Impact of PV, WT, GTG, and ESS on the Reliability of Distribution System

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ABSTRACT:
The addition of renewable energy sources to the traditional distribution network has transformed the centralized unidirectional power source into two-way and multiple power source system. This will improve overall system's reliability and also reduces the down time that are associated within the radial distribution system. This paper investigates the impact of distributed energy sources like PV, Wind, Electric Storage, and Gas Turbine Generator on the reliability of distribution system. The Monte Carlo simulation method is used to test bus-2 of IEEE RBTS distribution network. The distribution network has been customized to incorporate the WT, PV, ESS, and GTG distributed generation. The WT and PV stochastic models were employed to replicate the unpredictability of these sources since speed of wind and solar radiation are both unpredictable. This work shows that the integration of distributed generation enhances the distribution system's reliability.

KEYWORDS: Reliability Assessment, Distributed Generation, Customer Interruption Cost, Energy Storage.

1. INTRODUCTION

Since the beginning of electricity's evolution, the electrical power network is used to produce, transfer, and distribution of electrical power. The electrical utility's primary goal is to provide affordable and reliable power to the customers [1]. The power grid is very complicated, any fault/failure might result in power outages for a significant number of consumers, and it is very tough to analyse the entire network at once [2]. Thus to make analysis simpler the power system network is categorised into three different operational zones: generation network zone, transmission network zone, and distribution network zone, with each zone evaluating the system's reliability [3]. As shown in Fig. 1, these three operational zones in sequence could be regarded as hierarchical stages of the power system reliability analysis. Hierarchical Level-I contains only generation networks, includes the study of major indices such as LOEE (loss of energy expectation), LOLE (loss of load expectation), failure duration, and failure frequency [4][5]. Hierarchical level-II is made up of the generation network zone and transmission network zone, and it is concerned with the reliability of both systems. Hierarchical level-III contains all operational zones and is treated as a complete power network. it is concerned with the reliability assessment of all three systems.

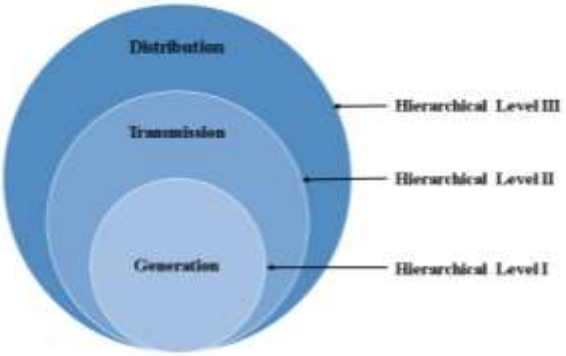

Fig. 1. Hierarchical stages of power system.

The traditional structure of power system and power system with DGs are shown in the Fig. 2. In the traditional system, the electricity is generated in high capacity central generating stations [6]. The use of renewable sources in the system has given rise to a new concept known as Distributed Generation (DG) [7] [8]. DGs are small-scale electricity production units (few kW) that are linked to distribution system, or user side of the meters to service a consumer on site while also

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providing assistance to distribution system or working independently with discrete rating ranges [9][10]. The incorporation of DGs will become the most cost-effective alternative to fulfil the rising demand in the traditional grid due to load growth [11][12]. DGs may play a major role in power system network, and they have various advantages, which are listed below [13][14][15].

- Improving the reliability of the system by offering an alternate source during outage.
- Providing good voltage profile, and deliver power in peak hours.
- Power loss due to long transmission line are reduced.
- Allowing customers to choose their energy source based on cost and environmental concerns.
- Relieving congestion in transmission networks and lowering the demand for transmission network expansion.

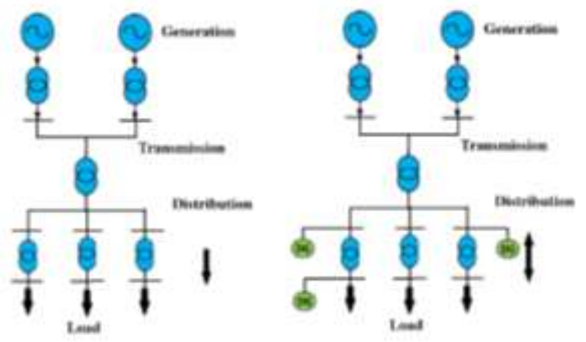

Fig. 2. Traditional power system and power system with DG.

Assessment of the reliability of distribution network with distributed generation has attracted the interest of power systems engineering researchers. Various researchers have evaluated distribution networks using renewable energy resources such as wind and solar power [16]. A stochastic model of output power must be employed to apply these resources in reliability investigations. In [17], A. David has developed output power models for uncertain energy resources like wind energy and solar radiation. Weibull, Normal and Beta distributions have been investigated in [18] as approaches for predicting the output power of solar systems. Researcher examined the results produced from these approaches in different seasons and advised utilizing Weibull and Beta to describe the intermittent nature of solar irradiance at the required period [19]. In [20], using probability theory, Suzuki, Sutoh, and Sekin have created a model of PV's power output. The variance and average of PV output power are modelled in their system. Meteorological data were gathered and compared to the model's outputs, which demonstrated that the variation of the power output follows a normal distribution

In order to build a realistic wind turbine model, the intermittent nature of speed of wind must be taken into account [21]. In [22], Utsurogi and Giorsetto have proposed a technique to evaluate the influence of WT implementation on the system's reliability. Using a probabilistic framework, they considered the impacts of forced outage of the WT and fluctuating speed of wind on total reliability. In [23], Dai, Wang, and Thomas have analyzed the effect of WT power generation on the power systems reliability and established a model that accounts for the failure rate of generators and the related components, such as "DC/AC" converters and the hourly wind speed was calculated using Weibull distribution. Bea and Kim [24] explored two scenarios of the evaluation of the reliability of distribution systems incorporating microgrids. In one scenario, the load duration curve model was employed to explore the influence of the load profile on system dependability, whereas, in another situation, the peak load was utilized. Implementing load peak data in reliability studies would provide deceptive reliability indices, as demonstrated by the results.

In this paper, the impact of distributed energy sources like PV, Wind, Electric Storage, and Gas Turbine Generator on the reliability of distribution system is evaluated. The MC simulation method is being used to test the IEEE RBTS distribution network. Modification has been made in the distribution network to incorporate the WT, PV, ESS, and GT distributed generation. The remaining paper is categorized as given. Section-2 shows different DGs model. In Section-3, load model is illustrated. Reliability indices are represented in Section-4. Section-5 describes the MC simulation. Section-6 investigates a variety of case studies. Finally, conclusion is drawn in Section-7.

2. DG MODELS

As solar irradiance and speed of wind both are irregular in nature, the power output of both systems are unpredictable. A stochastic model is thus necessary to simulate WT and PV output power. A stochastic model is basically a simulation-based approach for describing the system's non-deterministic nature and unpredictability. As a result, the probability distribution may be used to estimate PV and WT output power. Meteorological data from a range of climatic circumstances at one site should be considered in order to provide statistical information on solar irradiance and wind speed.

2.1. Modeling of PV output power

The intensity of the sun $I(t)$ and the area of the PV panels (S) have a significant influence on PV output power. The solar radiation fluctuates throughout the year and has a maximum value in summer. The following equation may be used to compute the power output of a PV system [25]

$$Po = \begin{cases} \frac{\eta}{K} * I(t)^2 * S & 0 < I(t) \le K \\ \eta * I(t) * S & I(t) > K \end{cases} \tag{1}$$

Where, *I(t)* is the hourly solar irradiation, η is the Photovoltaic system's efficiency, K is the threshold, and S is the area of the PV panel. The PV efficiency is not continuous; rather, it is proportional to solar irradiation until solar irradiation is less than the threshold *(K).* The hourly solar irradiation may be illustrated using the equation shown below.

$$I(t) = \begin{cases} I_m\left(-\frac{1}{36}t^2 + \frac{2}{3}t - 3\right) & 6 < t \le 18 \\ 0 & 0 \le t < 6 \ and\ 18 < t \le 24 \end{cases} \tag{2}$$

Various factors, such as relative humidity, temperature, and cloudy condition, can influence solar insolation. Thus a prediction tool should be developed to make the Photovoltaic model more realistic. According to research [26], the variance of output power of photovoltaic system follows the normal distribution. Therefore, the following equation can be used to express the *ΔPo* [26].

$$f(\Delta Po) = \frac{1}{\sqrt{2\pi}} e^{-\frac{\Delta Po^2}{2\sigma^2}} \tag{3}$$

Where, σ is the variance of photovoltaic power output(*Po*.) on a clear sunny day, the expected output power of PV includes *Po* plus *ΔPo* . Thus, the output of PV can be determined by using the equation that is provided below.

$$P_{pv} = Po + \Delta Po \tag{4}$$

2.2. Modeling of Wind Turbine Power

The amount of energy generated by a WT depends on the speed of wind. If the speed of wind falls lower than the cut-in speed, then there will be no sufficient power to create electricity, and the wind turbine should be turned off. For the range of rated to cut-in wind velocity, the WT power is variable in nature. The output of WT will be constant if the speed of wind is in the range of rated and cut-out velocity. If the wind speed crosses the cut-out velocity, the WT will be shut off since it has exceeded the mechanical safety limit. Fig. 3 indicates the relation between and wind speed and output power, which can be represented as [27].

$$P(v) = \begin{cases} 0 & 0 \le v < v_{ci} \\ Pr * \frac{v^3 - {v_{ci}}^3}{{v_r}^3 - {v_{ci}}^3} & v_{ci} \le v < v_r \\ Pr & v_r \le v < v_{co} \\ 0 & v_{co} \le v \end{cases} \tag{5}$$

Where, *Pr* is the rated output power of WT, *Vci* is cut-in speed of wind, *Vco* is cut-out speed of wind, *Vr* is rated speed of wind.

Since wind is stochastic in nature, the output power of WT may not be constant. As a result, a stochastic technique should be used to model the unpredictability of wind velocity. Wind speed probability distribution follows a Weibull distribution [28], and is given as

$$f(v) = \frac{k}{c} * \left(\frac{v}{c}\right)^{k-1} * e^{-\left(\frac{v}{c}\right)^k} \tag{6}$$

Where, v is the speed of wind, c is the scaling parameter, and k is the shape parameter.

The scaling *(c)* and shaping *(k)* parameter may be represented as function of standard deviation *(σ)* and average wind speed *(μ)*, and can be given as [28]:

$$k = \left(\frac{\sigma}{\mu}\right)^{-1.086} \tag{7}$$

$$c = \frac{\mu}{\Gamma(1 + 1/k)} \tag{8}$$

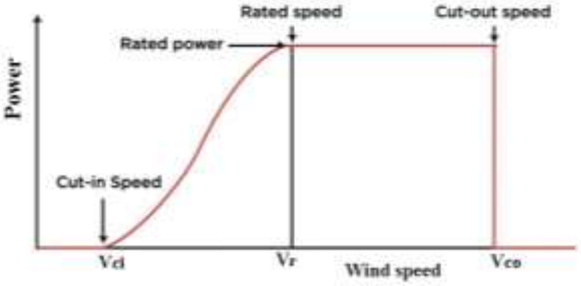

Fig. 3. Wind power curve.

2.3. Modeling of Gas Turbine Power

In distribution networks, gas turbine generators (GTs) are widely used. GTs are sometimes used as a backup power supply, particularly for critical loads, or they are linked to the main grid to provide the power at peak times. GT is a highly reliable energy source with a low failure rate. It has a predictable output power. As a result, building a gas turbine output power model is straightforward and dependent on the number of operating hours. In this paper, GTs is considered to operate for 5 hours during peak demand or when there is failure of main grid. According to the load profile shown in Fig. 4, the peak load demand time is between 5 to 9 pm.

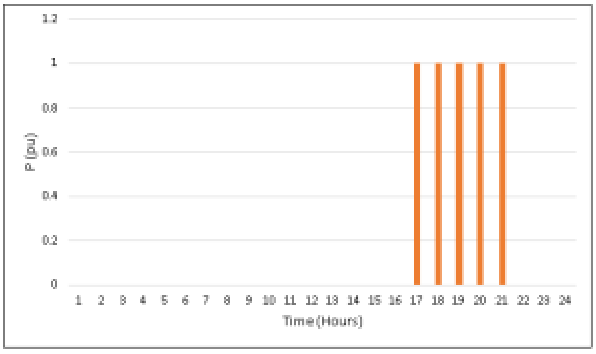

Fig. 4. GT daily generation plot.

2.4. Energy Storage System

Storage devices are typically integrated with intermittent power generation system like, WT and solar PV, to reduce the instability of these DGs' output and increase reliability, and power quality in micro-grids. When DGs output exceeds demand, excess energy is stored in ESS. When the production of the DGs is less than the demand, the ESS releases energy to supply the consumers. It is assumed that the output of the DGs and ESS is always in equilibrium with the load [29]. In this paper, a generic ESS is built to satisfy the motive of this work.

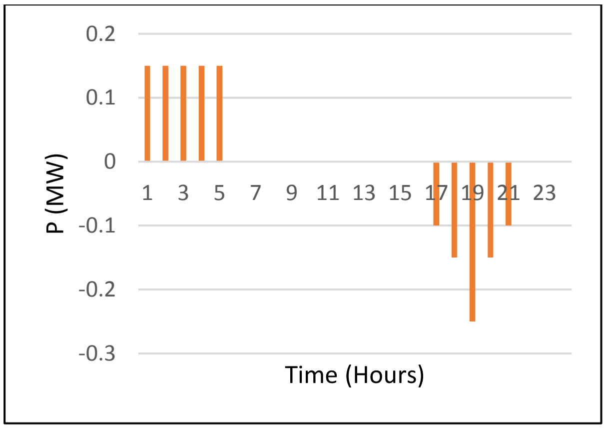

Fig. 5. Charging and discharging profile of ESS.

The capacity of the ESS and the converter are 750kWh and 300kW, respectively. The ESS's hourly charging and discharging profile are shown in Fig. 5. Since during night, the output of PV is nil, therefore the ESS is charged from the grid. According to load profile, the off-peak period is from 1 to 5 am, and ESS draws 150kW constantly to charge the battery during this time. The ESS is discharged to meet the load during peak hours (5 to 9 p.m.). If the ESS is completely charged, it can offer a load of 300kWh for 2.5 hours during fault or blackout.

3. MODELING OF LOAD

The load modelling method is an essential aspect of the power system modelling process and has a substantial impact on the results of power system simulation. Weather and seasonal events have an impact on the load. Fortunately, the majority of these events occur at the similar interval every year. Thus, the nature of loads is a common pattern under typical operating conditions. Using past data, a time-diverse model of load may be created. In this paper, a load model is built using hourly and monthly weight factor data [30]. The load at any load point *(i)* can be predicted using the equation shown below:

$$P_i(t) = W_m(m) * W_h(h) * P_{Li} \qquad (9)$$

Where, $W_m(m)$ & $W_h(h)$ are the monthly and hourly weight factors of load respectively.

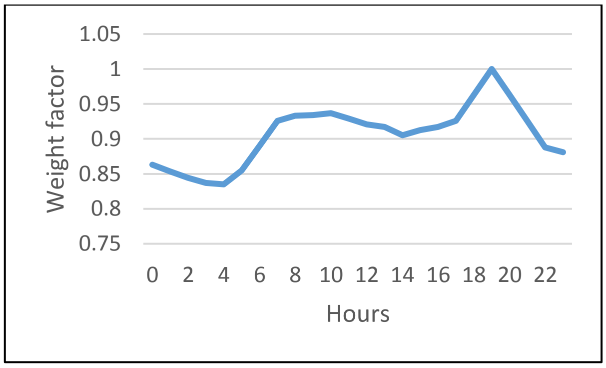

Fig. 6. Hourly weight factor.

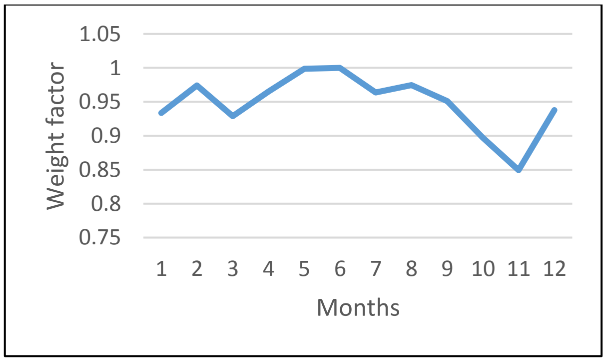

Fig. 7. Monthly weight factor.

4. RELIABILITY INDICES

The primary role of power utility is to offer its users with economically priced and reliable power supply. The distribution system's reliability is frequently assessed from two perspectives: customer and system level. The most often used reliability indices for load point users are average rate of failure and average yearly interruption period. The average failure rate is the total number of failures that occurs annually, and may be defined as the probability of a load point failing within a specific time period [31]. The average annual interruption period is basically the total average interruption period of a load point within a given timeframe. These particular reliability indices can be represented using the equations below [31, 32].

$$\lambda = \sum_{i=1}^{n} \lambda_i \qquad (10)$$

$$U = \sum_{i=1}^{n} \lambda_i * r_i \qquad (11)$$

Where, λ_i is the rate of failure of ith LP (Load Point), r_i represents the average restoration time, and n indicates the entire number of LPs.

The system's reliability is generally characterized as a function of the average interruption time, and the average rate of failures across the total number of consumers. The reliability indices of a system are measured by several characteristics that may be combined to offer an assessment of system performance through the use of a number of system indices such as the “System Average Interruption Frequency Index (SAIFI)” [31]. It is the frequency of permanent outages/failures that consumers might see in a year. The “System Average Interruption Duration Index (SAIDI)” [31] typically calculates the time period of permanent outages/failures experienced by the customer. The metric “Expected Energy Not Served (EENS) or Expected Energy Unserved (EEU)” [31] offers a metric that might be used to measure supply security as well as to establish a reliability standard in the electrical market. It is the expected amount of power demand not fulfilled by generation in a particular year, measured in megawatt-hours (MWh). following equations can be used to determine these indices [31].

$$SAIFI = \frac{\sum_{i=1}^{n} \lambda_i}{\sum_{i=1}^{n} N_i} \qquad (12)$$

$$SAIDI = \frac{\sum_{i=1}^{n} U_i * N_i}{\sum_{i=1}^{n} N_i} \qquad (13)$$

$$EENS = \sum_{i=1}^{n} E_i * N_i \qquad (14)$$

Where, N_i is number of ith load point consumers, E_i is the ith LP average interruption energy, U_i is the yearly outage period.

5. MONTE CARLO SIMULATION

Since the failure in power network are unpredictable, MCS may be utilized to simulate power system failures [33]. Basically MCS is an approach based on probabilistic prediction of behavior of the systems' components. When behavior of the system is reliant on previous events, a type of MCS called “time-sequential simulation” can be used [34]. In this simulation, an artificial history is required, which may be created by randomly generating the ON (up) and OFF (down) periods for the components that are present in the system.

Failure time (FT) or Time to failure (TTF) is the amount of time it takes for a component of the system to fail or the amount of time period for which the components of system stays in the working condition (UP-State). It can be predicted randomly by the equation given below [31, 32].

$$TFF = -\frac{1}{\lambda} * ln(m) \qquad (15)$$

Where, λ is rate of failure, and m is a randomly generated number and has any value between 0-1.

Time to replace/repair (TTR) is the total time period taken to fix a failed/faulty component of the system or the amount of time that the element is in the down state. It can be predicted randomly by following equation [31, 32].

$$TTR = -\frac{1}{\mu} * ln(m) \qquad (16)$$

Where, µ is the rate of repair.The failure action is basically the procedure of transitioning from the ON (up) state to OFF (down) state, which may be due to component failure or due to maintenance work. The random variables TTF and TTR have exponential distributions, as can be seen from Equations (15) and (16). TTR and TTF can thus be created to span simulation timeframes (e.g., a year) in chronological sequence to anticipate artificial history of components. MCS must be done for a great number of situations, and simulation period may be extended to extremely large (like 1000 yrs or above) based on the case study and required precision, and then average may be taken [35].

As the primary goal of this work is to assess the reliability of DG-enabled distribution network, the following assumptions are made that should not have substantial impact on the results:

- The miss-operation of protective devices are neglected, and only permanent faults are considered.
- Breaker is used to protect the segment and to isolate the fault.
- It will take sixty minutes to shift the load from down feeder to the nearby feeder via a standard operating point.
- A bidirectional protection device controls each circuit breaker.

Fig. 8 and Fig. 9shows the flow chart for reliability evaluation of distribution system with and without DG's.

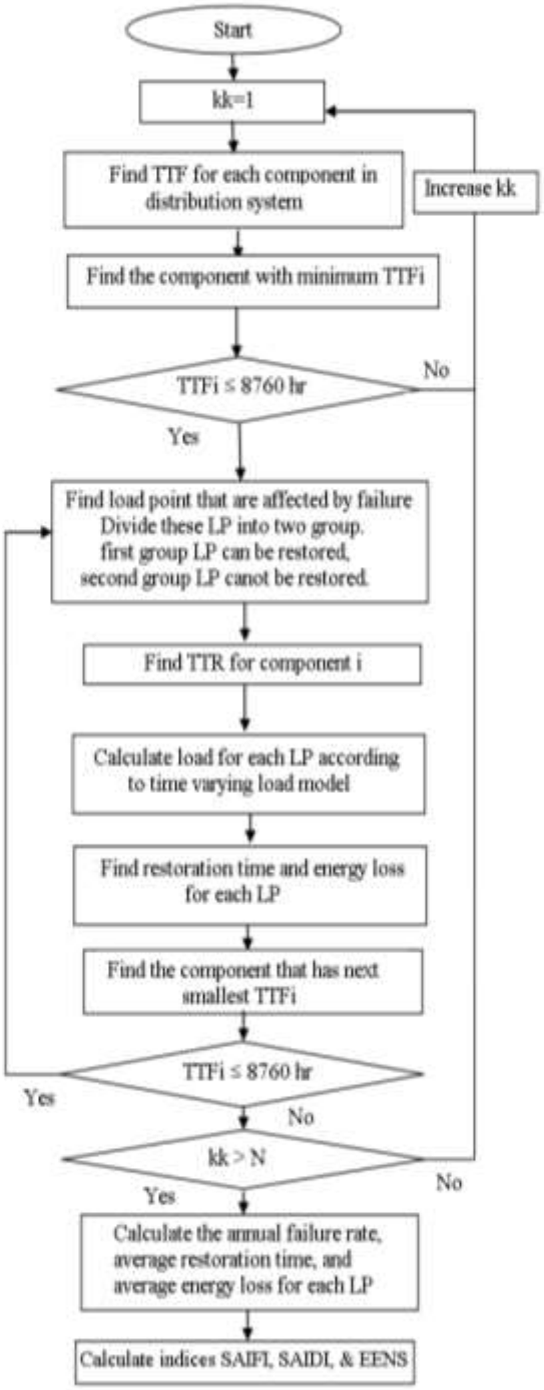

Fig. 8. Flowchart of reliability assessment of distribution network without microgrid.

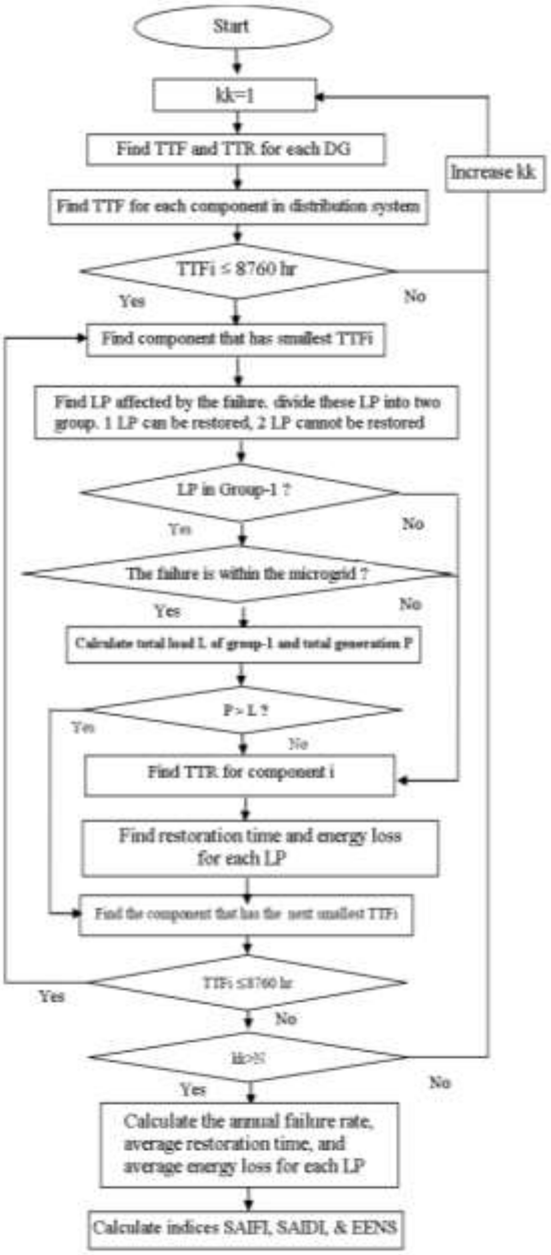

Fig. 9. Flowchart of reliability assessment of distribution network with microgrid.

6. CASE STUDY AND DISCUSSION

To study the effects of employing distributed energy resources, a RBTS distribution system is adopted which is shown in the Fig. 10. The RBTS Bus 2 has been modified to include 4 microgrids. Feeder-1 consists of microgrid-1 and is supplied by WT1, DGT1, and PV1. Feeder-2 consists of microgrid-2 where PV2 is connected. Feeder-3 is part of microgrid-3, which is powered by WT2, DGT2, and PV3. Feeder-4 consists of microgrid-4 where WT3, DGT3, and PV4 are incorporated. Customers' and feeders' information, as well as component failure and repair rates, may be found in [21].

Each photovoltaic unit has a maximum output of 1500 kW. PV units are assumed to fail at a rate of 0.1 failure/year and an average repair time of 20 h [25]. The storage system has a capacity of 700 kWh and the converter is rated at 300 kW. Each WT has a maximum output capacity of 2000 kW. WT's have rate of failure 0.25 f/yr and an average repair period of 20 hours [25]. Each gas generator is rated at 2000 kW. DGTs have 0.25 f/yr and an average repair time of 8 hours [25]. The different case studies are done to study the effects of distributed generation on the distribution network.

6.1. Case Study-I: System without distributed generation

This is a base case in which systems reliability is evaluated without any integration of distributed generations.

Table 1. Reliability indices of system for base case.

Indices	Without DG
SAIFI(Int./cust-yr)	0.2082
SAIDI (hr/cust- yr)	0.8654
ENS (MWh/yr)	13.7381

6.2. Case Study-II: DG at different places

In this case a single DG of 2MW is placed at different location of a feeder-1. First it is placed at section-1, then at section-2 and so on till section-4 which is last section of feeder-1. The reliability indices of system at each location are shown in below table.

Table 2. Reliability indices of system with DG at different places.

Indices	DG at F1S1	DG at F1S2	DG at F1S3	DG at F1S4
SAIFI(Int./cust-yr)	0.2079	0.2065	0.2057	0.2051
SAIDI (hr/cust- yr)	0.8652	0.8571	0.8535	0.8473
ENS (MWh/yr)	13.6954	13.6809	13.6354	13.6033

6.3. Case study-III: System with PV only

In this case, four PV unit of 1500kw each are taken. Each PV unit is placed at the end of each feeder of RBTS bus-2 system. Reliability indices of system of system for this case are shown in below table.

Table 3. Reliability indices of system with PV only.

Indices	With PV
SAIFI(Int./cust-yr)	0.2068
SAIDI (hr/cust- yr)	0.8574
ENS (MWh/yr)	13.6021

6.4. Case study-IV: System with WT only

In this case four WT unit of 1500kw each are taken. Each WT unit is placed at the end of each feeder of RBTS bus-2 system. Reliability indices of system of system for this case are shown in below table.

Table 4. Reliability indices of system with WT only.

Indices	With WT
SAIFI(Int./cust-yr)	0.2048
SAIDI (hr/cust- yr)	0.8411
ENS (MWh/yr)	13.5524

6.5. Case study-V: System with PV and WT

This case is a combination of case-III and case-IV. In this case both PV and WT are placed at the end of each feeder of RBTS bus-2 system. Reliability indices of system of system for this case are shown in below table.

Table 5. Reliability indices of system with PV & WT.

Indices	With PV & WT
SAIFI(Int./cust-yr)	0.2032
SAIDI (hr/cust- yr)	0.8390
ENS (MWh/yr)	13.3798

6.6. Case study-VI: System with PV, WT and DTG

A DTG of 2000kW capacity is added in the system along with the PV and WT units. Reliability indices of system of system for this case are shown in below table.

Table 6. Reliability indices of system with PV, WT & DTG.

Indices	With PV, WT & DTG
SAIFI(Int./cust-yr)	0.1998
SAIDI (hr/cust- yr)	0.8385
ENS (MWh/yr)	13.221

6.7. Case study-VII: System with PV, WT, DTG, and ESS

A ESS of 750kwh is added in the system along with the case-VI. Reliability indices of system of system for this case are shown in Table *7*.

Table 7. Reliability indices of system with PV, WT, DTG, & ESS.

Indices	With PV, WT,DTG, & ESS
SAIFI(Int./cust-yr)	0.1986
SAIDI (hr/cust- yr)	0.8257
ENS (MWh/yr)	12.9314

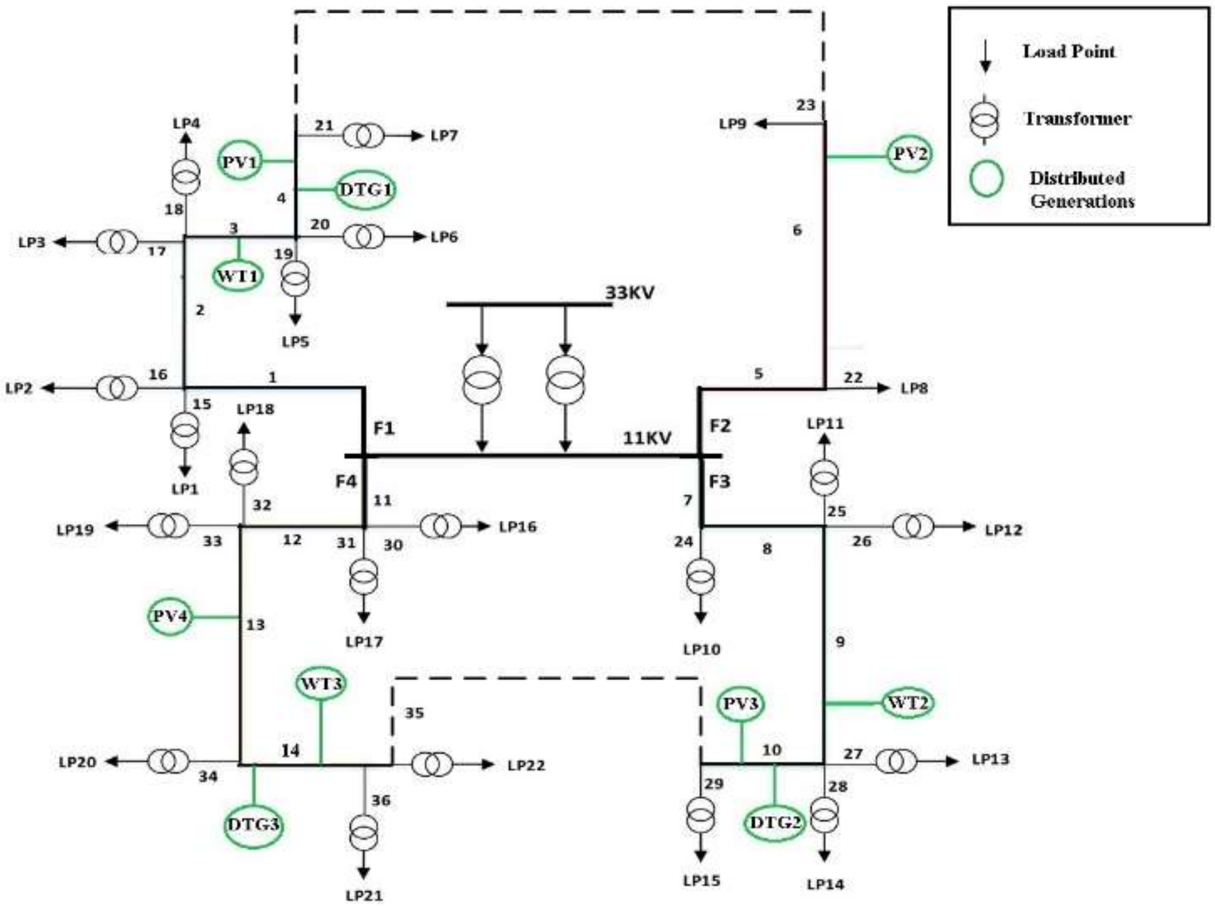

Fig. 10. Modified RBTS bus 2.

6.8. Customer Interruption Cost

Customer Interruption Cost is a cost of interruption (energy not supplied) for the customers . It depends on the down time, customer category, and the load. It can be calculated using the equation shown below.

$$ECOST = \sum_{i=1}^{n} C_i La_i \lambda_i \qquad (17)$$

Where,

C_i = composite customer damage cost at i^th load point and it is taken from Table 8.

La_i = i^th load point average load.

Table 8. Customers composite damage cost.

Duration (minutes)	Rs/kW
1	11.32
20	92.01
60	274.54
240	1145.16
480	3152.67

For all the case study the ECOST is determined and is shown in the Table 9

Table 9. ECOST for different cases.

Case	ECOST (cr/yr)
Base case	0.31
PV	0.305
WT	0.296
PV+WT	0.289
PV+WT+DTG	0.280
PV+WT+DTG+ESS	0.268

6.9. Yearly Cost Saving

The yearly cost-saving for different cases are calculated by using following steps.

1. Let us assume that on average P kW power is used, and annual energy used will be E1=P*8760 kWh

2. If price of unit is considered as J, then price of energy consumption is Ta=J*E1
3. After integration of DG of capacity X, the annual energy taken from utility will be E2=(P-X) *8760 kWh. and total cost of energy will be T2=J*E2.
4. Hence, the yearly cost saving = T1-T2.

Table 10. Yearly cost saving for different cases.

Case	Saving (cr/yr)
Base case	Nill
PV	2.208
WT	8.04
PV+WT	8.12
PV+WT+DTG	14.18
PV+WT+DTG+ESS	18.2

The simulation results obtained from case study-II shows that the reliability of network also depends on the location of the DG. Fig. 11, Fig. 12, and Fig. 13 show the reliability parameters of the system for different location of the DG. The values of EENS, SAIFI, and SAIDI improve as DG location moves toward the end of feeder.

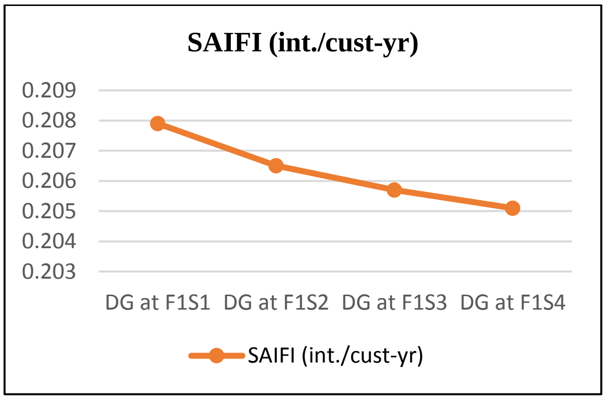

Fig. 11. SAIFI for different DG location.

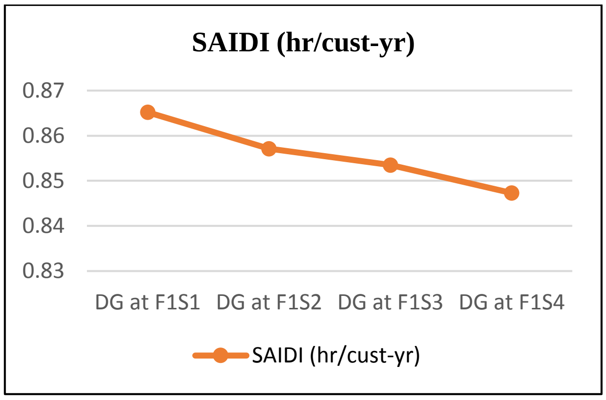

Fig. 12. SAIDI for different DG location.

In RBTS network without DG, LP which are placed at father end of feeder has higher failure rate than that of LP which are placed at starting of main feeder, this is due isolation of these LP from main feeder under permanent faults. However, the LP with DG placed at the farther end of feeder has less rate of failures. The additional generating capacity offered by the DG during the downtime of the major sources is responsible for the lower failure rate. The failure rate for each LP for all cases are shown in the Fig. **14**.

After the integration of DG, the overall reliability of the system has been improved. The indices for cases are shown in the Table 11.

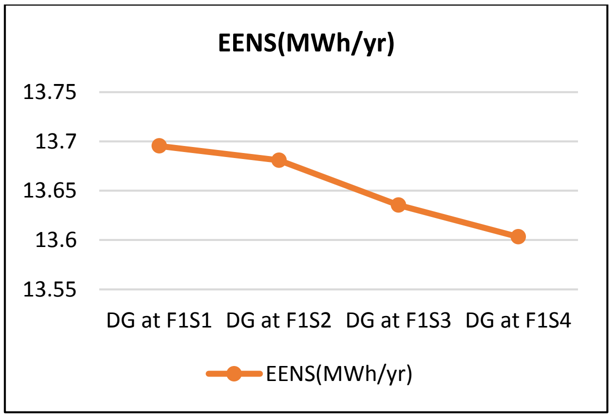

Fig. 13. EENS for different DG location.

Table 11. Reliability indices for different case study.

Indices	With-out DG	With PV	With WT	PV+WT	PV+WT+DG	PV+ WT+ DG+ ESS
SAIFI (Int./cust-yr)	0.2082	0.2068	0.2048	0.2032	0.1998	0.1986
SAIDI (hr/cust-yr)	0.8654	0.8574	0.8411	0.8390	0.8385	0.8257
EENS (MWh/yr)	13.7381	13.6021	13.5524	13.3798	13.221	12.9314
Saving (cr/yr)	-	2.208	8.04	8.116	14.182	18.2

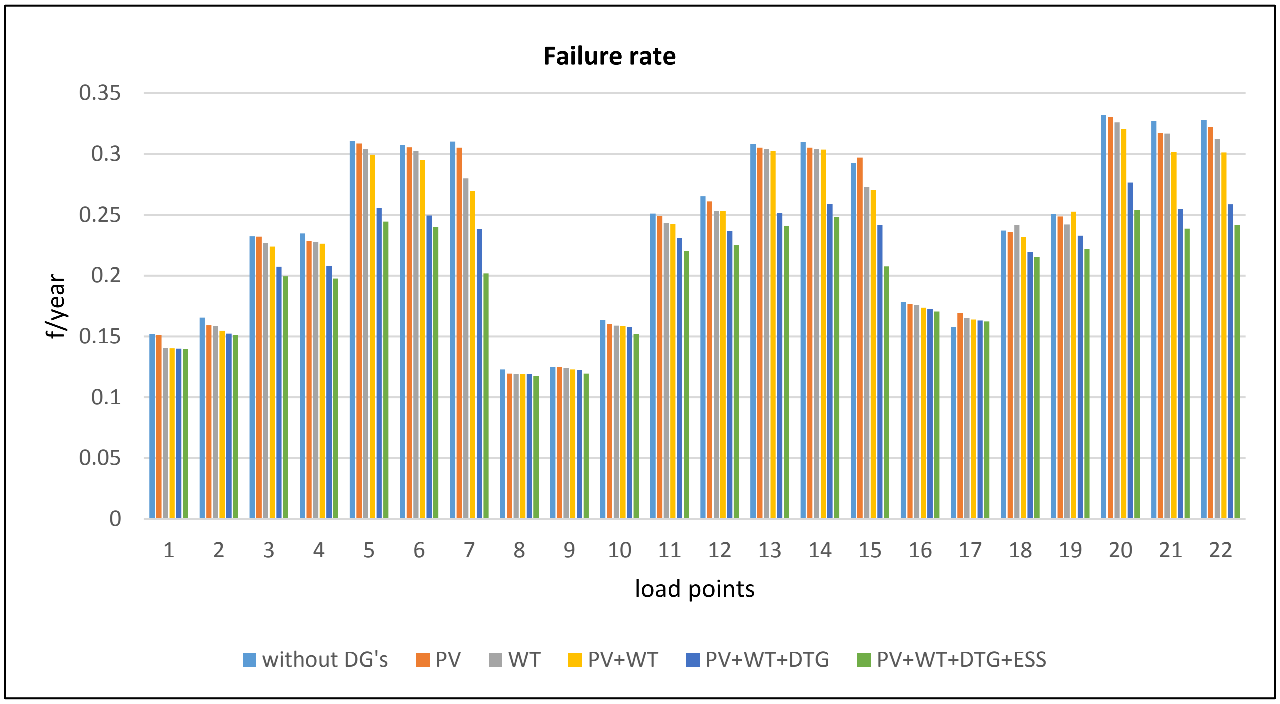

Fig. 14. Failure rate of each LP for all cases.

Fig. 15 shows the capital cost and ECOST plot for different cases. From this figure, it is clear that as we add more number of DG, capital cost increases. On the other hand, there is a decrement in the customer interruption cost (ECOST) as we add more number of DG.

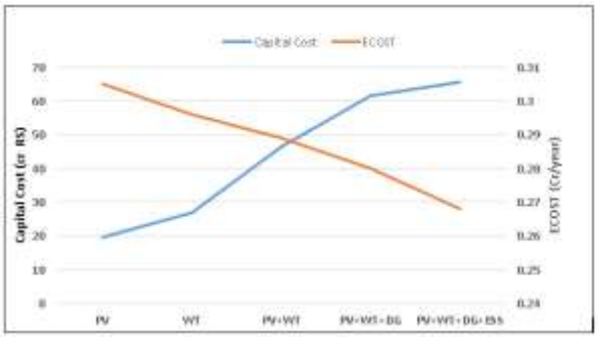

Fig. 15. Capital cost Vs ECOST.

7. CONCLUSION

The use of renewable sources in distribution system has various environmental and economic benefits, including lower greenhouse gas emissions, reduced energy losses in distribution systems, and improved power supply reliability. The DG might open the way for various modes of operations like island, and interconnected modes. This paper has also investigated the impact of distributed energy sources like PV, Wind, Electric Storage, and Gas Turbine Generator on the reliability of distribution system. The WT and PV stochastic models were employed to replicate the unpredictability of these sources since speed of wind and solar radiation are both unpredictable. The integration of DG has improved the failure rate, restoration time, energy loss, and overall systems reliability.

The improvement in EENS, SAIDI, and SAIFI for Case-III are 1%, 0.9%, and 0.9%, respectivey, for case-IV are 1.35%, 2.81%, and 1.63%, respectively, for Case-V are 2.61%, 3.05%, and 2.4%, respectively, for Case-VI are 3.33%, 3.10% and 4.03%, respectively and for Case-VII the improvements are 5.9%, 4.6%, and 4.61%, respectively. The annual cost saving for Case-III, Case-IV, Case-V, Case-VI, and Case-VII are 2.208 cr, 8.04 cr, 8.12 cr, 14.18cr, and 18.2 cr, respectively.

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