A New Scheme for Islanding Event Identification by Strategic Installation of Different DG Units

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Abstract: With the increasing load demand and emergence of various types of Distributed Generators (DG) the complexities and challenges for reliable operation of Distribution Network (DN) power system have increased. The major operational challenge in the DN is non-detection of Islanding event, which may cause the system to collapse. In this paper, two Modified Islanding Detection Techniques (MIDT-I \& MIDT-II) are proposed for accurate and early islanding detection in the presence of different types of DGs. These approaches utilizes robust parameters for accurate identification of the islanded bus. The proposed MIDT schemes combines the advantages offered by different existing passive Islanding Detection Techniques (IDTs) for early identification of the islander bus. In the proposed schemes the DGs are installed in the existing DN by Genetic Algorithm (GA) based Multi-Level Optimization (MLO) approach. The installation of DGs is performed to improve the voltage stability margin of the system and for power loss reduction. In the second stage during operation of the network two methods are proposed to detect unintentional islanding. The proposed scheme is demonstrated on IEEE 33 and IEEE 69 standard radial bus system for the effectiveness of the scheme.

Keywords: Distributed Generation, Islanding detection, Voltage-Active Power Sensitivity, Frequency-Reactive Power Sensitivity, Active Power loss, Voltage Stability Margin, Genetic Algorithm, Penetration Level.

1. Introduction

Electric power source connected directly to the DN is known as DG. The different definitions and technologies of DGs are explained in [1]-[2]. With more emphasis on green energy technology due to environmental concerns, the importance of the DG units in the network has increased. DG plays an important role in enhancing the security, reliability and efficiency of the modern power systems [3]. The different types of DGs are: (i) type-1: supplying only active power, (i) type-2: supplying only reactive power, (i) type-3: supplying both active and reactive power and (i) type-4: supplying active power while consuming reactive power [4]. An exhaustive analysis of different methods and models for optimal installation of DG units is given in [5]. Various techniques have been proposed for optimal placement of the DG units in the DNs using different AI techniques [6]-[9]. The advantages of various DGs for improvement of voltage profile, minimization of power, increased power transfer capability, overcoming uncertainties of load and fuel prices, planning of dispatchable and non-dispatchable DG units, better network security and reliability etc. are discussed in [10]-[13].

The electrical isolation of distribution system from the power system due to abnormal conditions while being connected to the DG is known as Islanding [14]. The islanding detection is critical during the operation of the system. A comprehensive survey of islanding protection with renewable DG is reported in [15]. The islanding detection techniques are broadly classified

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into Active and Passive techniques [16]. Active islanding detection techniques have smaller Non-Detection Zones (NDZ) but since pertubrations are introduced they suffer form large time of detection and could degrade the performance of system [16]-[19]. Most of the active IDTs are proposed for current controlled sources and for single DG unit only. The passive scheme utilizes local measurements of voltage and current signals ranging from usage of voltage variations and its derivatives, frequency variations and its derivatives, intelligent devices etc. have been proposed for islanding detection in the presence of DGs in the system [20]-[25]. The algorithms of passive scheme incorporates under/over frequency and voltage, rate-of-change of frequency and power, vector surge and harmonic distortion indices [26]-[28]. The passive methods have small time of detection but suffer from large NDZ.

In this paper, two MIDTs are proposed for early and effective detection of vulnerable bus for islanding. The proposed MIDTs utilize the advantages of the existing passive methods of islanding detection with identification of appropriate threshold values for early and effective detection of the islanding event. In the presence of Type-1 DG unit, MIDT-I is used for islanding detection. In the proposed MIDT-I a new parameter, based on the Voltage sensitivity to the Active power (Voltage-Active Power sensitivity parameter (ΔV_P) is utilized for effective identification of the islanding event. The proposed parameter is used in addition to the existing parameters used in the passive IDTs. The MIDT-II is used for the islanding detection when Type-3 DG units are present. In the proposed MIDT-II, two new parameters, Voltage-Active Power sensitivity parameter (ΔV_P) and Frequency-Reactive Power sensitivity parameter (Δf_O) are utilized for effective identification of the islanding event along with the existing parameters used in the passive IDTs. The proposed MIDTs are capable of detecting the islanding event early with lesser non-detection zones. The size and location of the DGs are obtained by proposed GA based MLO for improving the voltage profile of the buses and power loss minimization in the distribution system. The disadvantages in conventional GA requiring a large population size for achieving the optimal solution has largely been reduced by a proposed MLO. The results obtained by the proposed scheme shows that the effect of islanding can also be reduced by proper installation of the DG units. The proposed method of DG installation makes the operation of the DNs more reliable as the number of load buses in the island is reduced.

2. Problem Description

The optimal placement and sizing of DG plays an important role in the planning stage of any DN. The proper installation of DG units provides several advantages in terms of minimization of active power loss, increased network reliability, improvement of voltage stability, peak demand shaving etc. [2]. The appropriate placement of DGs in the DN leads to less load shedding requirements and aids in proper partitioning of system [29].

A. Assumptions for the proposed Multi-stage GA Based Placement of DG

The maximum penetration level of DGs is considered to be 30% of the total supply of the distribution system with the output of DGs is assumed to be in either UP or DOWN state without any intermediate state in between [9]. For both the test systems under consideration the number of DGs is assumed to be three with the mutation rate for GA fixed at 5%. [6].

B. Mathematical Formulation:

In the proposed scheme, the installation of DGs is performed for achieving the following objectives (i) Maximization of Voltage Stability Margin of the System through improvement of voltage profiles of the buses and (ii) Maximizing the system line losses reduction. The above problem is formulated as:

B.1. Maximization of the System Voltage Stability Margin:

The objective function for increasing the system voltage profile can be given as:

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$$f_1(V_s) = C_1 * max[\frac{\sum_{i=1}^m V_{i,DG} - \sum_{i=1}^m V_i}{\sum_{i=1}^m V_i} * 100\%]$$
(1)

Where $V_{i,DG}$ is the Voltage of i^{th} bus in the presence of DGs and V_i is the Voltage of i^{th} bus without DG, m is the total number of buses in the system and C_1 is the weight assigned to the given objective.

B.2. Maximization of System line losses Reduction

The objective function for increasing the line loss reduction can be given as:

$$f_2(P_{Loss}^{diff}) = C_2 * max[\frac{P_{Loss} - P_{Loss,DG}}{P_{Loss}} * 100\%]$$

$$\tag{2}$$

Where $P_{Loss,DG}$ is the Active Power Losses in the presence of DGs and P_{Loss} is the Active Power Loss without DG and is obtained as:

$$P_{Loss} = \left[\sum_{i=1}^{k} R_{m} * \frac{\left[P_{m}^{2} + Q_{m}^{2}\right]}{|V_{m}^{2}|}\right]$$
(3)

Where k is the total number of lines in the system, R_m is the Resistance of the line connecting any two adjacent buses. P_m , Q_m and V_m are the Active power, Reactive power and Voltage of the m^{th} bus respectively.

B.3. Overall objective function

Finally the objective function is formulated as nonlinear multi-objective optimization problem by combining the above objectives as:

$$F = \max[f_1, f_2] \tag{4}$$

 C_1 and C_2 are weights assigned to the objectives as desired and are related as: $C_1 + C_2 = 1 \forall C_1, C_2 \ge 0$ (5)

C. Constraints:

The mentioned objective is achieved by satisfying the following constraints: (i) Equality constraints (ii) Inequality constraints and (ii) DG capacity constraint.

C.1. Equality constraints

The equality constraints are characterized by the real and reactive power flow equations.

$$P_{m+1} = P_m - \frac{R_m}{|V_i|^2} * P_m^2 + (Q_m + Y_m |V_m|^2)^2 - P_{Lm+1}$$
(6)

$$Q_{m+1} = Q_m - \frac{X_m}{|V_i|^2} * Q_m^2 + (Q_m + Y_m |V_m|^2)^2 - Y_m |V_i|^2 - Y_{m2} |V_{m+1}|^2 - Q_{Lm+1}$$
(7)

The individual bus voltages are calculated as:

$$V_{m+1} = V_m + \frac{R_m^2 + X_m^2}{|V_i|^2} * P_m^2 + (Q_m + Y_m |V_m|^2)^2 - 2(R_m P_m + X_m (Q_m + Y_m V_m^2))$$
(8)

Where R_m and X_m are the Resistance and Reactance of the line connecting any two adjacent buses. P_m , Q_m and V_m are the Active power, Reactive power and Voltage of the m^{th} bus respectively. Y_m is the admittance matrix of the two adjacent buses.

C.2. Inequality constraints

The inequality constraints are characterized by real power generation and reactive power generation constraints, load bus voltage constraints, thermal limits. Real power generation constraints

$$P_{min,m}^{DG} \le P_{DG,m} \le P_{max,m}^{DG} \tag{9}$$

Where $P_{min,m}^{DG}$ and $P_{max,m}^{DG}$ are the minimum and maximum real power generation limits of the DG in kW at bus m.

Reactive power generation constraints

$$Q_{\min,m}^{DG} \le Q_{DG,m} \le Q_{\max,m}^{DG} \tag{10}$$

Where $Q_{min,m}^{DG}$ and $Q_{max,m}^{DG}$ are the minimum and maximum reactive power generation limits of the DG in kVA at bus m.

Load bus Voltage inequality constraints

$$V_{\min,i} \le V_i \le V_{\max,i} \tag{11}$$

Where $V_{min,i}$ and V_{maxi} are the minimum and maximum voltage limits of the DG in p.u. The minimum and maximum limits are taken as 0.95 p.u and 1.05 p.u respectively.

C.3. DG capacity limits

$$0 \le P_{DG} \le P_{Load}^{Total} * P_{PL} \tag{12}$$

$$0 \le Q_{DG} \le Q_{Load}^{1 \text{otal}} * Q_{PL} \tag{13}$$

where P_{PL} and Q_{PL} are Real and Reactive Power Penetration Levels respectively and is calculated as

$$P_{PL} = \frac{P_{DG}}{P_{DG} + P_{Grid}} *100\%$$
(14)

$$Q_{PL} = \frac{Q_{DG}}{Q_{DG} + P_{Grid}} *100\%$$
(15)

where P_{DG} and Q_{DG} are the total real and reactive power output of all DGs and P_{Load}^{Total} and Q_{Load}^{Total} are the total real and reactive power demand of the distribution system. P_{Grid} and Q_{Grid}

are the real and reactive power demand of the distribution system. One and Cond are the real and reactive power supplied by the Grid. Eqns 10, 13 and 15 are considered only for optimal installation of type-3 DGs only.

3. Genetic Algorithm (GA) Based Multi-Level Opti0mization (MLO)

The optimal installation of DG units in the system is performed through GA based optimization technique. GA derives its behavior from the process of Evolution [30]. The advantages of simplicity and flexibility in approach combines with robust response to changing environment makes GA a powerful tool for the optimal installation of DG units in the DNs. It

has been extensively used for power system optimization problems like loss reduction, improvement of voltage profile, and reconfiguration of DNs [31]-[33]. The various steps in implementation of the proposed GA based MLO for optimal DG location and capacity is summarized as:

A. Selection

The process of choosing two parents to produce a child is known as selection. In the present work, a two-level selection process is utilized. The weaker solutions are discarded in the initial round by a knockout selection. The fitter individuals are processed in further stages of optimization by selecting them through roulette wheel selection.

B. Crossover

Crossover is the process of producing a child from two parent solutions. In the present work, the fitter individuals selected by roulette wheel selection are taken for two-point cross over to enable a good mix of characteristics of both the parents in the children.

C. Mutation and Elitism



Figure 1. Flowchart for optimal placement of DGs using proposed GA Based MLO

Lost genetic information is recovered by Mutation and also restrains the algorithm to be trapped in a local optimum. The weakest individual of the current population is replaced by the fittest individual of the immediately preceding population by Elitism.

The encoding of each parent for type-1 DG is considered as:

$$\underbrace{Locations}_{Loc_1|Loc_2|Loc_3} | \underbrace{P_1|P_2|P_3}_{Active Power}$$

The encoding of each parent for type-3 DG is considered as:

$$\overbrace{Loc_1|Loc_2|Loc_3}^{\text{Locations}} | \underbrace{P_1|P_2|P_3}_{\text{Active Power}} | \overbrace{Q_1|Q_2|Q_3}^{\text{Reactive Power}}$$

Where Loc_1 is the location of the first DG, Loc_2 is the location of the second DG and so on. P₁ is the active power supplied by the first DG; P₂ is the active power supplied by the second DG and so on; Q₁ is the reactive power supplied by the first DG; Q₂ is the reactive power supplied by the second DG and so on.

A flowchart for the optimal placement and sizing of DG by the proposed method is shown in Figure.1.

4. Proposed Modified Islanding Detection Techniques (MIDTs) For Islanding Event Identification

A system wide blackout can be caused by faults upstream or failure of grid. Intentional islanded operation of the systems is one major advantage of presence of DG units in the distribution system. Controlled islanding can also restrict the amount of load shedding needed in the system in case of any contingency. However, the active or reactive power imbalance leads to frequency, angle or voltage instability in the unintentional islands. These may further lead tripping of interconnected tie-lines causing instability in the interconnected parts of the network. Hence, the islanding event has to be detected early and accurately for initiating appropriate control actions by the system operator to avoid a blackout of the islanded region of the system. The passive islanding detection techniques utilizes local measurements of voltage, frequency, current. The passive techniques have the drawback of large NDZ and requires precise setting of threshold values of different parameters. Very low threshold values results in unwanted tripping and higher threshold values results in failure of detection of islanding event. The passive IDTs are preferred as the cost of implementation is less along with early detection of islanding. Since the DG can supply only a small amount of load, the islanding has to be detected early and accurately.

The instability in the islanded part can cascade into the stable part of the system and lead to a complete failure of the system if undetected. The accurate identification of islanding becomes difficult due to complexity in monitoring the system parameters in the presence of DG units. Hence, the existing methods need to be re-investigated for early and accurate detection of the islanding event. For accurate and early detection of islanding the existing passive IDTs are modified by utilizing more robust parameters along with the existing parameters used in the passive IDTs. The existing parameters are used as alarm signals for the impending islanding event and the system moves into an alert state. In the alert state if the proposed MIDT parameters also violate the threshold limits, it is identified as an islanding event and the bus where the parameters violate the limits is identified as the islanding bus. In the existing passive detection techniques the following parameters are utilized:

The variation in voltage at each bus is measured for every time instant as:

Variation of Voltage = dV (Volts)

(16)

The voltage parameter is computed by averaging the variation of voltage over five continuous cycles. The averaging of voltage over 5 continuous cycles is performed to avoid any errors in measurement and is measured in (V/sec).

$$Voltage Parameter(\delta V_i) = \left| \frac{dV}{dt} \right| < \sigma \text{ for 5 cycles}$$
(17)

 σ is the predefined threshold value for the parameter and is taken as 160 V/sec [21]. The frequency at each bus is monitored and the variation in frequency is calculated for every time instant as:

$$Frequency Variation = df (Hz)$$
⁽¹⁸⁾

The Rate of Change of Frequency (ROCOF) is calculated as frequency parameter at every bus for each cycle in (Hz/sec).

Frequency Parameter
$$(\delta f_t) = |\frac{df}{dt}| < \varepsilon$$
 (19)

The ROCOF is used for quick islanding detection. The ROCOF is calculated usually between 2 and 50 cycles. The typical ROCOF settings are between 0.1 and 1.2 Hz/sec for a 60 Hz system. The frequency variations are used for for detecting the islanding event in ROCOF relays. However, the ROCOF relays may become ineffective for power imbalance less than 15% in the island. The threshold value of \mathcal{E} is set as 2.18 (Hz/sec) for 60 Hz system [23].

The net active power is monitored for every cycle at each bus. The variation will be less in DG buses since the power available from DG units is fixed. But, the buses farther away from the DG bus will have more variation of active power when the load demand changes.

Active Power Variation =
$$dP(MW)$$
 (20)

The Rate Of Change Of Active Power (ROCOP) is calculated at each bus for every time instant in (MW/sec).

Rate of change of Active Power
$$(\delta P_t) = \left| \frac{dP}{dt} \right| < \Lambda$$
(21)

 Λ is the pre-defined threshold limit and is fixed as 0.64 MW/sec [23].

A new Voltage-Active Power sensitivity parameter (ΔV_P) is proposed in the presence of type-1 DG units. As voltage and active power is cross coupled, monitoring the variation of voltage with active power ensures accurate identification of the islanding event. The Voltage-Active Power sensitivity parameter is calculated by dividing eqn. (16) by eqn. (20). This gives the variation of voltage to real power parameter at a bus and is measured in (V/MW).

$$Voltage-Active Power Sensitivity (\Delta V_P) = \left|\frac{dV}{dP}\right| < \mu$$
(22)

' μ ' is the threshold value of the proposed Voltage-Active Power Sensitivity parameter. The threshold value of ' μ ' is set as 10%. After rigorous simulations it was observed that if ' μ ' was considered less than 10%, false tripping of islanding event occurred. Some islanding events are not detected for greater threshold values. The identification of the vulnerable bus is a two-step process. In the first step the system operator is alerted for an impending islanding event if either the voltage parameter (δV_t) or frequency parameter (δf_t) or Rate-of-change of Active Power (δP_t) violate the pre-defined threshold limit. Mathematically it can be expressed as:

Alert of the Islanding Event =
$$\left|\frac{dV}{dt}\right| > \sigma(or) \left|\frac{df}{dt}\right| > \varepsilon(or) \left|\frac{dP}{dt}\right| > \Lambda$$
(23)

If the Voltage-Active Power sensitivity parameter also violate the threshold in the alert state, it is classified as an islanding event and the bus at which the violation occurs, is identified as the islanding bus. It can be expressed as:

Islanding Detection = Alert State &
$$\left|\frac{dV}{dP}\right| > \mu$$
 (24)

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A flow chart of the proposed MIDT-I for type-1 DG units is shown in Figure 2.



Figure 2. Flowchart for MIDT-I with type-1 DG

For type-3 DG unit installed in the system, MIDT-II is proposed. It utilizes the existing parameters for the islanding suspicion and the system enters into the alert state. A frequency-Reactive Power sensitivity parameter is also utilized for effective identification of the islanding event along with the Voltage-Active Power sensitivity parameter. The cross-coupling of parameters ensures against any false triggering of islanding event. The Reactive Power variation is calculated at each bus for every time instant as:

Reactive Power Variation =
$$dQ(MVAr)$$

(25)

The Rate Of Change of Reactive Power (ROCOQ) is measured at each bus for every time instant in (MVAr/sec).

Rate of change of Reactive Power
$$(\partial Q_i) = |\frac{dQ}{dt}| < \psi$$
 (26)

An additional Frequency-Reactive Power sensitivity parameter (δf_Q) is proposed. This parameter is calculated by dividing eqn. (18) by eqn. (25). The Frequency-Reactive Power sensitivity parameter is measured in (Hz/MVAr).

Frequency–Reactive Power Sensitivity
$$(\Delta f_Q) = \left| \frac{df}{dQ} \right| < \beta$$
(27)

' β ' is the predefined threshold limit for the Frequency-Reactive Power sensitivity parameter. The threshold values of these two proposed parameters were set after extensive testing. The value of ' β ' is set at 2%. The Frequency-Reactive Power sensitivity parameter is highly sensitive. Throughout the simulations it was observed that if ' μ ' and ' β ' are considered less than 10% and 2% respectively, false tripping of islanding event occured and some islanding events are not detected for greater threshold values.

The islanding event is identified by a two-stage process. In the first step, if either the voltage parameter (δV_t) or frequency parameter (δf_t) or Rate-of-change of Active Power (δP_t) violate the predefined threshold limit, the system operator is alerted for a suspected islanding event and the system goes into alert state. Mathematically it can be expressed as:

Alert of the Islanding Event =
$$\left|\frac{dV}{dt}\right| > \sigma(or) \left|\frac{df}{dt}\right| > \varepsilon(or) \left|\frac{dP}{dt}\right| > \Lambda$$
(28)

In the second stage, if the Voltage-Active Power sensitivity (ΔV_P) parameter and the Frequency-Reactive Power sensitivity (Δf_Q) also violate the threshold limit at any bus, when the system is in alert state, it is classified as an islanding event.

The bus at which these proposed parameters initially violate the limit is identified for islanding. Mathematically it can be expressed as:

Islanding Detection = Alert State &
$$\left|\frac{dV}{dP}\right| > \mu \& \left|\frac{df}{dQ}\right| > \beta$$
(29)

A flow chart of the proposed MIDT-II for type-3 DG units is shown in Figure 3.



Figure 3. Flowchart for MIDT-II with type-3 DG

5. Results and Discussion

The proposed algorithm has been tested on standard IEEE 33 bus and 69 radial bus test systems. All simulations have been carried out using MATLAB [34] and PSAT [35]. The dynamic simulation has been performed after the optimal installation of DG units. The real and reactive loads are increased exponentially during dynamic simulation. If islanding occurs during

simulation the vulnerable bus is observed. In this section firstly the results obtained for optimal location and capacity for the two test systems are discussed and then the results of the two proposed MIDTs are presented on the two test systems at base case and 140% of base case.

A. Simulation results of Optimal Placement and location of DGs by GA based Multi-Level Optimization

The optimal locations of type-1 DG units for 33 Bus system obtained by the proposed method are 13, 30 and 23 and sizes as 786, 745 and 42 kW respectively. The optimal locations of DG units for 69 Bus system obtained by the proposed method are 62, 43 and 16 and sizes as 788, 644 and 45 kW respectively. The results obtained for type-1 DG units are compared with two existing method and is shown in Table. 1. The proposed method of DG installation has been tested with the minimum load at 140% of base load.

The optimal locations of type-3 DG units for 33 Bus system obtained by the proposed method are 13, 30 and 24 and sizes as 40,1443 and 13 kVA respectively. The optimal locations of DG units for 69 Bus system obtained by the proposed method are 61,18 and 11 and sizes as 937,551 and 11kVA respectively. The results obtained for type-3 DG units are compared with existing PSO method and is shown in Table. 2.

From the tables it can be observed that the proposed MLO based optimal location and sizing of DG units give better result in terms of improvement of Voltage stability margin and reduction of losses when any type of DG unit is installed. Type-3 DG unit gives better result than Type-1 DG unit as both real and reactive power are supplied at the same bus.

Bus System	Loading Conditions	Cases	DG Location	DG Size (kW)	Minimum Voltage (p.u.)	Improvement in Voltage Stability Margin (%)	Active Power Losses (MW)	Reduction in active Power Losses (%)			
		Without DG	-	-	0.9131	-	0.202	-			
	Base Load	Proposed GA base MLO	13,30,23	786,745,42	0.9872	4.97	0.08283	59.13			
		SA[8]	17,18,33	719,113,1043	0.9693	4.32	4.32				
33 Bus		HSA[6]	17,18,33	572,107,1046	-	-	0.09676	52.26			
system		Without DG	-	-	0.8738	-	0.42464	54 -			
	140 % base Load	Proposed GA base MLO	13,30,23	786,745,42	0.9766	7.36	Active Power (MW) Reduction in active Power Losses (%) 0.202 - 0.08283 59.13 - - 0.09676 52.26 0.42464 - 0.19219 54.74 - - 0.2112 50.26 0.225 - 0.08677 61.44 0.47768 - 0.18752 58.11 - - 0.19801 55.77				
		SA[8]	17,18,33	719,113,1043	0.9688	6.34	-	-			
		HSA[6]	17,18,33	572,107,1046	-	-	0.2112	50.26			
		Without DG	-	-	0.9104	-	0.225	-			
	Base Load	Proposed GA base MLO	62,43,16	788,644,45	0.9943	2.48	0.0779	65.38			
		SA[8]	26,65	656,1606	0.9808	2.08	-	-			
69 Bus		HSA[6]	63,64,65	1302,369,1018	-	-	0.08677	61.44			
System		Without DG	-	-	0.8690	-	0.47768	-			
	140 % base Load	Proposed GA base MLO	62,43,16	788,644,45	0.9918	3.66	0.18752	58.11			
		SA[8]	26,65	656,1606	0.9718	3.11	-	-			
		HSA[6]	63,64,65	1302,369,1018	-	-	0.19801	55.77			

Table 1. Comparative Analysis of Results with Type-1 DGs in 33 and 69 Bus Systems for various operating Conditions

Bus System	Loading Conditions	Cases	DG Location	DG Size (kVA)	Minimum Voltage (p.u.)	Improvement in Voltage Stability Margin (%)	Active Power Losses (MW)	Reduction in active Power Losses (%)	Reactive Power Losses (MVAr)	Reductio n in reactive Power Losses (%)
		Without DG	-	-	0.9131	-	0.202	-	0.13514	-
		Proposed GA base MLO	13,30,24	40, 1443, 13	0.9914	5	0.0534	73.65	0.03573	73.56
33 Bus	Base Load	PSO[4]	6	3025	0.9509	3.83	0.07612	62.44	0.05797	57.1
system		Without DG	-	-	0.8738	-	0.42464	-	0.28343	-
	140 % base	Proposed GA base MLO	13, 30, 24	40, 1443, 13	0.9874	7.41	0.15187	64.24	0.11365	59.64
	Load	PSO[4]	6	3025	0.9509	5.71	0.16069	62.16	0.11913	70.41
		Without DG	-	-	0.9104	-	0.225	-	0.10219	-
69 Bus System	Deer Leed	Proposed GA base MLO	61, 18, 11	937, 551, 259	0.9943	2.51	0.0551	75.51	0.025	75.44
	Base Load	PSO[4]	61	2243	0.9935	2.42	0.08801	60.88	0.04353	57.04
		Without DG	-	-	0.8690	-	0.47768	-	0.216	-
	140 % base	Proposed GA base MLO	61, 18, 11	937, 551, 259	0.9921	3.77	0.18733	58.16	0.08847	59.04
	Load	PSO[4]	61	2243	0.9639	2.75	0.23585	47.32	0.11286	47.75

 Table 2. Comparative Analysis of Results with Type-3 DGs in 33 and 69 Bus Systems for various operating Conditions

B. Results of MIDT-I with type-1 DGs

The results of the proposed MIDT-I is compared with existing passive IDT using the Rate of change of voltage as given in eqn. (17) [22], Rate of change of frequency as given in eqn. (19) [23] and Rate of change of Active Power as given in eqn. (21) [23]. In the proposed method, along with parameters used in existing IDTs like voltage, frequency and active power at each bus for every instant of time, the Voltage-Active Power sensitivity is also calculated. The proposed method is also tested when the base load in the system is set at 140% of the initial base load. The results of islanding detection and the vulnerable bus of 33 Bus system and 69 Bus system is shown in Table 3.

From the tables it can be seen that, the proposed MIDT is effective in identifying the islanding event early and accurately along with the vulnerable bus. The MIDT-I is triggered by the frequency variations initially. The problem of NDZ in the frequency parameter is overcome in the proposed MIDT-I as the variations of voltage to active power is considered for each bus. By the proposed method of DG installation the number of buses islanded is also reduced.

The islanded bus moves away from the grid when the minimum load in the system is increased as the effect of DG penetration cannot be effective on buses away from the DG buses. The number of buses islanded in the 33 Bus system at base load condition and at overloaded condition is shown in Figure 4. A representation of the islanded buses at overloaded condition of the 69 Bus system is shown in Figure 5.



Figure 4. Formation of Islands in 33 Bus System with type-1 DGs

	Islanding Detection													
Bus		DG	Passeiv	e Metho	d I [23]	Passi	ve Method I	[[21]]	Pas	ssive Method	III	Proposed MIDT-I		
System	Loading Level	t Techniqu e	Time of Detectio n	Islan ded Bus No.	No. of Buses Islanded	Time of Detectio n	Islanded Bus No.	No. of Buses Islanded	Time of Detectio n	Islanded Bus No.	No. of Buses Islanded	Time of Detectio n	Islanded Bus No.	No. of Buses Islanded
	Base	Proposed GA Method	1.05	4	23	1.083	3	27	1.074	2	32	1.05	5	22
	Load	SA [8]	1.058	2	32	1.0833	2	32	1.074	2	32	1.058	3	27
33 Bus		HSA [6]	1.058	2	32	1.0833	2	32	1.074	2	32	1.058	3	27
System	140% of	Proposed GA Method	1.0412	4	23	1.085	3	27	1.077	2	32	1.0412	6	21
	Base Load	SA [8]	1.043	3	27	1.0916	2	32	1.079	2	32	1.043 3	27	
		HSA [6]	1.043	3	27	1.0916	2	32	1.079	2	32	1.043	3	27
	Base Load	Proposed GA Method	1.05	7	40	1.083	21	7	1.07457	6	41	1.05	6	41
		SA [8]	1.058	7	40	1.084	8	39	1.07457	8	39	1.058	6	41
69 Bus System		HSA [6]	1.058	4	47	1.1162	7	40	1.07457	8	39	1.058	6	41
	140% of Base Load	Proposed GA Method	1.0412	7	40	1.0845	15	13	1.07457	7	40	1.012	8	39
		SA [8]	1.042	7	40	1.0857	7	40	1.07457	6	39	1.042	6	41
		HSA [6]	1.042	7	40	1.1162	7	40	1.07457	8	39	1.042	6	41

Table 3. Comparative Analysis of Islandi	ng Detection technic	ques with Proposed	d MIDT-1 (33 Bus Sy	stem and 69 Bus Sy	ystem with ty	pe-1 DGs)
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Figure 5. Formation of Islands in 69 Bus System with type-1 DGs at overloaded condition

C. Results of MIDT-II with type-3 DGs

The results of the proposed MIDT-II is compared with existing passive IDT using the Rate of change of voltage as given in eqn. (17) [22], Rate of change of frequency as given in eqn. (19) [23] and Rate of change of Active Power as given in eqn. (21) [23]. In the proposed method, along with voltage, frequency and active power variations at each bus for every instant of time, the Voltage-Active Power sensitivity and Frequency-Reactive Power sensitivity are also calculated. The proposed method is also tested when the base load in the system is set at 140% of the initial base load. The results of islanding detection and the vulnerable bus of 33 Bus system and 69 Bus system is shown in Table. 4.





		Islanding Detection												
_		DG Placement Technique	Passeive Method I [23]			Passive Method II [21]			Passive Method III			Proposed MIDT-II		
Bus System	Loading Level		Time of Dete ction	Islanded Bus No.	No. of Buses Islanded	Time of Detection	Islanded Bus No.	No. of Buses Islanded	Time of Detection	Islanded Bus No.	No. of Buses Islanded	Time of Detection	Islanded Bus No.	No. of Buses Islanded
33 Bus System	Base	Proposed GA Method	1.05	3	27	1.083	3	27	1.07457	2	32	1.05	4	23
	Load	PSO [4]	1.05 8	2	32	1.084	13	6	1.07457	2	32	1.058	3	27
	140% of G	Proposed GA Method	1.04 12	3	27	1.083	3	27	1.083	2	32	1.0412	6	21
	Load	PSO [4]	1.04 2	2	32	1.0833	2	32	1.0833	2	32	1.042	3	27
69 Bus System	Base Load	Prposed GA Method	1.05	6	41	1.085	6	41	1.07457	6	41	1.05	7	40
		PSO [4]	1.05 8	6	41	1.085	10	18	1.075	7	40	1.058	6	41
	140% of Base Load	Proposed GA Method	1.04 12	7	40	1.083	14	14	1.08	15	12	1.0412	8	39
		PSO [4]	1.04 2	6	41	1.1162	12	16	1.1162	13	15	1.042	6	41

Table 4. Comparative Analysis of Islanding Detection techniques with proposed MIDT-II (33 Bus System and 69 Bus System with type 3 DGs)

From the tables it can be seen that, the proposed MIDT-II is effective in identifying the islanding event early and accurately. TThe problem of NDZ in the existing technique using frequency parameter is largely overcome in the proposed MIDT-II as the variations of frequency to reactive power is considered for each bus. As the Frequency-Reactive Power sensitivity (δf_Q) is very sensitive, the vulnerable bus is identified accurately. The number of buses islanded is also reduced by the proposed method of DG installation. As the minimum load in the system is increased, the islanded bus moves away from the grid as the effect of DG penetration cannot be effective on buses away from the DG buses.

The number of buses islanded in the 33 Bus system at base load condition and at overloaded condition is shown in Figure. 6. A representation of the islanded buses at base load condition and at overloaded condition of the 69 Bus system is shown in Figure 7.



Figure 7. Formation of Islands in 69 Bus System with type-3 DGs

From the analysis of MIDT-I and MIDT-II for different loading conditions in both the test systems, the installation of DG units by the proposed MLO based GA method reduces the effect of islanding. The cross-coupling of parameters in MIDT-I and MIDT-II ensures that the identified vulnerable bus for islanding is far from the grid and nearer to the DG bus. As the effect of DG penetration cannot be near the grid, the proposed MIDT-I and MIDT-II does not give any false triggering of islanding event.

6. Conclusion

A GA based MLO is utilized for optimal installation of DGs in the DN in this paper. The MLO has been applied for optimal placement and sizing of type-1 and type-3 DGs in the DN. As the type-3 supplies both active and reactive power at the same bus, the loss reduction and

voltage stability margin improvement is better with type-3 DG units. In the proposed technique using MLO since the weaker solutions are neglected at an early stage the DGs tend to get placed in the most sensitive bus.

For early detection of islanding event accurately in DN in the presence of DGs, two MIDTs schemes are also proposed. The two schemes MIDT-I and MIDT-II are proposed for type-1 and type-3 DGs respectively. The main features of these proposed schemes is fast islanding event detection based on the advantages offered by the existing passive IDTs. The correct identification of islanding event is facilitated by utilizing dynamic parameters like Voltage-Active Power sensitivity (ΔV_P) and Frequency-Reactive Power sensitivity (Δf_Q). Since the parameters are cross-coupled the islanding event is not triggered due to any transient events like sudden switching of loads or capacitor switching events. The inherent disadvantages of the existing methods like slow detection, Non-Detection zones and false triggering of islanding event have been reduced considerably in the proposed schemes. Even under different operating conditions the performance of the proposed methods of islanding detection is satisfactory making them more robust and effective.

7. References

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