# Evaluation of The Reliability of Distribution System with Distributed Generation using ETAP

**Sreevidya.L, S. U. Prabha, S. Sathiya**

***Abstract:** Distributed Generation (DG) is an electric source connected directly to the distribution network. DG has been growing rapidly in deregulated power systems due to their potential solutions to meeting localized demands at distribution level and to mitigate limited transmission capacities from centralized power stations. In this paper effort has been made to study the impact of DG on the reliability of the distribution network. IEEE 33 Bus distribution network was used for the study. Firstly, DGs were optimally sized and located in the network using Modified Particle swarm optimization and ETAP software was used to model and evaluate the reliability indices. Two scenarios were considered. Scenario one was the integration of one DG and two was integration of two DGs. The results obtained showed that as the number of DG in the system increases the reliability of the system also increases.*

***Keywords:** Distributed Generation, Reliability indices, Modified Particle Swarm Optimization, ETAP.*

## I. INTRODUCTION

Distributed Generation (DG) has been growing rapidly in deregulated power systems due to their potential solutions to meeting localized demands at distribution level and to mitigate limited transmission capacities from centralized power stations. Penetration of DG into an existing distribution system has so many impacts on the system. However, incorrect sizing and siting of DG sources in power system would jeopardize reliable system operation. Consequently, there is need to identify the optimal location and size of the DG to be installed in distribution network infrastructure.

In power systems, reliability evaluation can be defined as analysing the ability of the system to satisfy the load demands. The Reliability computation of the whole system depends on the reliability of each component included in that system. Each component has two states, an operating state and a failed state. By specifying whether the component is operating or failed we can discern the status of the system. Reliability analysis and assessment are essential factors for the continuous operation of the system. The primary objective is to evaluate the impact of DG on the reliability of the system. IEEE 33 Bus distribution network was used for the study. The optimal placement and sizing of DG was done using Modified Particle swarm optimization and ETAP software was used for the modelling and reliability evaluation.

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### 1.1. Problem Formulation

In this work the objective of the placement technique for the DG is to minimize the real power loss and to improve the voltage profile at the distribution level. The real power loss reduction in a distribution system is required for efficient power system operation.

The loss in the system can be calculated using (1) in [1], called the 'exact loss formula' given the system operating conditions.

The objective of the placement technique is to minimize the total real power loss and improved voltage profile. Mathematically, the objective function can be written as:

$$Minimize P_L = \sum_{i=1}^{N} |I_i|^2 R_i \quad (1)$$

$$\sum_{i=1}^{N} P_{DGi} = \sum_{i=1}^{N} P_{Di} + P_L \quad (2)$$

$$VoltgeConstraints: |V_i|^{min} \leq |V_i| \leq |V_i|^{max} \quad (3)$$

$$CurrentsLimits: |I_{ij}| \leq |I_{ij}|^{max} \quad (4)$$

Where i is the number of bus, N is the total number of Buses, $P_L$ is the real power loss in the system, $P_{DGi}$ is the real power generation of DG at bus i, $P_{Di}$ is the power demand at bus i , $I_{ij}$ is the current between buses i and j and $R_i$ is the resistance. The current $I_i$ is determined from the load flow using Hybrid load flow studies Method called Backward – Forward and Newton Raphson. For single source network all the power is supplied by the source but with DG that are optimally placed there is going to be reduction in power loss []. This reduction in power loss is determined as the difference of the power loss with DG and without DG. Thus, the new power loss in the network with DG is:

$$P_{L-new} = \sum_{i=1}^{N} |I_i^{new}|^2 R_i \quad (5)$$

$$P_{L-new} = \sum_{i=1}^{N} I_i^2 R_i - 2JI_i I_{DG} R_i - JI_i I_{DG}^2 R_i \quad (6)$$

Where j=1for a feeder with DG or else j = 0 Hence, the power loss reduction value for bus i with DG is obtained by subtracting (5) from (6) as;

$$PLR = P_{L-new} - P_L \quad (7)$$

$$PLRi = - \sum_{i}^{N} (2JI_i I_{DG} R_i + JI_i I_{DG}^2) R_i \quad (8)$$

The bus that gives the highest value of PLR is selected as the optimal location of DG. The emphasis is to place the DG at a location that will give maximum loss reduction.



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To obtain the DG current that will give maximum loss reduction, equation (8) is differentiated with respect to IDG and equated to zero, hence the current is given by equation (9) below

$$I_{DG1} = -\frac{\sum_{i=1}^{n} I_{ai} R_i}{\sum_{i=1}^{n} R_i} \quad (9)$$

The procedure is repeated for all the buses in order to obtain the highest power loss reduction value as the DG units are singly located. Assuming there is no significant changes in the voltage as DG units are connected, the power that can be generated is;

$$P_{DGi} = I_{DG} V_i \quad (10)$$

Where V is the voltage magnitude of the bus i and the optimum DG size is obtained from equation (10). The optimal location of the DG is bus i for maximum power loss reduction.

*1.1.1. Particle Swarm Optimization (PSO)*

Standard PSO is an attractive stochastic optimization techniques, introduced by Dr. Kennedy and Dr. Eberhart in 1995. During each iteration of the algorithm, the velocity and position of each particles are updated by following equation (6) and (7) till the stopping criterion is met.

$$V_{m,n}^{new} = V_{m,n}^{old} + G_1 \times r_1 \times (P_{m,n}^{local\ best} - P_{m,n}^{old}) + G_2 \times r_2 \times (P_{m,n}^{global\ best} - P_{m,n}^{old}) \quad (6) \quad P_{m,n}^{new} = P_{m,n}^{old} + V_{m,n}^{new} \quad (7)$$

Where $V_{m,n}^{old}$ = Particle velocity, $P_{m,n}^{old}$ = Particle position, $r_1 = r_2$ independent uniform random number

$G_1 = G_2$ Learning Factors, $P_{m,n}^{local\ best}$ = Best local solution, $P_{m,n}^{global\ best}$ = Best global solution

*1.1.2. Modified PSO (MPSO)*

Standard PSO uses both current global best and the local best, represented by $P_{m,n}^{global\ best}$ and $P_{m,n}^{local\ best}$ respectively to update the position and velocity. The purpose of local best is to increase the diversity in the quality solution. However, this same diversity can be simulated with some randomness. There is no need to use individual best until and unless the optimization problem of interest is highly non-linear. In a simplified version of PSO, the global best can accelerate the convergence of an optimization algorithm. Hence the velocity vector at k+1 iteration can be generated by the following equation (8).

$$V_{m,n}^{new} = V_{m,n}^{old} + \alpha \times randn\ (k) + \beta \times (P_{m,n}^{global\ best} - P_{m,n}^{old}) \quad (8)$$

Where $\alpha$ *and* $\beta$ are the acceleration constants and randn is random variable with values from 0 to 1.

The update of the position at new iteration is simply by

$$P_{m,n}^{new} = P_{m,n}^{old} + V_{m,n}^{new} \quad (9)$$

Where m = 1, 2…y and n = 1, 2….z

In order to increase the convergence even further, we can write the update of position in single step as

$$P_{m,n}^{new} = (1-\beta)\, P_{m,n}^{old} + \beta P_{m,n}^{global} + \alpha randn\ (k) \quad (10)$$

The values of $\alpha$ is from 0.1 to 0.5 and the value of $\beta$is from 0.1 to 0.7.

*1.1.3. MPSO Implementation*

Optimal DG placement and sizing to reduce the power loss in distribution system using MPSO based method takes the following steps.

Step 1. Read the input data including bus data and branch data, base voltage, base MVA, desired accuracy ($1\times 10^{-3}$) of system.

Step 2. Calculate the power loss of each branch and voltage of each node using forward backward load flow.

Step 3. Set the number of iteration, number of particles, $\alpha$ *and* $\beta$ values.

Step 4. Generate the initial population randomly for velocity $v_i$ and position $p_i$.

Step 5. Calculate total power loss for each particle using forward backward load flow.

Step 6. Check out the system constraints.

Step 7. Compare the objective function from individual best for each particle.

Step 8. Select the particle associated with lowest individual pbest and set this value as gbest.

Step 9. Update the particle's velocity.

Step 10. Update the particle's position.

Step 11. Check the number of iteration reaches to the final value, if it so then go to next step otherwise go step 6 for k = k+1.

Step 12. Print the optimal solution. This will be the best solution for optimal placement and sizing of DG in radial distribution system.

*1.1.4. Reliability Evaluation*

The term reliability means the ability of the system to perform its intended function, where the past analysis helps to estimate future performance of the system. Reliability is the probability of a device or system performing its function adequately, for the period of time intend, under the specified operating conditions.[9] System reliability can be computed from the failure probability of the composite power system due to outage of lines, transformers and generators. There may be more than one failure condition for outage of a line, transformer or generator.

Results from a reliability study can be expressed using different reliability indices. There are many possible reliability indices, which often are interdependent [6]. In order to reflect the severity or significance of a system outage, reliability indices are evaluated. Depending on the application, a suitable set of indices has to be chosen, to perform the reliability evaluation. It is fairly common practice in the electric utility industry to use the standard IEEE reliability indices like CAIDI, SAIFI, SAIDI to track and benchmark reliability performance. These reliability indices include measures of outage duration, frequency of outages, system availability and response time. The standard deviation of the reliability indices provides distribution engineers with information on the expected range of the annual values. [6]The evaluation of reliability indices for a composite system is very much computationally demanding

**SAIFI:** System average interruption frequency index The SAIFI index gives information about how often these interruptions occur on the average for each customer.



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$$\text{SAIFI}=\frac{Total\ number\ \ of\ all\ interruptions}{Total\ number\ \ of\ customers\ \ connected}(\text{f/c/r}) \qquad (11)$$

**SAIDI:** System average interruption duration index
The SAIDI index gives information about the average time the customer is interrupted in minutes (or hours) in one year.

$$\text{SAIDI}=\frac{Total\ duration\ \ of\ all\ interruption}{Total\ number\ \ of\ customers\ \ connected}(\text{hr/cr}) \qquad (12)$$

**CAIDI**: Customer average interruption duration index.

CAIDI captures the average time that the utility responds by measuring the average time to restore service. CAIDI=

$$\frac{Totalduration\ \ of\ all\ interruption}{Totalnumberofall\ \ interruption}(\text{hr/c/Int.}) \qquad (13)$$

**ASAI**: Average service availability index.

$$\text{ASAI}=\frac{Totalnumberof\ \ hours\ \ availability}{Totaldemand\ \ \ hours}\ (\text{p.u}) \qquad (14)$$

**ASUI**: Average Service Unavailability Index

$$\text{ASUI}=1-\text{ASAI (p.u)} \qquad (15)$$

**EENS**: Expected energy not supplied.
EENS = Capacity outage x Probability of Capacity outage x Time of Capacity outage (MW/Yr) These are measuring tool that are used in order to evaluate the performance of the system. Utility supply companies are seeking to be within the standard approved range to motivate customers selecting them among others. [4]

*1.1.5. Findings*

**Optimal location and size of DG**

**Table 1: Optimal Location and Sizes of DGs**

| S/No | Configuration | Type of DG | Location (s) | Size(s) MW |
|---|---|---|---|---|
| 1 | IEEE 33 Bus with 1 DG | Solar | Bus 6 | 2.51 |
| 2 | IEEE 33 Bus with 2 DG | Solar | Bus 7 and 16 | 2.14 and 0.654 |

*1.1.6. Solar Photovoltaic Design*

Suniva ART245-60 modules of 240 Wp solar panels was used in the design. ART245-60 module is a well-known robust solar cell's type that is designed to be used in grid tied solar projects and power stations. The characteristics of the ART245-60 are taken under STC "Standard Test Conditions" in laboratory environment. The standard conditions are 1000W/m2 irradiation, 25°C, and 1.5 solar spectrum air mass. Basic features of the used modules are presented in Table V (T) =V@25 C (1 + β × ΔT) Where $\beta$ is the temperature de-rating factor shown in table 2

**Table 2: Basic features of the PV modules**

| S/No | Parameter | Rating |
|---|---|---|
| 1. | Maximum power | 240W |
| 2. | Voltage @ maximum power point | 30.9V |
| 3. | Current @ maximum power point | 7.95A |
| 4. | Open circuit voltage | 37.4V |
| 5. | Short circuit current | 8.44A |
| 6. | Cells per module | 60 |
| 7. | β (Voltage de-rating factor (Voc % / °C)) | -0.332 |
| 8. | α (Current de-rating factor (Isc % / °C)) | 0.035 |
| 9. | γ (Power de-rating factor (Pmax % / °C)) | -0.465 |

**Table 3: Features of the ABB 1 MW central inverter**

| S/No | Parameter | Rating |
|---|---|---|
| 1. | Rated power | 1000 Kw |
| 2. | Maximum power | 1200 kW |
| 3. | DC voltage range (MPPT) | 600-850 V |
| 4. | Maximum DC voltage | 1100 V |
| 5. | Maximum DC current | 1710 A |
| 6. | DC inputs | 8-20 A |
| 7. | Nominal AC voltage | 400 V |
| 8. | Nominal AC current | 1445 A |

*1.1.7. Modelling IEEE 33 Bus Distribution Network*

IEEE test system has 33 bus and 32 sections with the total load of 3.72 MW and 2.3 MVAR. Base MVA 100, conductor type is All Aluminum Alloy Conductor (AAAC), Base voltage 11kV, Resistance of 0.55per km and reactance of 0.35ohm per km. In ETAP IEEE 33 Bus Model was created in edit mode with the configuration status set to normal. ETAP's electrical system diagram is a one line representation of balanced three phase system. It was constructed graphically by connecting the buses, branches, transformers and protective devices from the one line diagram edit toolbar. Elements were graphically connected to the buses by using info page of the device property editor. The property editor was opened by double clicking on the element. The engineering properties of the element such as ratings, settings, loading, connection etc. were assigned using the editor. The DG (solar PV) were designed and placed at the optimal location as suggested by the MPSO. The ETAP Model of the system is shown in Figure 1.

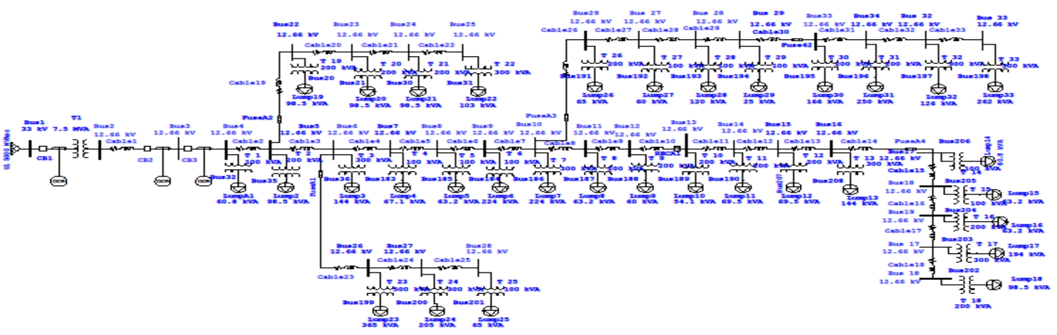

**Figure 1. ETAP Model of IEEE 33 Bus Test System**

### 1.1.8. *Reliability Evaluation Results*

In other to investigate the reliability of the system, the following reliability indices such as SAIDI. SAIFI, CAIDI, EENS, ASAI, ASUI and ECOST of the systems were evaluated using ETAP. The reliability data for each components provided in the reliability library of ETAP were used for the analysis. The indices were evaluated considering two scenario cases. Scenario one was IEEE 33 Bus system with 1 DG and scenario two was IEEE 33 Bus system with two DGs. The results are presented in Table 4

**Table 4: Reliability Indices Value for System with and Without DG**

| Network Conf. | SAIFI (f/c.yr) | SAIDI (hr/c. yr) | CAIDI (hr/c. Int.) | EENS (MW hr/yr) | ECOST ($/yr) | ASAI (p.u) | ASUI (p.u) | AENS MWhr/c.yr |
|---|---|---|---|---|---|---|---|---|
| IEEE 33 Bus System Base Case | 1.897 | 8.208 | 4.326 | 29.336 | 112,970.40 | 0.9991 | 0.00094 | 0.1424 |
| IEEE 33 Bus System with 1 DG | 0.523 | 3.442 | 6.581 | 16.147 | 73,976.11 | 0.9996 | 0.00039 | 0.0784 |
| IEEE 33 Bus System with 2 DG | 0.447 | 3.029 | 6.776 | 11.211 | 40,872.68 | 0.9997 | 0.00035 | 0.0544 |

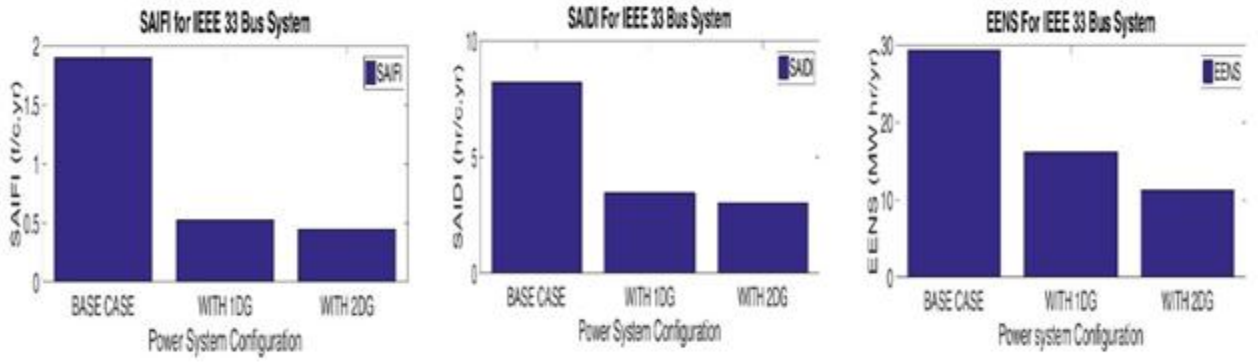


**Figure 2: SAIFI, SAIDI and EENS Plot for IEEE 33 Bus System**

## II. CONCLUSIONS

In this paper IEEE 33 Bus test system has been modelled using ETAP software. Optimal placement and sizing of DG was done using MPSO. The results obtained showed that optimal sizing and placement of DG in distribution system improves the performance of the network which in turn increase the reliability. Furthermore, the more the integration level of DG, the better the reliability of the network.

## REFERENCES


1. Adefarati, T., & Bansal, R. C. (2016). Integration of renewable distributed generators into the distribution system: a review. IET Renewable Power Generation, 10 (7), pp. 873-884.
2. Alberts, J. A., & de Kock, J. A. (2017). "Impact on power factor by small scale renewable energy generation". In Domestic Use of Energy (DUE), International Conference on power systems and control. pp. 146-151
3. Anudevi.S. Vinayak.N.Shet (2017) "Distribution Network with optimal DG Placement and Protection Impacts: Review Analysis" International Journal of Electrical and Electronics Engineering (SSRG – IJEEE) Volume 4 Issue 2.
4. M. Sedighizadeh, M. Fallahnejad, M. R. Alemi, M. Omidvaran and D. Arzaghi-haris (2010) "Optimal Placement of Distributed Generation Using Combination of PSO and Clonal Algorithm", IEEE International Conference on Power and Energy, Malaysia
5. MCV Suresh and Belwin Edward J (2017)" Optimal placement of distributed generation in Distribution systems by using shuffled frog leaping algorithm" ARPN Journal of Engineering and Applied Sciences Volume. 12, No. 3
6. Tefera M., T.Tolesa, K. Ramesh Babu (2017) 'Reliability Improvement of Power Distribution System Using Auto Recloser Case Study'. International Journal of Innovative Research in Computer and Combination Engineering'. Vol 5, Issue 3