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Using Renewable Energy Sources on Micro grid System to Assess Generation Reliability

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Abstract: ***Micro grid allows incorporation of different distributed energy resources like energy storage system ESS and distributed diesel generator is used. However, the essential requirement is considered as maintenance of generation reliability with micro grid topology addition. The major objective of this proposed study is to evaluate the reliability of the proposed micro grid system with renewable energy sources of PV, wind and battery. In generation system, the customer load point's reliability assessment are evaluated using reliability indices. Based on simulation results it has observed that the renewable DG resources have great effect on generation reliability.***

Keywords: Micro grid, Generation Reliability Assessment, Wind, PV, Battery, Distribution Generator, Priority Load

1. Introduction

In today's world the micro grids together with renewable energy resources is growing and the need also increased. In power systems, the engineers and researchers look for more economic and efficiency of these systems. the challenges seen while using renewable energy is overcome by Energy storage system incorporated with renewable energy resource system [1]. At an economic cost, electrical energy availability considered as power system reliability. The reliability optimization contributed into total cost minimization. While distributed energy sources integrating the micro grid is appeared while increase in renewable energy resources seen. The distribution generation DG unit is increasing the multiple DG units organized symmetrically contains in micro grid has proposed in this study. The micro grid can be analyzed in two scenarios such as, micro grid with energy storage system and micro grid without an energy storage system [2, 3]. The reliability and economic costs has been mainly considered for the performance of the system. The micro grid components are shown in figure 1.

Figure 1: [4]Micro Grid components

The micro grid development provides quality power and reliability to consumers. A micro grid can be hybrid mode - the combination of AC or DC, AC and DC. It also can be single phase or three phases connected to distribution network low voltage or medium voltage [5]. On a small scale the micro grid system are designed with PV, wind or battery or the combination two or energy sources. The micro grid features shows the generating ability in small scale power system and the electrical energy flow in regulated and distributed manner. The advantages of micro grid includes enhanced reliability, economic growth, more revenue making and saving money [4]. The distribution energy system for residential part includes wind turbines, battery, PV photovoltaic and so on and for industrial or commercial field wind, heat and power system, PV photovoltaic cell, biomass combustion and others [6]. For PV power, with the help of sun's energy which is thermal or heat energy directly or from PV panel of photovoltaic cell, the electricity generated. The PV panels can be kept on roof and it generate direct current DC electricity only. By suing PV or boost inverter the DC current converted into AC [7]. For battery power, a battery that saves energy and discharges by chemical energy into electricity conversion. Through parallel or series circuit batteries are connected. For the wind kinetic energy can be converted into mechanical power by wind turbines. The mechanical power can be used for pumping water or grinding grains or with the help of generator it can be converted into electricity [8].

Generation system reliability is the most important part in this study and it provides reliability measurement and evaluate total performance of the generation system capacity which is sufficient to provide adequate electricity if required. The generation system is vital part of electricity supply chain and ensures about the generated electricity which meet the demand.

The main contribution of the paper is a hybrid method of micro grid with combination of battery, PV and wind power established. The simulation techniques used to evaluate the reliability at customer load point in generation system. The simulation methods used renewable energy resources variations and reliability indices.

1.1 Paper organization

The proposed study organized as literature survey presented in section II. The methodology of the proposed work emphasize on generation reliability assessment elaborated in

section III. The results and discussion depicted in section IV. Followed by the paper concluded in section V.

2. Review of Existing Works

This section briefly explains the literature review of the proposed micro grid system using various renewable energy sources. [9, 10] This study focused on large scale storage of battery reliability with various battery modules assessed. The evaluating system reliability consists of convertor of DC AC power electronics and separate battery modules. The battery cell state of health introduced in this study to evaluate the battery model reliability. For reliability evaluation universal generating function UGF presented in this paper. The analysis presented with various approaches of management and system configuration mainly performed for system of battery storage. For reconfigurable battery energy storage system RBESS compared with basic BESS, the RBESS reliability system and power output values shows greater in RBESS. [11] This paper emphasized on the future generation of energy contributed by renewable energy sources. The conservative power plants discharged energy crisis and greenhouse gases which have been decreased by renewable energy sources of wind and PV resources of energy. The renewable distributed generation impact and power outrage cost calculated by reliability evaluation. The requirement of consumer load with photovoltaic, system of electric storage and wind turbine generator penetration satisfied by distribution system reliability assessment. The reliability influence analyzed by proposed Markov model. The results shows that the improved reliability has been seen.

[12] In the present study, the renewable energy source of mathematical model depends on meteorological processing of data have been proposed. The realistic situation integrated by the pumped storage hydro plant with multi state model upper reservoir probability have been designed. The system of PV wind energy reliability assessment integrating with pumped storage hydro plant have been made. Monte Carlo simulation and analytical method used to assess reliability. This paper pumper storage hydro plant system possess reliable higher than the system comprised of battery storage.

[13] According to this study, the automotive industry used clean source of energy. The electric vehicles introduction in renewable energy sources have been focused by big companies. The safety and reliability of the electric vehicle have been assessed considered as major challenge in this paper. The electric vehicle comprised of electrical system lifetime performance have been based on power electronic convertor, electric motor and battery pack. The electric vehicle reliability has been studied in this paper. Generally the reliability method of classification has shown in following figure 1.

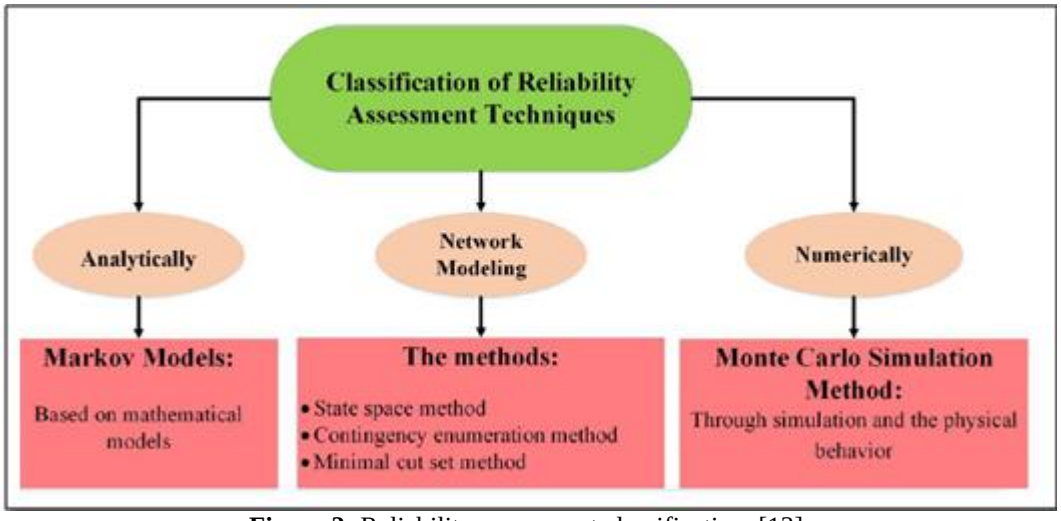


Figure 2: Reliability assessment classification [13]

[14] Based on renewable energy generation like wind, PV, distributed generation and micro grid the Monte Carlo Simulation and Distribution system reliability assessment DSRA have been evaluated in this study. Because of higher time in computing the reliability evaluation has been focused on compact system. The renewable energy source randomness stated by numerical states. [15] In this research, the power system reliability increased and over dependency decreased by measures of renewable energy sources. The traditional micro grid power system enhanced and annualized energy cost decreased by system of battery storage, wind turbine generator and photovoltaic. Using Markov model the reliability influences reviewed. The renewable energy based technology of distributed generation applications obtained better performances.

[16] Based on micro grid system, the renewable energy resources of environmental, reliability and economy assessments have been focused in this study. The main motivation of this paper involves to reduce all costs and green technologies benefits enhanced. The reliability improvement obtained by using basic probability. The renewable energy sources of optimal feasibility in system of micro grid has been elaborated in this study. Related to power outages, the socioeconomic issues and projects of rural electrification have been studied. [17] For the wind energy conversion system (WEC) lifetime evaluation and thermal behavior evaluation, the specific function influence and strong micro grid operation of different modes have been considered in this study. The Joint probability distribution function has been used in this work which joints

wind generation gathered field of data and level of load demand. The results obtained shows that the WEC reliability evaluation and thermal behavior have impacted greatly by specific function in the study.

[18] Based on data of historical wind speed this research work proposed statistical model of 2 - D wind speed. Various scales of wind speed time duration probability distribution seen in first dimension. Each scale of wind speed probability distribution seen in second dimension. Micro grid reliability evaluation technique has been integrated in this study and effectively used by the researchers.

[19] With respect to degradation in performance of Hidden Markov model has developed in this study which possess novel reliability evaluation method. The proposed model probability state leads to reliability curve. Based on wind turbine sample data the proposed work of reliability assessment has been made. The reliability validity has been proved finally. [20] According to this study the load of high priority and the load of low priority have been categorized for load and technique of load shifting imposed. Based on high reliability and low energy cost standalone hybrid energy systems of wind/PV/battery or diesel have been proposed for sizing of techno economic program. The production of energy has been maximized. For decision makers appreciated results obtained. [21] This study reveals the load management – a smart grid technique reduce the renewable energy system of hybrid components and also the energy costs. Wind turbines, diesel generator, photovoltaic array, fuel cells and batteries considered as source of energy. The optimal size find out by particle swarm optimization. The results shows that the load division percentage has been inversely proportional to generated energy cost.

[22] The PV water heater cost maintenance of lifetime estimated by probability model. For various system configurations supply of hot water price computed. Analysis based on sensitivity executed for products economic viability. [23] The reliability assessment and the respected system of energy storage has been evaluated. Particle swarm optimization used for optimizing load series. System of energy storage participation designed with demand management. The power system reliability has been finally assessed reveals the proposed approach validity.
Hence the above related papers were discussed and analyzed.

3. Proposed Technique

On micro grid topology, the proposed method analyze the reliability which presented by micro grid generation with renewable generation presence. The distribution energy system also enhances the generation system reliability in which they are connected. However the renewable energy sources impose various challenges in power system planning and operation. Based on several factors like geographical location and weather conditions the renewable energy source output has depended. Based on the source of energy like wind, PV and battery, the renewable energy source possess various features. For all renewable energy sources using common model is difficult or using similar models in which the conventional generators utilized. The unavailability, repair time and own failure rates are unavoidable in some cases by renewable energy source generator. The reliability evaluation is focused in this proposed reliability study which involves simulation methods.
The reliability evaluation has been done in following cases,
Case 1: For three general distributor Generator unit
Case 2: For DG and battery resources
Case 3: For DG and PV energy resources
Case 4: For DG and wind energy resources
Case 5: For DG and PV and battery
Case 6: For DG and wind and PV
Case 7: For DG and wind and battery
Case 8: For DG and PV and wind and battery

Component Specification

Component	Rated input	Failure rate/year (λ)	Repair rate/year (μ)
Generator [24]	1400 watt	0.08	2.7625
PV System [24]	1400 watt	0.01	0.0037
Wind Turbine [25]	1400 watt	0.02	0.0625
Battery [24]	- - - - -	0.05	0.125

3.1 Reliability Assessment

To perform generating capacity adequacy assessment various methods have been followed. By mathematical models the evaluation methods represented [26]. By simulating system random behavior and actual process the reliability indices are estimated. The basic reliability indices are,

Loss of Load Probability LOLP
Loss Of Load Probability LOLP estimated by regular peak load for duration of one year and in some cases for every hour load for 24 hours per day. The LOLP calculation denoted by mathematical formula as,

$$LOLP = \sum_j P[C_A = C_j] . P[L > C_j] \sum_j \frac{P_j - t_j}{100} \quad (1)$$

Where,
P denoted as probability, L is expectable load, C_A is the available generation capacity, C_j = left over generating capacity, P_j is the capacity outage probability and t_j is denoted as when load exceed C_j the percentage of time measured.

Loss of Load Expectation LOLE
The Loss of Load expectation is usually used more than LOLP index probability in daily applications. The LOLE and LOLP relationship denoted by following equation 2,

$$\text{LOLE} = \text{LOLP x T} \quad (2)$$

Where,
- T is 365 days with annual continuous load curve and unit is days per year.
- T is 8760 hours for hourly loaded curve and unit is hours per year.

In index case the LOLE is formulated as,

$$LOLE = \sum_{k=1}^{n} P_k t_k = \sum_{k=1}^{n} (t_k - t_{k-1}) P_k \quad (3)$$

Where,
n is defined as total number of capacity outage, P_k
Cumulative probability and t_k = number of time when loss of load exist.

Expected Energy not supplied EENS
The expected energy not supplied is calculated by given formula 5,

$$EENS = \sum L_k D_k F_i \quad (4)$$

$$EENS = \sum L_k P_k \ 8760 \quad (5)$$

The term L_k defined as load current, D_k is the rate of departure and F_i is the frequency.

Reliability
The reliability of a parallel system having n number of component is given by formula 6,

$$R = 1 - \prod_{i=1}^{n} (1 - e^{-\lambda_i t}) \quad (6)$$

Here λ denotes the failure rate of the component and t denotes the time.

3.2 Method of Assessment

The reliability assessment steps determined as,

Phase 1 - From the ancient data the aggregate distribution of wind and PV radiation is obtained.

Phase 2 - For required number of samples, simulated values of PV radiation and wind speed generated by inverse transformation method and cumulative distribution functions. Random number X generation required for every sample.

Phase 3 - Using wind power curve the wind speed converted to wind power and similarly PV power generation by PV radiation.

Phase 4 - The output of all renewable energy sources are combined and if all loads cannot supply by renewable energy source then at first the highest priority is provided by following load in list of priority and others.

Phase 5 - Each of the load points are counted by RES in which the number of occurrences at load supplied.

Phase 6 - Then the LOLP, LOLE, LOEE, EENS, EDLC, ELS and NLC reliability indices are calculated.

Phase 7 - Based on the index results of the previous phase, the performances evaluated.

3.3 Proposed Flow

There are 8 stages followed in proposed reliability assessment on renewable energy sources.

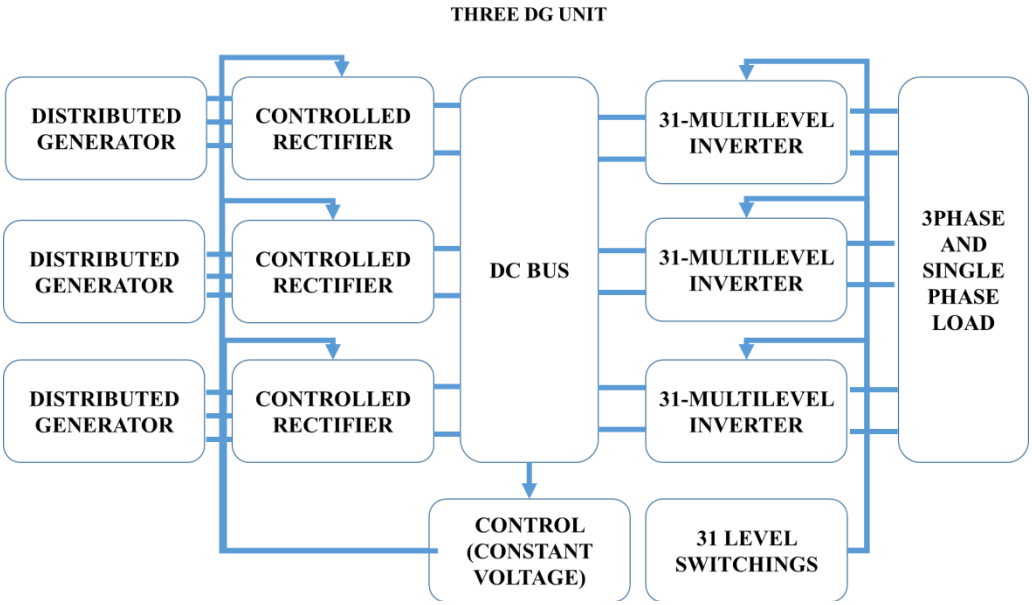


Figure 3: Case 1

There are three phase distributor generator DG presented shown in above figure 2 which converts AC to DC by the rectifier. The distribution generator performed like single structure and it is a part of micro grid. While connecting to distribution lines of lower voltage from electric utility the DG provided clean and reliable power. The electricity loss also decreased further. Then rectifier connected into DC bus contains all DC which next convert into AC. During conversion it takes 31 levels for changing from irregular to similar form and finally send to 3 phase load.

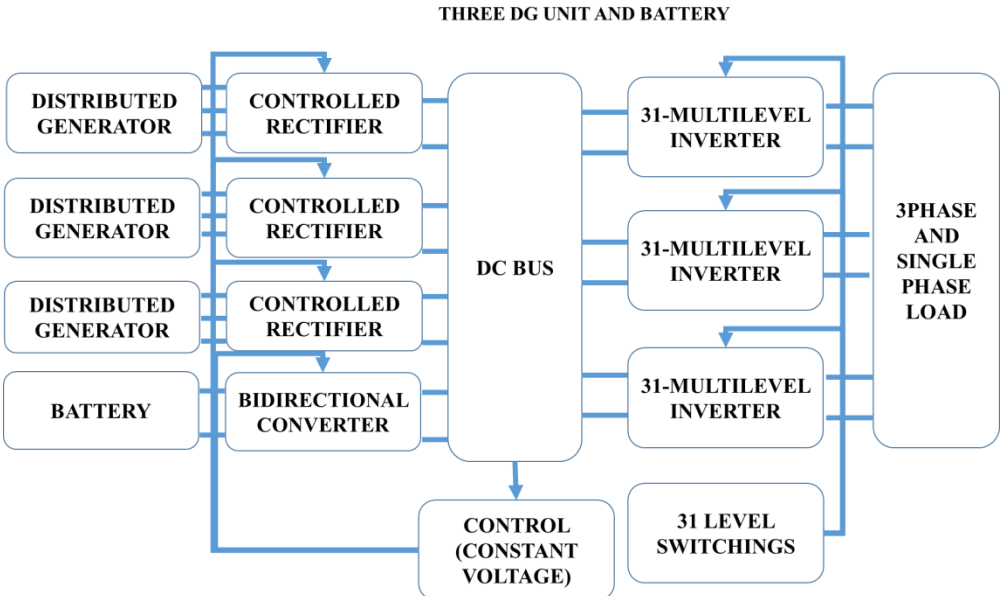


Figure 4: Case 2

In addition to three phase DG, the battery is included to analyze the performance. For charging and discharging feature the bidirectional convertor is used. While converting chemical energy into electrical energy, the battery can save electric charges and direct current DC is generated.

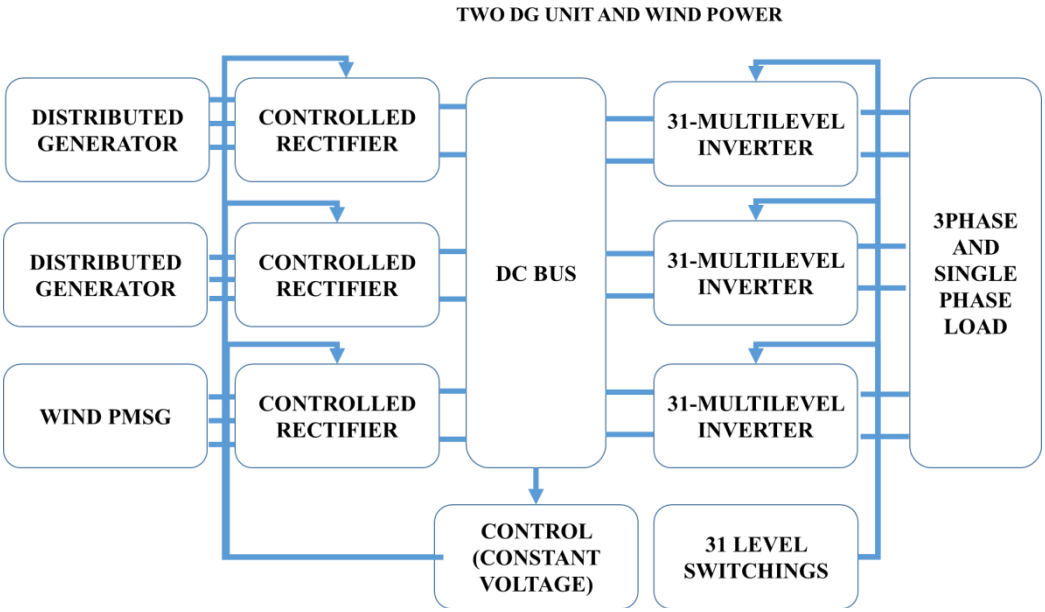


Figure 5: Case 3

Instead of one DG from figure 2 the wind power is included as shown in figure 4. For wind also the rectifier is connected for AC to DC. The performance has been analyzed further. Through wind turbines the mechanical power is provided using wind energy.

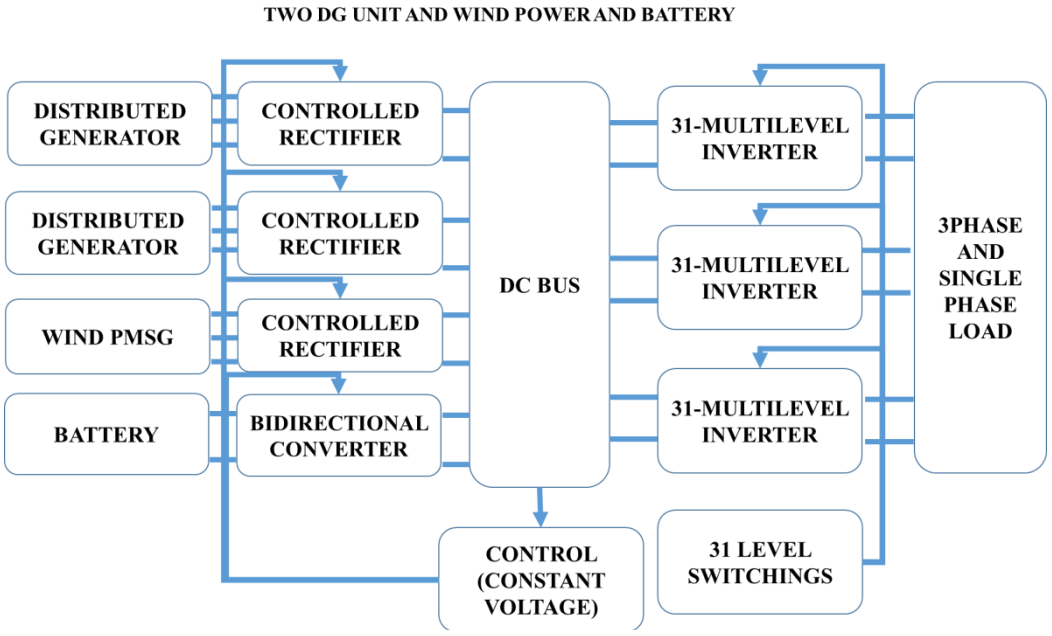


Figure 6: case 4

The above figure 3 and 4 combined and showed in figure 5. The wind and battery performances connected to rectifier and convertor analyzed respectively.

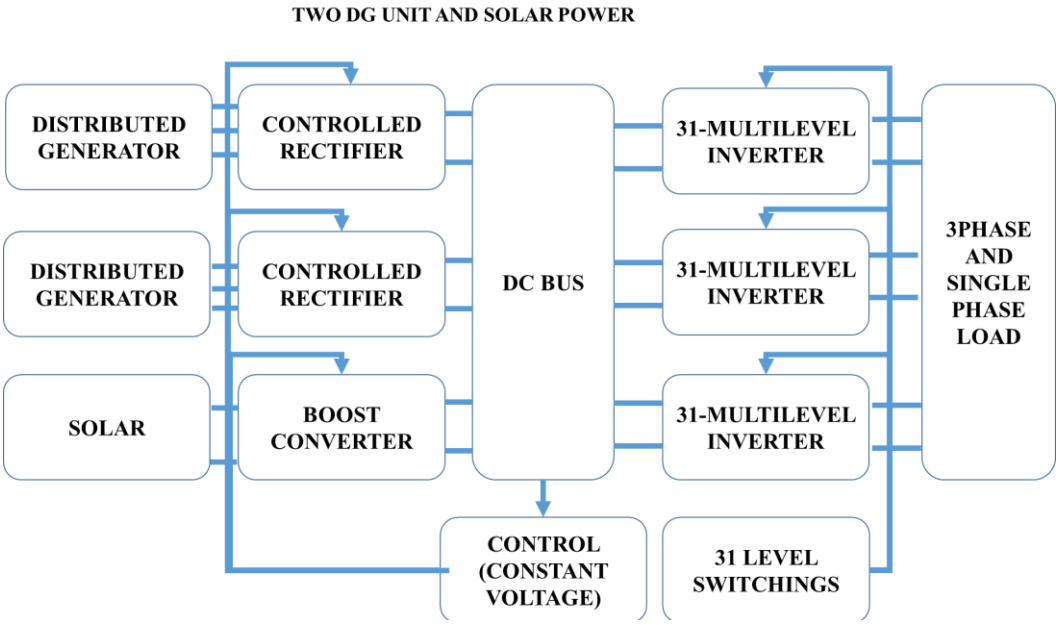


Figure 7: Case 5

Instead of one DG unit the PV energy source connected with boost convertor as shown in figure 6. PV power converting sunlight energy into electricity by photo voltaic directly or by concentrated PV power indirectly or by combining these two. The boost convertor can convert the DC current to AC since PV power generate only DC.

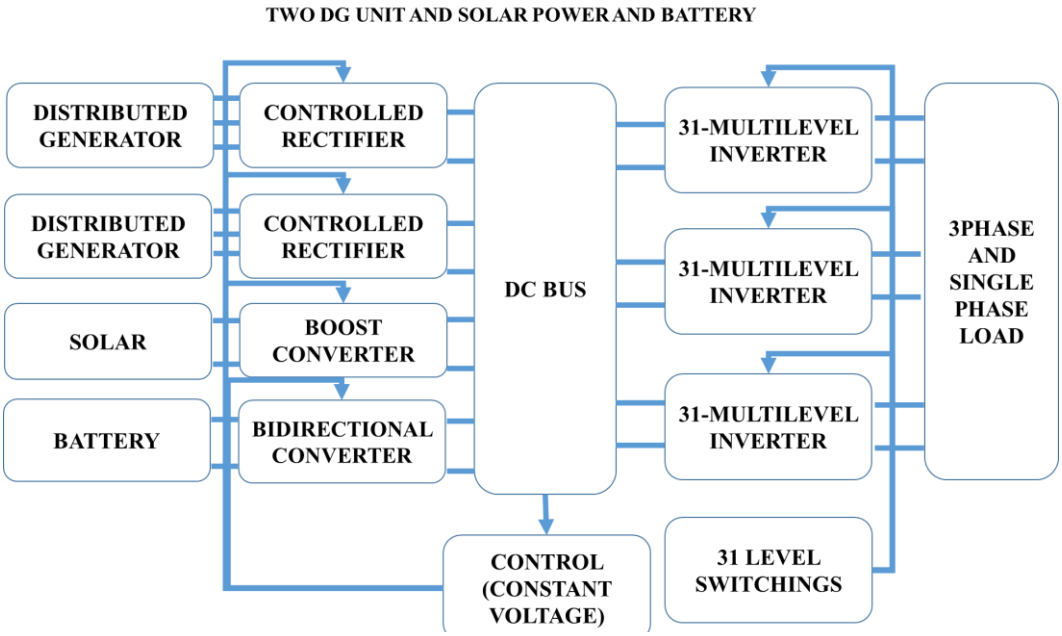


Figure 8: Case 6

In addition to two distributed generator, PV and battery energy source added and the performance analyzed on single phase load.

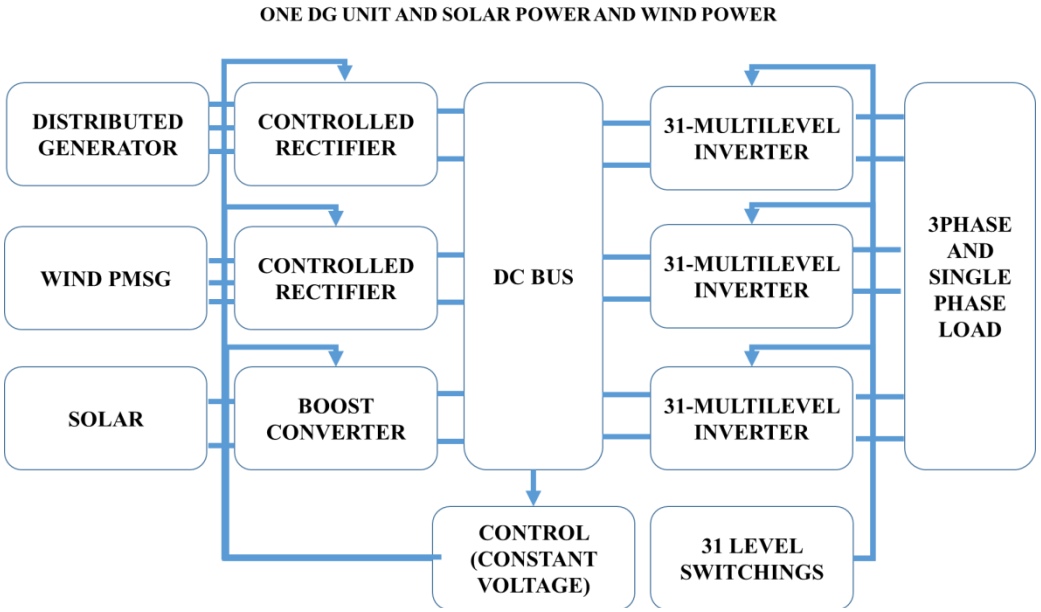


Figure 9: Case 7

In this stage with one distributor generator the wind power and PV power included with respective rectifier and convertor. The outcome has been analyzed further.

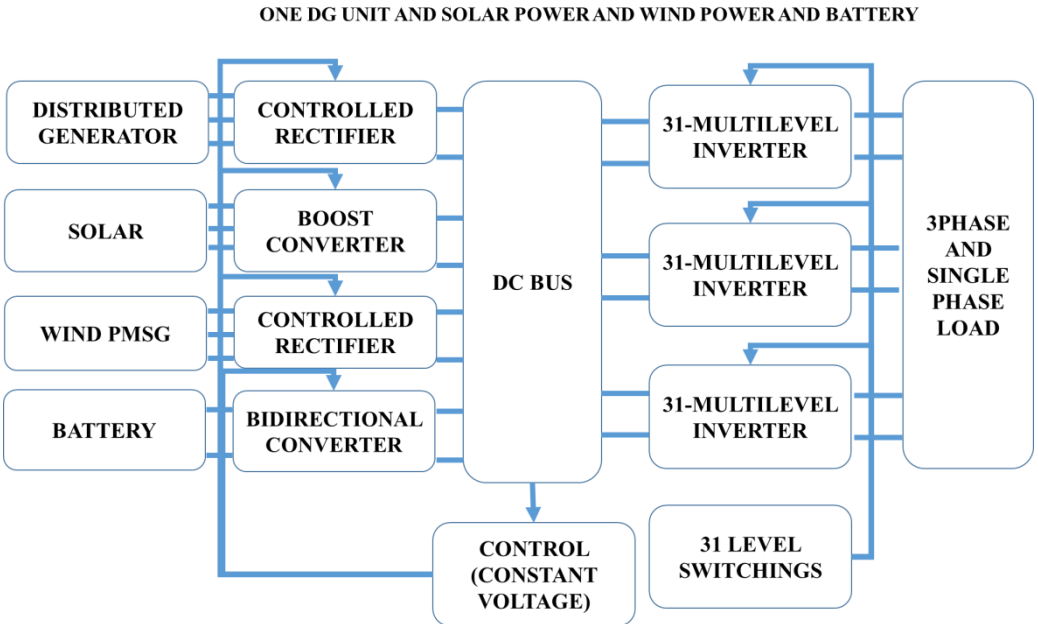


Figure 10: Case 8

The final process shows the combination of wind, PV and battery power and DG unit. It is expected that this final proposed process shows better performance with respect to renewable energy resources.

4. Results and Analysis

The performance analysis of the proposed reliability assessment for various renewable energy sources have determined below.

4.1 Performance analysis

1) Case 1:

The results of three distributor generator unit with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 1.

Table 1 - Case 1:

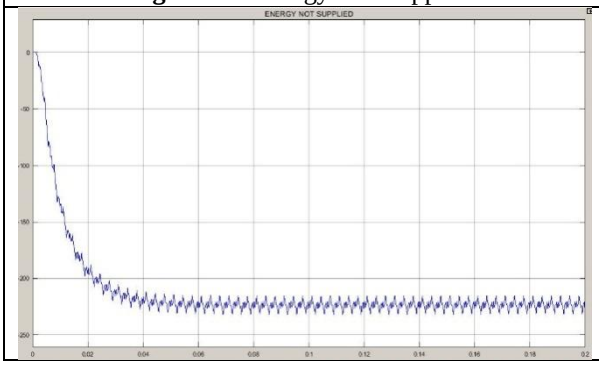
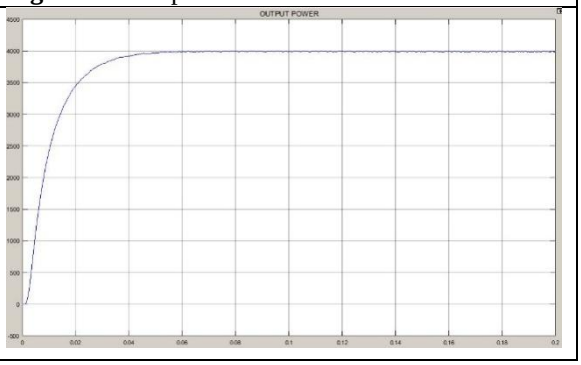
Figure 11: Energy Not Supplied	**Figure 12:** Output Power
	

Figure 11 - For not supplying Energy

The above figure 11 determines the energy of the three distributor generator unit Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 12 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 13.

2) Case 2:

The results of three distributor generator unit and battery with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 2.

Table 2 - Case 2:	

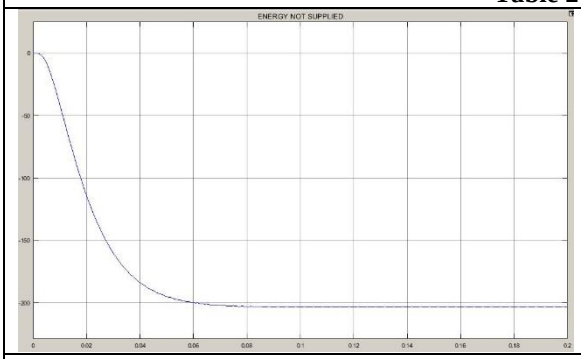
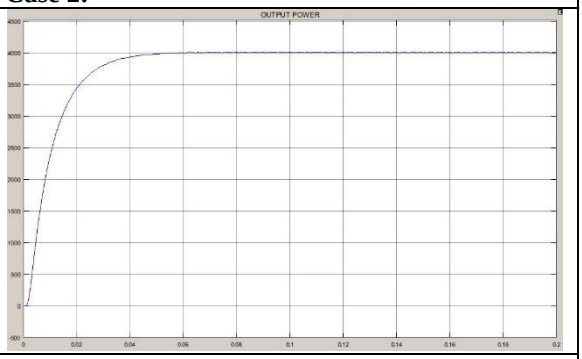

	

Figure 13: Energy Not Supplied	**Figure 14:** Output Power

Figure 13 - For not supplying Energy
The above figure 14 determines the energy of the three distributor generator unit and battery Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 14 - Output power
Similarly for output power also for variations in time increases the output power increases shown in figure 13 for three DG unit and battery.

3) Case 3:

The results of two distributor generator unit and wind power with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 3.

Table 3 - Case 3:	

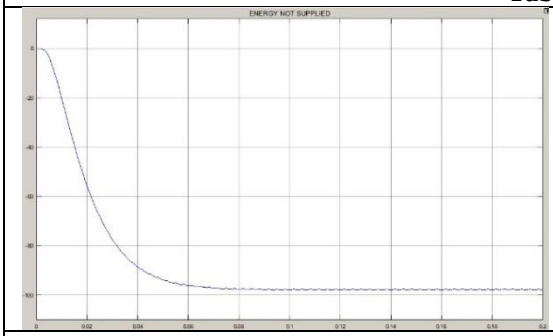
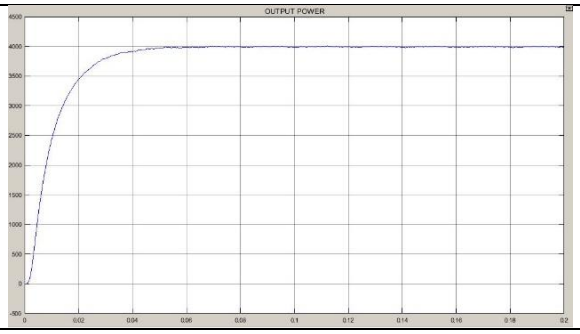

	

Figure 15: Energy Not Supplied	**Figure 16:** Output Power

Figure 15 - For not supplying Energy The above figure 17 determines the energy of the two distributor generator unit and wind power Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 16 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 13 for two DG unit and wind.

4) Case 4

The results of two distributor generator unit, wind power and battery with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 4.

Table 4 - Case 4:	

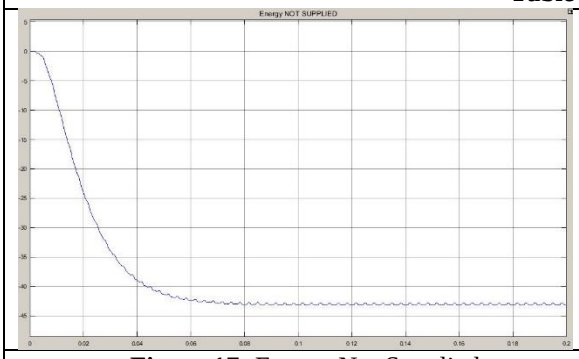
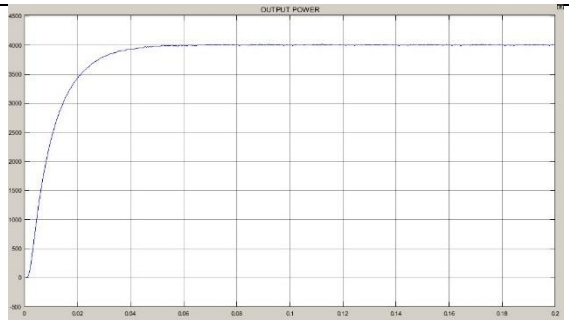

	

Figure 17: Energy Not Supplied	**Figure 18:** Output Power

Figure 17 - For not supplying energy

The above figure 20 determines the energy of the two distributor generator unit, wind power and battery Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 18 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 22 for two DG unit, wind and battery.

5) Case 5

The results of two distributor generator unit and PV power with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 5.

Table 5 - Case 5:

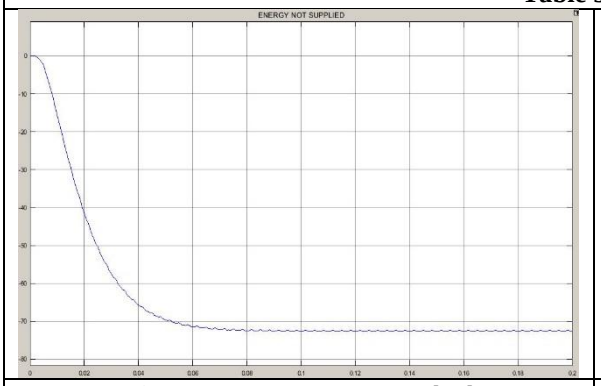


Figure 19: Energy Not Supplied

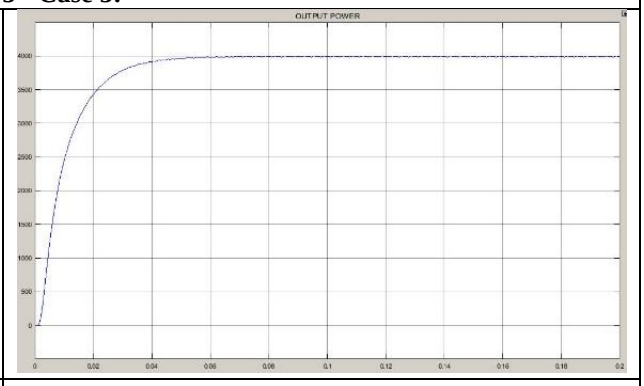


Figure 20: Output Power

Figure 19 - For not supplying Energy

The above figure 23 determines the energy of the two DG and PV Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 20 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 25 for two DG unit, PV power.

6) Case 6:

The results of two distributor generator unit PV power and battery with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 6.

Table 6: Case 6:

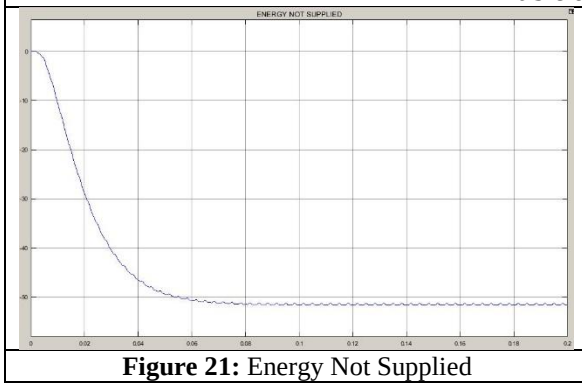


Figure 21: Energy Not Supplied

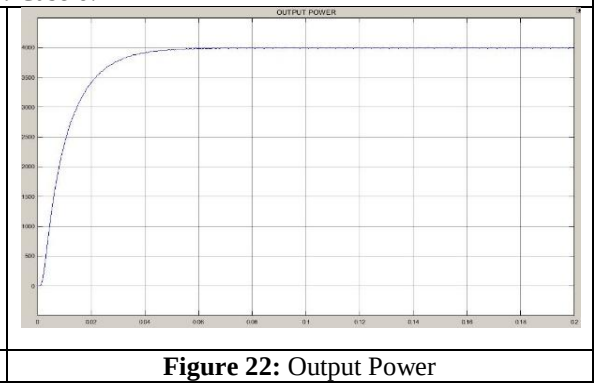


Figure 22: Output Power

Figure 21 - For not supplying Energy

The above figure 26 determines the energy of the two DG, PV and battery Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 22 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 28 for two DG unit, PV power and battery.

7) Case 7

The results of two distributor generator unit, PV and wind power with respect to input power, output power and energy

not supplied has been analyzed and graphically described below table 7.

Table 7 - Case 7:

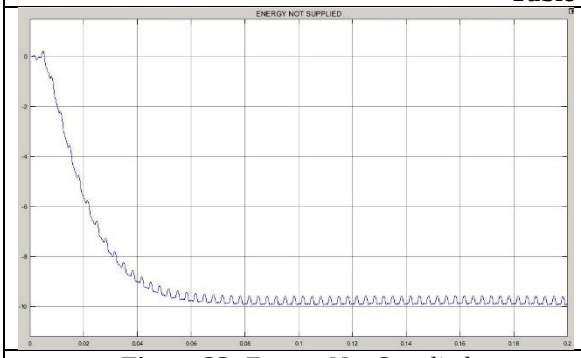


Figure 23: Energy Not Supplied

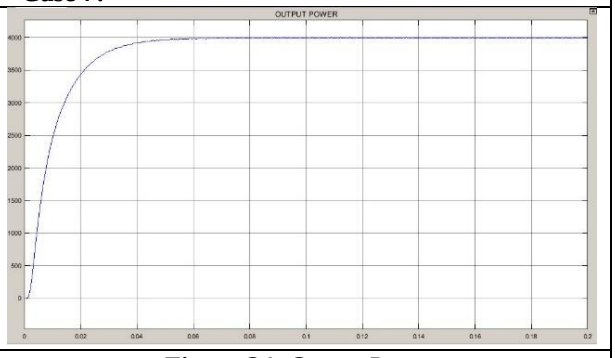


Figure 24: Output Power

Figure 23 - For not supplying Energy

The above figure 29 determines the energy of the one DG, PV and wind Vs time. In response to time variations increases the energy not supply has been reduced.

Figure 24 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 31 for one DG unit, PV power and wind.

8) Case 8

The results of one distributor generator unit, PV, wind power and battery with respect to input power, output power and energy not supplied has been analyzed and graphically described below table 8.

Table 8 - Case 8:

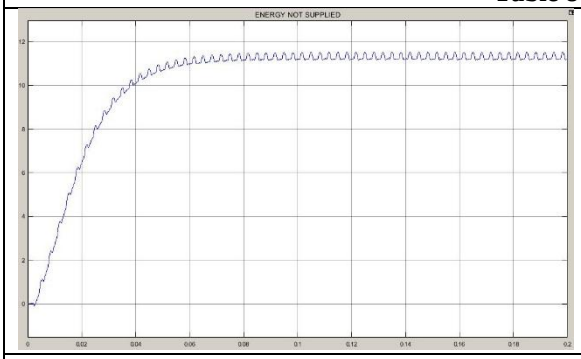


Figure 25: Energy Not Supplied

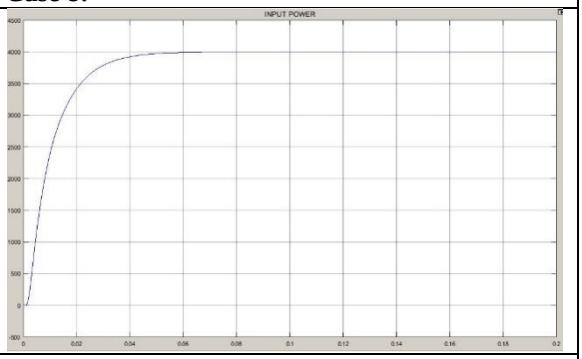


Figure 26: Output Power

Figure 25 - For not supplying Energy

The above figure 32 determines the energy of the one DG wind, battery and PV Vs time. In response to time variations increases the energy not supply has been increased further and the better performance finally resulted.

Figure 26 - Output power

Similarly for output power also for variations in time increases the output power increases shown in figure 34 for one DG unit, battery, PV power and wind.

Reliability Evaluation:

The reliability assessment for the proposed micro grid system with renewable energy resources has been analyzed for every stage tabulated below in table 9. With respect to reliability indices of LOLE Loss Of Load Expectation and LOLP Loss Of Load Probability the reliability determined and shown in table 10.

Table 9: Reliability assessment Reliability

3DG	3DG and battery	2DG and wind	2DG, wind and battery	2DG and PV	2DG, PV and battery	1DG, PV and wind	1DG, PV, wind and battery
76.93	96.9	97.6	98.43	97.99	98.57	98.87	99.9

Table 10: Reliability indices values

Reliability indices	3DG	3DG and battery	2DG and wind	2DG, wind and battery	2DG and PV	2DG, PV and battery	1DG, PV and wind	1DG, PV, wind and battery
LOLP	0.01891	0.015697	0.0080928	0.003467	0.0060492	0.0041306	0.00083694	0.00000066935
LOLE	68.075	56.511	29.134	12.481	21.777	14.87	3.013	0.0024097

4.2 Discussion

With respect to all the stages of three, two and one distributor generator unit and combined with renewable energy sources, the performance metrics such as input power, output power and energy not supplied values are determined and graphically explained above. From the all 8 stages the final stage of one DG unit, PV, wind and battery utilization shows better results. However the input power and output power values are same for all stages. Apart from 8th stage, the rest of all stages shows energy not supplied in decreased state. From the assessment of reliability it stated that the one DG with wind, PV and battery renewable energy source performances are far better compared to other stages as shown in table 9.

With respect to reliability indices LOLE and LOLP, all the stages of distributor generator unit and combined renewable energy sources performances evaluated. It shows that the 1DG, wind, PV and battery shows higher performances compared to other types tabulated in table 10.

5. Conclusion

To measure the renewable distributor generator DG resources impact in traditional power distribution system of micro grid, the reliability method is considered as performance indicator. Based on simulation results it has observed that the renewable DG resources have great effect on generation reliability. To increase the reliability of the systems the power utilities should encourage the incorporation of renewable energy resources. Finally this paper concluded that the wind, PV and battery renewable energy sources with one renewable distributor energy resources unit exhibited better generation reliability and hence the performances have increased.

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