Assessment of Reliability of Distribution Network with embedded Generation

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Abstract

Distributed Generation (DG) is an electric source connected directly to the distribution network or on the customer site of the meter. 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 Ran feeder in Bauchi 11kV distribution network. Firstly, DGs were optimally sized and located in the network using Modified Particle swarm optimization and ETAP software was used to evaluate the reliability indices. Two scenario 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, Modified particle swarm optimization, Reliability indices, 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. [4] Consequently, there is need to identify the optimal location and size of the DG to be installed in distribution network infrastructure.

Power system reliability is a measure of its ability to supply electricity to all its customers continuously and economically. Electric power system is one of the largest and most complex systems. It depends on the number of outages or power failures that will occur in the service period and outage duration. [1] A power system can be divided into three main functional regions designated as generation, transmission and distribution systems. Reliability evaluation of the power systems can be performed in each individual functional zone. Time dependent failure rates of a component are commonly represented using bath tub curve. Probabilistic methods are used for expressing reliability qualitatively. In power systems, reliability evaluation can be defined as analysing the ability of the system to satisfy the load demands. The basic function of a composite power system is to generate and deliver a required electrical energy to the load centres. 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. [11] By specifying whether the component is operating or failed we can discern the status of the system. In power systems, reliability analysis and assessment are essential factors for the continuous operation of the system. It is necessary to verify what kind of outages may occur in a practical system. In this paper the optimal placement and sizing of DG was done using Accelerated Particle swarm optimization and ETAP software was used for the reliability evaluation. [2]

II. 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. 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. [10]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.

SAIFI=$\frac{Total\ number\ of\ all\ interruptions}{Total\ number\ of\ customers\ connected}$(f/c/r) (1)

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.

SAIDI=$\frac{Total\ duration\ of\ all\ interruption}{Total\ number\ of\ customers\ connected}$(hr/cr) (2)

CAIDI: Customer average interruption duration index.
CAIDI captures the average time that the utility responds by measuring the average time to restore service.

CAIDI= $\frac{Total\ duration\ of\ all\ interruption}{Total\ number\ of\ all\ interruption}$ (hr/c/Int.) (3)

ASAI: Average service availability index.

ASAI= $\frac{Total\ number\ of\ hours\ availability}{Total\ demand\ hours}$ (p.u) (4)

ASUI: Average Service Unavailability Index
ASUI=1−ASAI (p.u) (5)

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]

III. METHODOLOGY FOR THE PLACEMENT OF DG

Standard PSO is an attractive stochastic optimization techniques. Introduced by Dr. Kennedy and Dr. Eberhart in 1995 [6]. 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.

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

$$P_{m,n}^{new} = P_{m,n}^{old} + V_{m,n}^{new} \quad (7)$$

Where
$V_{m,n}^{old}$ = Particle velocity
$P_{m,n}^{old}$ = Particle variable
$r_1 = r_2$ 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

A. Modified PSO (MPSO)

Typically, standard PSO uses both current global best and the individual best, represented by $P_{m,n}^{global\ best}$ and $P_{m,n}^{local\ best}$ respectively. The purpose of individual 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 of individual best until and unless the optimization problem of interest is highly non-linear and multimodal [8]. In a simplified version of PSO, the global best can accelerate the convergence of an optimization algorithm [5]. 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 α is from 0.1 to 0.5 and the value of β is from 0.1 to 0.7.

B. MPSO Implementation

Optimal DG placement and sizing to reduce the power loss in distribution system using APSO based method takes the following steps.
Step 1. Read the input data including bus data and branch data, base voltage, base MVA, desired accuracy (1×10^{-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.

C. Optimal location and size of DG

TABLE 1: optimal location and sizes of DGs

S/No	Network	Type of DG	Best Location (s)	Size(s) MW
1	Ran feeder with 1 DG	Small hydro	Bus 41	1.062
2	Ran feeder with 2 DG	Small hydro	Bus 30 and 50	0.598 and 0.503

VI. MODELLING OF RAN FEEDER, BAUCHI

Ran feeder has 69 bus and 68 sections with the total load of 3.958 MW and 11.56 MVAR. Base MVA 100, conductor type is All Aluminium Alloy Conductor (AAAC), Base voltage 11kV, Resistance of 0.55per km and reactance of 0.35ohm per km. The network was modelled in ETAP environment as shown below.

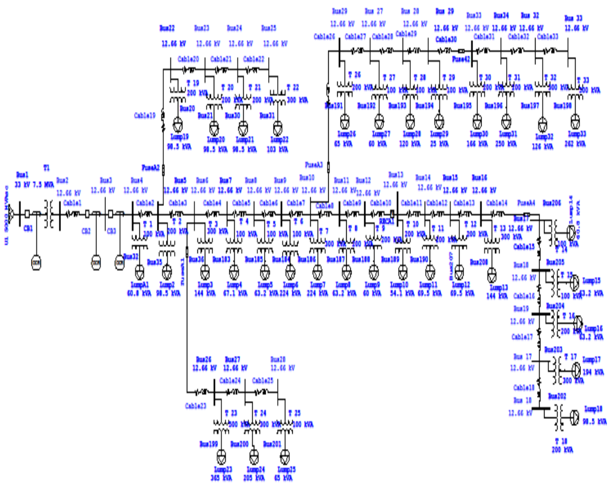

Fig 1: Part of ETAP Model of Ran Feeder

V. RELIABILITY EVALUATION RESULTS

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 are provided in the reliability library of ETAP were used for the analysis. The indices were evaluated considering two scenario cases. Scenario one was Ran feeder with 1 DG and scenario two was Ran feeder with two DGs. The results are presented in Table 2 and plotted in Figure 2 to 4

TABLE 2: Reliability indices value for the system with and without DG

INDICES	BASE CASE	WITH 1DG	WITH 2 DG
SAIFI	1.6216	0.7941	0.5804
SAIDI	17.4595	12.3512	8.6102
CAIDI	10.767	15.553	14.835
EENS	60.513	42.449	28.328
ECOST	425,058.10	267,138.90	195,189.20
ASAI	0.9980	0.9986	0.9990
ASUI	0.00199	0.00141	0.0098
AENS	0.8899	0.6243	0.4166

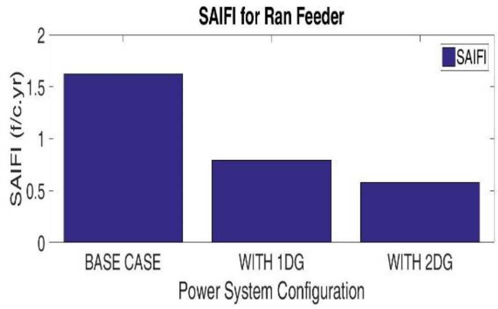

Figure 2: SAIDI plot for Ran feeder

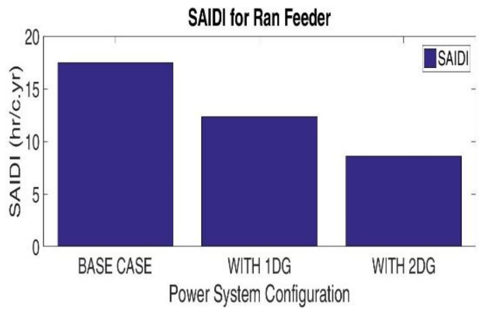

Figure 3: SAIFI plot for Ran feeder

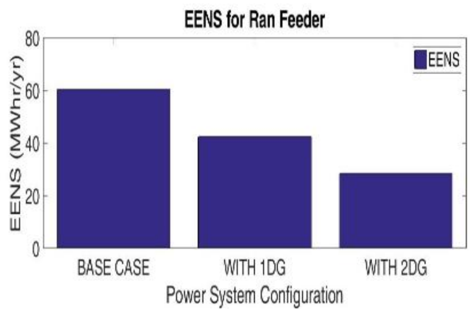

Figure 4: EENS plot for Ran feeder

VI. CONCLUSIONS

In this paper Ran feeder 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.

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