Research Article

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Voltage Profile Improvement in a Renewable Energy Based Hybrid Distribution System

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ABSTRACT

The technique of designing and analyzing the mixing of high photovoltaic (PV) and wind penetration into the Distribution device is a critical undertaking that calls for careful consideration and assessment. This integration has been meticulously accomplished on a 33kv machine and a 14-bus node take a look at inside the distribution feeder. The objective of this observe is to illustrate the weight flow assessment and the impact of together with Distributed Generation (DG) in the medium voltage distribution community using ETAP software program. It is important to understand that renewable energy resources preserve big capability in assembly the escalating strength demands on a worldwide scale. Particularly on the distribution facet, there is a great absorption of reactive energy, necessitating the equalization by renewable strength assets to enhance the voltage stage in the distribution community. Moreover, an in-depth exam of the grid performance below those situations is important for ensuring the robustness and reliability of the machine. Within the ETAP software program surroundings, the Adaptive Newton-Raphson approach has been employed in the distribution community to facilitate accurate and efficient evaluation of the gadget conduct.

Keywords: Electrical transient analysis program (ETAP); Distributed generation (DG); Photovoltaic (PV); Renewable energy; Load flow analysis.

1. INTRODUCTION

Power intake is a critical thing of our daily resources that plays a crucial position in maintaining our contemporary way of life. The disparity between purchaser calls for and supply era remains a good-sized undertaking, leading to an imbalance within the energy region. In the year 2020, there has been a fantastic incorporation of 20% renewable energy into the grid, marking a shift in the direction of a greater sustainable power blend. The convergence of awesome strength resources is normally referred to as a hybrid energy source. Presently, traditional power shops have become increasingly more restrained and are contributing to environmental pollution. Consequently, governmental tasks are now focusing on transitioning toward renewable power resources consisting of solar, wind, fuel cells, biomass, and hydroelectricity. However, a tremendous hassle of renewable sources lies in their dependency on natural conditions. When evaluating exclusive renewable resources, wind and solar energy stand out for his or her ability to generate high megawatts of energy. Unlike conventional power sources that require electricity generation over lengthy distances, renewable strength sources produce energy toward the factor of intake. Wind and sun energy, particularly, play a key function in forming a Distributed Generation (DG) network. One of the number one challenges faced by the electricity region today is the losses incurred inside the distribution network. Wind energy emerges as one of the quickest-growing and most promising renewable strength sources because of its abundance, affordability, sustainability, huge distribution, cleanliness, and environmental friendliness. Weak buses, characterized by using insufficient protection of transmission line parameters inclusive of voltage, modern, and electricity factor, make contributions to inefficient voltage law.

This discourse delves into the intricacies of reactive energy capacity and control algorithms inherent in converters, presenting an optimized framework that harmonizes the operations of On-Load Tap Changers (OLTCs), Photovoltaics (PVs), and converter-driven loads to enrich the voltage profile of the distribution system. Zhang *et al.* (2022) is proposed. Various methodologies are scrutinized, encompassing the fusion of wind-generated electricity, the amalgamation of photovoltaic energy, and the infusion of reactive power through the integration of Flexible Alternating Current Transmission Systems (FACTS) (Ali *et al.* 2022) gadgets, and these methodologies are applied to the IEEE 57 bus system with modern FACTS using simulation models developed in MATLAB. The reactive power capacity and control algorithms of the converters are deliberated, and an optimization framework is proposed to synchronize the operation of On-Load Tap Changers (OLTCs), photovoltaics (PVs), and converter-based loads to enhance the voltage profile of the distribution system (Zhang *et al.* 2022) is proposed. A dynamic voltage restorer (Kumari *et al.* 2022) that is related in series acknowledges voltage flickering proper away and restores excessive voltage to its authentic tiers is used to resolve the voltage flickering problem. An intelligent DE optimization algorithm (Bhatt *et al.* 2022) is proposed to tackle issues such as exceeding voltage limits, loss of feeder capacity, and diminished power factor within a hybrid (Solar/Wind) distribution grid employing ETAP. The reduction of power loss is achieved, along with a simultaneous enhancement of the voltage profile of the system through the utilization of the Atom Search Optimization (ASO) technique. The efficacy of the proposed algorithm has been validated on IEEE 33 and 69 radial and weakly meshed networks with five tie lines, aimed at minimizing power loss (Tahiliani *et al.* 2022) using single and multiple DG. An optimization quandary with multiple objectives is delineated, employing non-ruled sorting and crowding distance for a multifaceted hybrid algorithm that amalgamates the virtues of Particle Swarm Optimization (Ali *et al.* 2022) and Sine Cosine Optimisation algorithms.

Now a days the home appliances are inductive load so it absorbs more reactive power from the era source. Therefore, voltage drop occurs within the distribution networks and also in distribution community have a plethora of circuits branching out to distribute electricity to consumers not only creates a conducive environment for voltage decline but also accentuates the impact of photovoltaic (PV) integration on large-scale power distribution grids, especially during critical network conditions and instances of fault occurrence. This ends in the importance of examining the short circuit stage to guarantee the validity of connecting such DG to make certain easy community operation and reliability (Afifi *et al.* 2014). The integration of distributed generation poses inherent risks, including the potential to elevate the voltage profile beyond acceptable limits and exceed the network's short circuit capacity, thus constraining the interconnection of distributed generation resources. This study aims to investigate the influence of Doubly Fed Induction Generator wind turbines on the short circuit level within a distribution test system using ETAP software. This evaluation is performed by way of the ETAP software. This ETAP simulator that's the maximum fantastic software program to represent the actual electric electricity grid machine and to have a look at all the case research of electrical power packages (Afifi *et al.* 2013). Photovoltaic (PV) systems can be extremely high quality for commercial in addition to home institutions which use inverters, turbines and other auxiliary resources to decrease power prices and also guarantee energy continuity inside the event of faults/ outages. The affects are came even as putting in the hybrid energy (Abdulkareem *et al.* 2014) analyzing the distribution network entails identifying the bus affected by faults and pinpointing voltage drops within the system. Based on this assessment, strategic placement of renewable energy resources and capacitors is determined to enhance voltage levels across the distribution network.

2. HYBRID NETWORK

In this task, the aggregate of the solar PV panel and wind turbine are used for hybrid renewable power belongings. Using this renewable electricity resources to enhance the voltage degree inside the distribution network. In Solar energy is generating the power although the sun radiant slight and warmth. Solar energy is categorized into two main types: solar thermal and solar power. Solar thermal utilizes direct sunlight as a source of heat energy to generate hot water and fulfill household needs. On the other hand, solar power harnesses photovoltaic technology to convert sunlight into electricity. Photovoltaic systems are adept at transforming solar radiation into electrical energy efficiently, making them a preferred choice in this project. The photovoltaic (PV) panel functions as a semiconductor apparatus, converting solar radiation into electrical power (Afifi *et al.* 2014). Typically, it's miles few inches in period and produces about 1 Watt of electricity. In order to generate high power, PV cells are grouped in series and parallel circuits to shape a PV module. Hence, numbers of PV modules are electrically related in a chain-parallel configuration to generate the required cutting-edge and voltage. The PV array output electricity is stricken by the going for walks conditions and the net website online conditions inclusive of geometric location, irradiance level, and ambient temperature.

The mechanism of solar panels interlinks with the electrical grid in the ensuing way:

- As sunlight cascades upon the solar panels, they initiate the generation of direct current (DC) electricity.
- This DC electrical energy is conveyed into a solar inverter, which transfigures it into alternating current (AC) electricity at 240 V and 50 Hz.
- The 240 V AC electrical power is utilized to animate appliances within your dwelling.

In instances of sunlight exposure, including overcast conditions, the solar cells produce electrical energy. The grid-interconnected inverter alters the DC strength generated via the solar panels into 240 V AC power, that's then available for usage by the premises. In instances in which a grid-related gadget surpasses energy consumption, the excess energy is directed into the number one strength grid. Certain electricity providers meter the electricity contributed to the grid by your setup and issue a credit on your bill accordingly. The remuneration amount is contingent on the feed-in tariff. During periods of solar cell dormancy, such as nighttime, regular power is furnished by the primary power grid.

The energy provider levies the standard rate for the electricity consumed. Given that all components of a grid-connected system lack movable parts, one can anticipate an extended and hassle-free operational lifespan from their solar energy system. Substantial governmental solar incentives and rebates facilitate considerable savings on a grid-connected system for a specified duration. The various stages in the design of PV based system is shown in Fig 1.

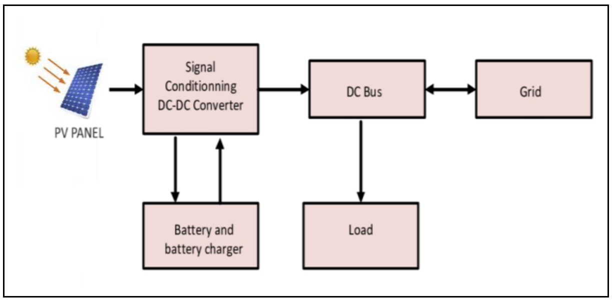

Fig. 1: Various stages in the design of PV panel-based system

Within the sector of wind turbines lies the tricky approach via which wind is harnessed to generate electricity. Wind generators, in essence, transmute the kinetic electricity inherent inside the wind into mechanical energy. Through the utility of a generator, this mechanical electricity may be in addition transmuted into strength. Alternatively, mechanical strength can be directly hired for precise undertakings, together with water pumping. The United States Department of Energy (DOE) has produced a concise animation elucidating the principles underlying wind electricity technology, thereby presenting a comprehensive expertise of wind turbine capability and the wind sources available across the US. Wind, a phenomenon spurred by the asymmetrical heating of the environment with the aid of the solar, the various topography of the Earth's floor, and the rotational movement of the planet itself, serves as the impetus for wind turbine operation. Various geographical features, consisting of mountains, bodies of water, and vegetative formations, exert impact upon the patterns of wind waft.

Wind mills harness the energy latent in the wind by means of propelling blade-like structures round a vital rotor. The rotational movement of the rotor impels the pressure shaft, thereby driving an electric generator. The efficacy of a turbine in harnessing wind energy is contingent upon 3 pivotal elements: wind velocity, air density, and the surface vicinity encompassed through the turbine blades. The equation governing wind electricity is expressed as follows:

$$P = \frac{1}{2} \rho A V^3 \quad (1)$$

2.1 Wind speed

The magnitude of energy within the wind is subject to fluctuations corresponding to the cubic function of wind velocity; put differently, if wind velocity undergoes a twofold increase, the energy within the wind escalates eightfold ($z^3 = 2 \times 2 \times 2 = 8$). Even minor alterations in wind velocity yield substantial ramifications on the available power potential within the wind.

2.2 Density of the air

The greater the density of the atmosphere, the higher the quantum of energy intercepted by the turbine. Atmospheric density is contingent upon factors such as altitude and temperature. At elevated altitudes, air tends to be less dense compared to sea level, and warm air exhibits lower density relative to cold air. All other factors held constant, turbines are poised to yield heightened power outputs when situated at lower elevations and in locales characterized by cooler mean temperatures. Owing to the influence of wind, the turbine initiates rotational motion driven by kinetic energy. This turbine, in turn, is linked to a generator via a shaft facilitated by a gearbox. The generator, in its operation, produces electrical energy which is subsequently integrated into the grid network. Notably, wind turbines have the capability to generate reactive power, which serves to offset the consumption of reactive power by loads within the distribution network. However, a significant drawback is encountered in the form of its potential interference with military security radar systems.

3. EXISTING SYSTEM

Conducting a load glide evaluation at the IEEE 14-bus distribution take a look at gadget includes utilizing the ETAP software program as a simulation tool. This machine incorporates a novel generator and 14 bus gadgets within the network. Through this setup, diverse parameters inclusive of voltage regulation, actual and reactive electricity, and power element are scrutinized. Employing ETAP software program allows an in-intensity examination of load drift dynamics across the distribution community. Initial observations screen a suboptimal nation in which voltage regulation on the bus nodes is notably poor, observed with the aid of a decline in energy component. Addressing these issues necessitates the method of solutions geared toward enhancing voltage law and power issue. The single-line diagram depicting the existing system is illustrated in Fig. 2.

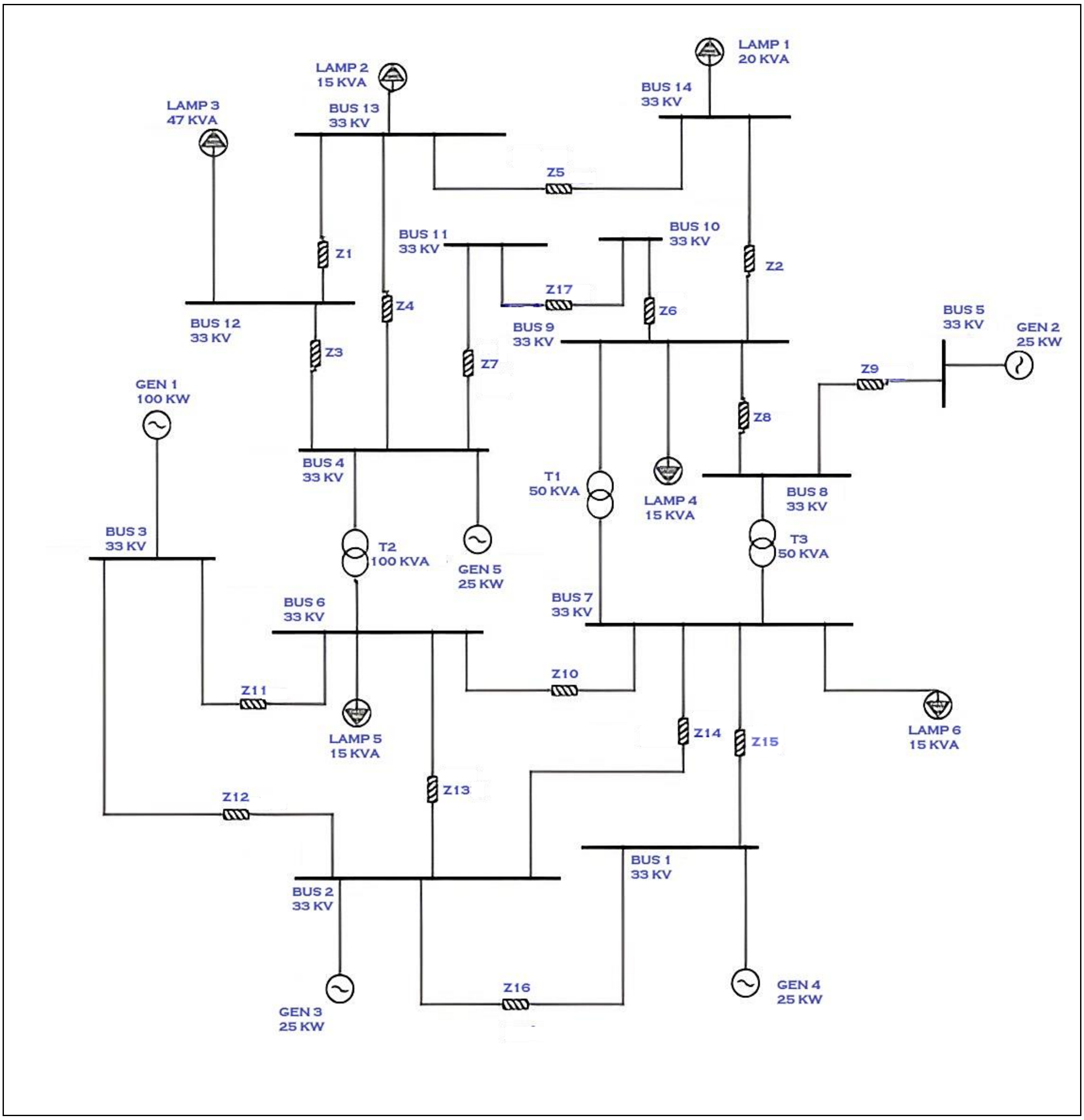

Fig. 2: Single Line Diagram of the IEEE 14-Bus Distribution System (Existing system)

4. PROPOSED SYSTEM

The primary objective of this proposed system revolves around enhancing voltage stability and power factor within the distribution network. In contemporary times, consumers predominantly rely on inductive loads, resulting in the absorption of reactive power from the distribution system and subsequent voltage degradation. Addressing this problem entails the injection of reactive electricity into the community, executed with the aid of integrating capacitors into the distribution gadget. Additionally, the incorporation of renewable power assets together with PV panels and wind turbines serves to mitigate transmission losses within the gadget.

There are six sources of power generation, one synchronous generator it must be used as slack bus, two PV panels and three wind turbines are used in this distribution system. There are three rating of transformers are used 100 KVA, 50KVA, 50KVA and the output is connected with the Loads. There are six different lumped loads are connected in the 14-bus test.

In this network there are five sources are used to reduce the losses in the network and four capacitors have been used to improve the voltage level in the distribution feeder. The single line diagram of the proposed hybrid system is shown in Fig 3.

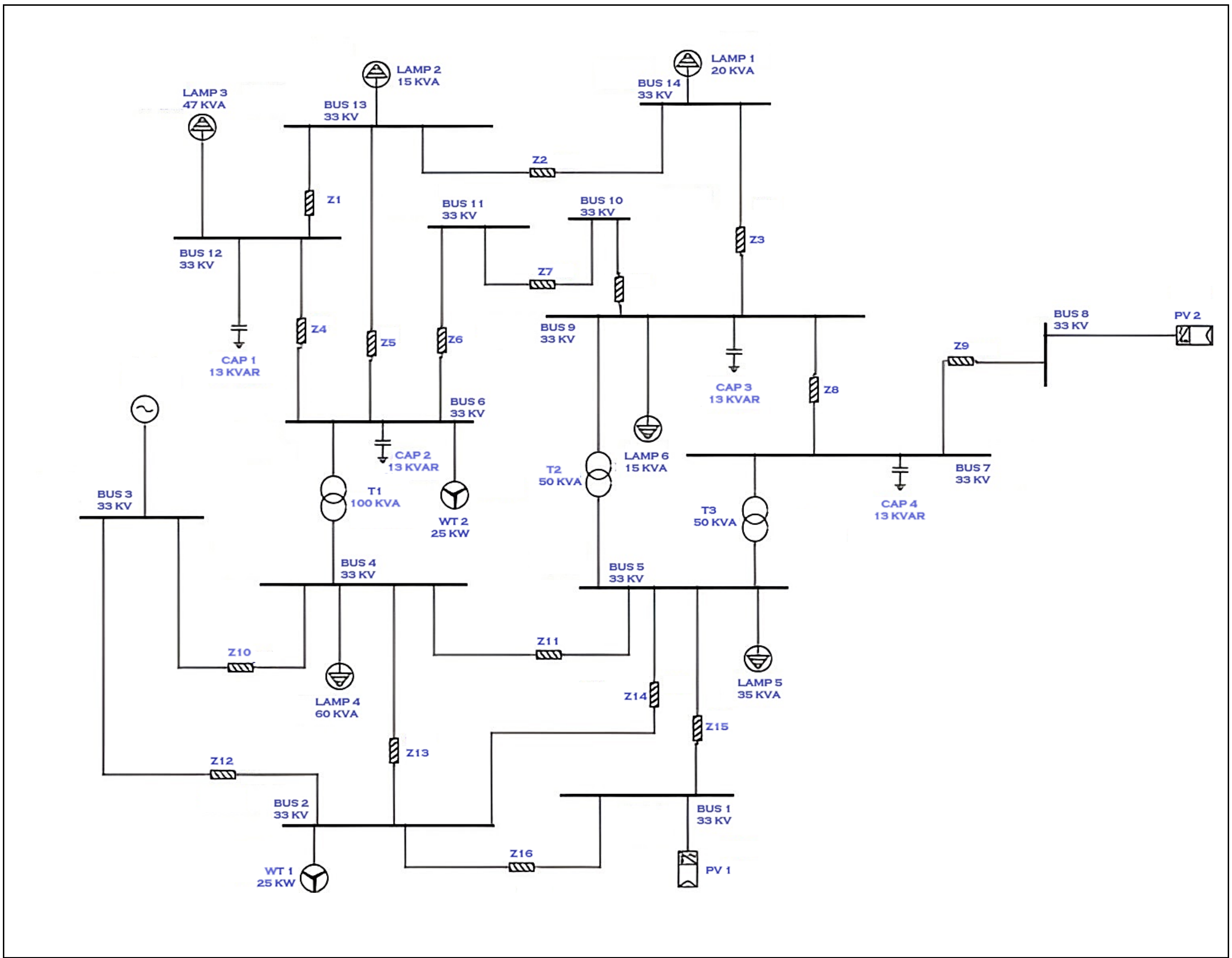

Fig. 3: Single line diagram of hybrid system using ETAP software

Table 1. Capacitor ratings

Capacitor	KVAR	Bus
Capacitor 1	13	6
Capacitor 2	13	7
Capacitor 3	13	9
Capacitor 4	13	12

In the both solar panels are YINGLI manufacture, YL 280 P-35b at 1000 max Vdc, 185 size(w), 7.64 imp(A) and 8.27 Isc (A). Cells are 10 in series and 1265 in parallel. Synchronous Generator was used as a swing. In the realm of contemporary power system simulation, ETAP emerges as a cutting-edge software solution, amalgamating both standard and advanced models to facilitate the meticulous modeling and simulation of diverse power systems. ETAP stands out by offering a comprehensive array of analyses, encompassing Load Flow, Short Circuit, Arc Flash, Transient Stability, and more. Notably, within this network configuration, four capacitors have been strategically integrated and its ratings are shown in Table 1.

5. SIMULATION RESULT

The final results of the Existing and Proposed system are tabulated in Table 2 and Table 3. The burden flow evaluation for the hybrid gadget is revealed through the usage of ETAP software program. In this state of affairs, upgrades in voltage ranges throughout the distribution network are executed by way of integrating hybrid renewable power sources with capacitors. Within the distribution network, the absorption of reactive strength because of inductive hundreds necessitates the usage of wind energy and capacitors to strengthen reactive energy levels, facilitated through the ETAP simulator software.

Table 2. Existing system report

FROM BUS	TO BUS	KW	KVAR	VOLTAGE REGULATION	I (AMPS)	POWER FACTOR (%)
Bus 1	Bus 2 Bus 5	3.622 21.378	-10.110 10.110	99.992	187.9 413.8	62.6 90.4
Bus 2	Bus 3 Bus 1 Bus 5 Bus 4	-24.039 -3.622 26.510 26.150	-33.478 9.823 13.995 9.660	99.993	721.1 183.2 524.5 487.8	58.3 63.7 88.4 93.8
Bus 3	Bus 4 Bus 2	58.470 24.040	41.168 33.242	100	1251.1 717.7	81.8 58.6
Bus 4	Bus 3 Bus 2 Bus 5 Bus 6	-58.467 -26.150 -0.180 17.543	-41.349 -9.862 17.088 24.073	99.990	1253.0 489.0 299.0 521.2	81.6 93.6 68.7 58.9
Bus 5	Bus 2 Bus 1 Bus 4 Bus 9 Bus 7	-26.510 -21.378 0.180 8.767 8.734	-14.179 -10.377 -17.158 12.023 12.012	99.989	526.0 415.8 300.2 260.4 259.9	88.2 90.0 41.8 58.9 58.8
Bus 6	Bus 12 Bus 13 Bus 11 Bus 4	12.673 33.817 -3.971 -17.529	12.622 13.998 -3.656 -22.964	96.956	322.8 660.4 97.4 521.2	70.9 92.4 73.6 60.7
Bus 7	Bus 9 Bus 8 Bus 5	33.722 -25.000 -8.722	11.459 0.001 -11.460	96.961	642.6 541.1 259.9	94.7 100.0 60.6
Bus 8	Bus 7	25.000	0.000	96.961	541.1	100.0
Bus 9	Bus 10 Bus 14 Bus 7 Bus 5	3.971 26.042 -33.722 -8.754	3.656 10.923 -11.456 -11.469	96.959	97.4 509.6 642.6 260.4	73.6 92.2 94.7 60.7
Bus 10	Bus 9 Bus 11	-3.971 3.971	-3.656 3.656	96.958	97.4 97.4	73.6 73.6
Bus 11	Bus 6 Bus 10	3.971 -3.971	3.656 -3.656	96.956	97.4 97.4	73.6 73.6
Bus 12	Bus 13 Bus 6	-28.288 -12.673	-10.428 -12.620	96.949	544.1 322.8	93.8 70.9
Bus 13	Bus 12	28.289	10.430	96.954	544.1	93.8
Bus 14	Bus 6 Bus 14 Bus 9 Bus 13	-33.817 -7.080 -26.041 7.081	-13.997 -4.559 -10.922 4.559	96.956	660.4 152.0 509.6 152.0	92.4 84.1 92.2 84.1

6. CONCLUSION

This manuscript delves into a real-time scrutiny of the IEEE 14-bus distribution lattice. By juxtaposing the network against a solitary generator and coupling it with renewable energy reservoirs, the inquiry uncovers a suite of quandaries plaguing the existing infrastructure under peak load exigencies. Predicaments encompassing diminished voltages, escalated line dissipations, overtaxed segments, and prospective expansion impediments are prevalent. A modus operandi is formulated herein to delineate the optimal locales for photovoltaic arrays and wind turbines alongside capacitors. Diverse hypothetical scenarios are scrutinized across a gamut of hybrid network amalgamations. It transpires that the amalgamation of photovoltaic arrays and wind turbines assuages the aforementioned anomalies within the distribution grid. By deploying a quintet of generation sources strategically stationed where entrenched loads subsist, and interspersing various capacitors to augment reactive potency, the proposed stratagem yields an enhanced voltage contour, augmented active potency, and ameliorated power coefficient. Moreover, real and reactive potency losses register a decrement. Notably, the voltage contour progresses from node 6 to node 12 escalates from 96.956 to 99.034, the active potency burgeons from 12.673 to 18.118, and concurrently, the power coefficient ascends from 70.9 to 99.2. Furthermore, in subsequent expansions, should additional loads necessitate provisioning, the surplus capacity of the network could be harnessed. Prospects exist for extending this inquiry nationwide across India, employing the aforementioned stratagems to mitigate line dissipations, bolster power coefficient, and enhance power quality countrywide, thereby fostering commendable voltage regulation. Distribution restoration assumes a pivotal role in the forthcoming "Smart Grid" epoch, furnishing the power grid at the distribution tier with an inherent self-rejuvenation capability. Swathes of demand in zones affected by service hiatuses ought to be expeditiously reinstated following isolation of faults. A restoration blueprint for distribution entails minimizing switching maneuvers and streamlining a sequence of operations to mitigate the repercussions of outages and amplify system reliability. The distribution system restoration quandary is a multifaceted, non-linear, combinatorial optimization conundrum replete with myriad constraints, encompassing topological, electrical, and operational caveats.

Table 3. Proposed system report

FROM BUS	TO BUS	KW	KVAR	VOLTAGE REGULATION	I (AMPS)	POWER FACTOR (%)
Bus 1	Bus 2 Bus 5	3.865 23.124	-8.976 8.976	99.994	171.0 434.0	95.5 93.2
Bus 2	Bus 3 Bus 1 Bus 5 Bus 4	-25.492 -3.865 28.492 3.858	-22.767 8.689 12.019 0.200	99.995	598.0 166.4 541.1 67.6	74.6 60.2 92.1 99.9
Bus 3	Bus 4 Bus 2	73.999 25.492	20.762 22.531	100	1344.6 595.2	96.3 74.9
Bus 4	Bus 3 Bus 2 Bus 5 Bus 6	-73.995 -3.858 -5.408 16.008	-20.942 -0.218 3.643 7.467	99.992	1345.5 67.6 114.1 309.1	96.2 99.8 82.9 90.6
Bus 5	Bus 2 Bus 1 Bus 4 Bus 9 Bus 7	-28.498 -23.123 5.408 8.008 7.998	-12.203 -9.243 -3.649 3.717 3.699	99.991	542.4 435.7 114.2 154.5 154.2	91.9 92.9 82.9 90.7 90.8
Bus 6	Bus 12 Bus 13 Bus 11 Bus 4	18.118 31.693 -4.811 -15.999	17.167 4.612 -4.503 -7.077	99.034	279.7 565.8 116.4 309.1	99.2 99.0 73.0 91.5
Bus 7	Bus 9 Bus 8 Bus 5	10.992 -2.999 -7.993	19.200 0.000 -3.505	99.042	390.8 53.0 154.2	49.7 100.0 91.6
Bus 8	Bus 7	2.999	0.000	99.042	53.0	100
Bus 9	Bus 10 Bus 14 Bus 7 Bus 5	4.811 26.721 -10.992 -8.004	4.503 10.072 -19.199 -3.522	99.038	116..4 504.5 390.8 154.5	73.0 93.6 49.7 91.5
Bus 10	Bus 9 Bus 11	-4.811 4.811	-4.503 4.503	99.036	116.4 116.4	73.0 73.0
Bus 11	Bus 6 Bus 10	4.811 -4.811	4.503 -4.503	99.035	116.4 116.4	73.0 73.0
Bus 12	Bus 13 Bus 6	-26.336 -14.625	-0.192 -7.166	99.031	474.2 279.7	100.0 89.2
Bus 13	Bus 12	26.843	0.193	99.033	474.2	100.0
Bus 14	Bus 6 Bus 14 Bus 9 Bus 13	-31.692 -7.759 -26.720 7.759	-4.611 -3.708 -10.071 3.708	99.035	565.8 151.9 504.5 151.9	99.0 90.2 93.6 90.2

SCOPE FOR FUTURE STUDY

The conception of a self-repairing power grid capable of anticipatory response to disturbances holds promise for elevating system dependability and customer contentment in forthcoming power networks. This research endeavors to pioneer novel methodologies and apparatuses in this realm, fostering the capacity of expansive national infrastructures to autonomously rectify in the face of hazards, material deficiencies, and other destabilizing factors. Against the backdrop of burgeoning global concern for energy governance and preservation, diminutive energy regulators the Internet of Things (IoT) are poised to propagate the advantages of interconnectedness beyond the precincts of dispensation, automation, and surveillance currently overseen by utility purveyors. Oversight systems tailored for domestic and commercial usage will empower consumers to scrutinize their energy consumption and modulate their behaviors an endeavor known as Demand Side Management (DSM). These frameworks will gradually evolve to effectuate automatic regulation, functioning during periods of minimal energy demand and interfacing with sensors to monitor occupancy, luminance levels, and sundry other parameters. Yet, the genesis of this paradigm shift lies in the establishment of a smarter, more interlinked grid.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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