0
49	50.4	37.8
50	80	60
51	128	96
52	128	96
53	128	96
54	128	96
55	128	96
56	0	0
57	80	60
58	252	189
59	380	228
60	256	192
61	0	0
62	280	210
63	80	60
64	302.4	226.8
65	0	0
66	380	285
67	128	96
68	128	96
69	504	378

CONCLUSION

The demand for energy from end users is on the increase, and it is essential to maintain a balance between supply and demand in this market. The construction of brand-new power plants is very necessary. Because the burning of fossil fuels discharges greenhouse gases into the environment, switching torenewable energy sources is very important.By integrating dispersed energy resources that are close to load centers, it may be possible to minimize the issue of growing energy expenditures as well as accumulating energy waste. Because of the research that was conducted, the real-time system that is now being used by the Ramachandrapuram feeder in Kota, India, has been improved. The forward-backward sweep method of load flow analysis was used to quantify the voltage drop, as well as the active and reactive power losses that occurred in the distribution network. The results of the simulation show that the active and reactive power losses in the network may be reduced to a minimum by including DERs, and the voltage profile at the nodes can be maintained within acceptable limits.

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