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Optimal Location for Fixing Fuel Cells in a Distributed Generation Environment using Hybrid Technique

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Abstract: The paper proposes optimal location for fixing fuel cells in a distribution system using an innovative hybrid technique. The novelty of the proposed method is the combined performance of the Genetic Algorithm (GA) and Recurrent Neural Network (RNN) technique, thereby integrating GA first phase, RNN technique and GA second phase. The optimum location for fixing the fuel cell is attained by using the GA first phase. Here, the GA first phase utilizes the load flow data at different loading conditions for determining the optimum location. The RNN is aptly trained by the target fuel cell size and the corresponding inputs such as load variation and bus number. During the testing time, the RNN provides the fuel cell capacity according to the load variation and bus number. By using the attained fuel cell capacities, the GA second phase optimizes the fuel cell capacity to minimize the power loss and the voltage deviation. The objective function mainly helps to improve the bus voltage profile and the power loss reduction. Thus, the proposed hybrid technique is implemented in the MATLAB/simulink platform and its effectiveness is analyzed by comparing it with the GA, PSO and other hybrid PSO techniques. The comparison results unequivocally demonstrate the superiority of the proposed approach and confirm its sterling potential to solve the problem.

Keywords: fuel cell, GA, PSO, voltage, real power, reactive power

1. Introduction

The particular electrical power system commonly features a generating system, a transmission system, power substations and the distribution network [1]. Principle performance of the bulk generation and transmission system would be to provide with the electric power and also energy essential for the customers that has a specific level of reliability and good quality of support, at least expense [2]. Currently, the particular electrical power market can be in the process of sizeable transform regarding design, functioning and also regulation [3]. Deployment of distributed generators (DG) within just distribution network is becoming more inviting on account of many benefits which small scale generation could possibly to enhance the electric power resources [12]. The particular distributed generation (DG) can be constituted within a new emphasis for the electrical power generation [4].

Distributed Generation can be defined as any kind of power generation that's bundled in the distribution process [5]. Distributed generation has extensively found their place in power process which is going to help the organization needs on reliability cost and worth requirements [6]. Consequently, installing DG in distribution system often have important impact on power flow, voltages in addition to reliability indices that may be positive or maybe negative. It might be optimistic should they are generally correctly matched using all of those other system [7]. The actual siting connected with distributed generator throughout distribution feeders probably will have an impact around the operations and handle the power process, a process created to perform using large, and core generating amenities [11].

Apart from, application of DGs offers several advantages, including far better economy which have a practical the actual advancement of huge power plants, decreased environmental pollution, higher efficiency, increased high quality of power supply to the users, decreased loss within distribution systems, increased voltage profile, and releasing of network

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capacity [13]. Reliability can be interdependent having economics and increased expense is essential to accomplish increased stability or maybe to keep up stability on latest and acceptable levels [8]. Random approaches are now used more broadly within power system operations and planning due to a various uncertainties engaged [9]. Loss of load probability (LOLP) is the primary instance that employs indexes for planning generation capacity [10].

The paper proposes optimal location for fixing fuel cells in a distribution system using an innovative hybrid technique. The novelty of the proposed method is the combined performance of the Genetic Algorithm (GA) and Recurrent Neural Network (RNN) technique, thereby integrating GA first phase, RNN technique and GA second phase. The optimum location for fixing the fuel cell is attained by using the GA first phase. Here, the GA first phase utilizes the load flow data at different loading conditions for determining the optimum location. The RNN is aptly trained by the target fuel cell size and the corresponding inputs such as load variation and bus number. During the testing time, the RNN provides the fuel cell capacity according to the load variation and bus number. By using the attained fuel cell capacities, the GA second phase optimizes the fuel cell capacity to minimize the power loss and the voltage deviation. The objective function mainly helps to improve the bus voltage profile and the power loss reduction. The rest of the paper is organized as follows: 3. Past to that particular, this current exploration works tend to be offered with section 2. The effects along with the discussion tend to be offered with section 4. Within section 5 the paper is usually concludes.

2. Literature Survey: A Recent Related Work

From the literary works, various connected performs usually are readily available which often using the best location and ability of the micro grid in the distribution system surroundings. Some of them usually are looked at here. Qin et al. [14] have looked into reactive power aspects within power system reliability analysis. A strategy is actually suggested to analyze technique in addition to load point reliability of power systems with reactive power shortage on account of failures due to reactive power resources for generators, synchronous condensers, and compensators. This reliability indices on account of reactive power shortage usually are divided with those of real power shortage. Reactive shortage is established making use of reactive power procedure for the nodes while using voltage abuse to deliver more details pertaining to system planning and operation.

Mohammadi et al. [15] have offered a method using Particle Swarm Optimization approach (PSO) for placing Distributed Generators (DG) in the radial distribution systems to reduce the actual real power losses also to improve process reliability. A hybrid goal purpose is employed with the maximum DG position. It's got two parts, in first component the power loss is given and is named as first index. Power Loss Reduction Index is known as the second component the consequence of DG about reliability improvement of process have been thought to be a single index known as Reliability Improvement Index.

Heydari et al. [16] have suggested a problem formulation and remedy for the placement and dimensions of DGs optimally. The target is usually to enhance the reliability indices. The placement along with size regarding DGs are generally optimized having a Genetic Algorithm (GA). To analyze the recommended algorithm, the particular IEEE 34 buses distribution feeder is employed.

Kansal et al. [17] get recommended the use of Particle Swarm Optimization (PSO) technique to search for the best dimensions as well as optimum location for that placement of DG inside radial distribution systems pertaining to active electrical power compensation by lowering of electrical power loss as well as development throughout voltage profile. In first portion, the perfect dimensions of DG can be calculated on each bus employing the precise loss formula as well as in the next portion the optimal location of DG can be found with the loss sensitivity factor. This analytical expression will be based upon precise loss formula. The optimal dimensions of DG can be calculated on each bus by employing the precise loss formula and also the best location of DG can be found with the loss sensitivity factor.

Mohammadi et al. [18] have reviewed about an optimal DG unit placement using GA. The optimal dimensions from the DG unit is usually computed analytically using estimated reason acceptable nodes are motivated intended for DG unit placement. Reliability along with power loss reduction indices of distribution system nodes are designed. GA that contain a few rules can be used to look for the DG unit placement. DG unit they fit with all the highest suitability index. Simulation results demonstrate the advantage of maximum DG unit placement.

Paliwal et al. [19] have recommended a solution to find optimal distributed generation allocation for loss minimization associated with voltage regulation in distribution network. The system is usually more examined for elevated numbers of Reliability. Distributed Generator supplies the additional advantage to maximize throughout reliability levels since proposed through the upgrades in numerous reliability indices such as SAIDI, CAIDI and AENS. Relative scientific studies are usually executed and linked the desired results are resolved.

Shayeghi et al. [20] have proposed the optimal generation expansion planning in restructured power system employing the hybrid coded genetic algorithm and particle swarm optimization. Additionally, individual power producer's contribution as well as a couple of reliability criteria (LOLP and EENS) are deemed with GEP issue. The recommended technique is a quick way of computation regarding reliability criteria and will greatly attain maximum purchase prices for several types of IPP.

Distributed generator is now commonly used in distribution system to improve the overall performance of the distribution system. Major advantages of using distributed generator in distribution system are: it reduces total power losses in the system, improvement in voltage profile and reliability of the system and many more. There are different types of distributed generators are in literature. Some of them are wind power, solar power, hydroelectric power, tidal power, small hydro power, photovoltaic cells, fuel cells etc. Among the different types of distributed generators, this work considers fuel cells for distributed generation. The fuel cells are generated because of its renowned advantages over the conventional resources that are increased efficiency, increased reliability, less maintenance, excellent part- load performance, modularity and fuel flexibility, low chemical, acoustic and thermal emissions. While reviewing the recent research works, it is clear that in most of the works any one of the load condition is considered and some of the works determined the optimal location, but the result is not up to the level and also in most of the works fuel cells are not considered as distributed generator. The major problem in distributed generator is identifying optimal location for fixing distributed generator and also the amount of power to be generated by that distributed generator depends on the load conditions. The formulated problem related to the above mentioned problems is described in the following section 3.

3. Problem formulation

The fuel cells installation at optimal location ultimately leads to various factors such as line loss reduction, improved voltage stability, reliability and security. The optimum location and sizing of the fuel cell are the optimization problems with nonlinear objective function having corresponding constraints like power balance constraint, voltage constraint and fuel cell constraint etc. The main aim of the proposed method is focused on reducing the exact power loss, load balancing and voltage deviation of the given radial distribution network at the peak load condition. Hence, it utilizes the multi-objective function to determine the optimum location and sizing of the fuel cell. Here, the multi-objective function is mathematically formulated as per the following equation (1).

$$J = Min\{f_1, f_2\} \tag{1}$$

Where, f_1 and f_2 are the power loss and voltage deviation respectively. The mathematical equation of the multi-objective function is described as follows:

A. Power loss (f_1)

The distribution systems build instability during the peak loading conditions, which leads to constraint violations. The obtained fuel cell location and capacity minimize the power loss and realize the limits of the constraints. The required exact loss of the distribution system is calculated by the following equation [26] (2).

$$f_1 = P_L = \sum_{i=1}^{n} I_i^2 R \tag{2}$$

Where P_L is the exact loss of the distribution system, R the resistance between bus i and bus j, and I_i, the line current. The voltage deviation is determined as detailed in the following section 2.1.

B. Voltage deviation (f_2)

The radial distribution network voltage profile management is the main factor. When the fuel cell is connected to a distribution network, the voltage profile is changed. It can be evaluated at all of the buses in the radial distribution systems. Here, the identified fuel cell has to minimize the difference between the normal bus voltage and the rated bus voltage for improving the voltage stability. The required voltage deviation equation is described in the following equation (5).

$$f_2 = \sum_{i=1}^{N} \left(V_i - V_{rated}\right)^2 \tag{5}$$

Where, V_{rated} is the specified voltage; V_i the voltage at bus and N the number of buses. The objective function is dependent on the constraints such as the power balance constraints, bus voltage constraints and DG capacity constraints, which are described in the following section 3.3.

C. Constraints

(i). Power balance constraint

The power balance equation mainly describes the fact that the generated fuel cell power has to satisfy both the demand and the loss of the system. The required power balance equation is described in the following equations (8) and (9).

$$P_{Di}^{D} = P_{Gi}^{D} - Y_{ij} \sum_{i=j=1}^{N} V_i V_j \cos(\delta_i - \delta_j - \theta_i) \tag{8}$$

$$Q_{Di}^{D} = Q_{Gi}^{D} - Y_{ij} \sum_{i=j=1}^{N} V_i V_j \sin(\delta_i - \delta_j - \theta_i) \tag{9}$$

Where, P_{Gi}^{D} and Q_{Gi}^{D} are the power generations of generators at bus i, Y_{ij} the admittance of the line between i and j, θ_i the phase angle of the bus i, P_{Di}^{D} and Q_{Di}^{D} the load demands at bus j which lie in the following limits $P_{Di}^{D(\min)} \le P_{Di}^{D} \le P_{Di}^{D(\max)}$ and $Q_{Di}^{D(\min)} \le Q_{Di}^{D} \le Q_{Di}^{D(\max)}$.

(ii). Bus voltage constraint

The voltage limits of each bus must lie within the prescribed limits, which are given in the following equation (10).

$$V^{\min} \le V_i \le V^{\max} \tag{10}$$

Where, $V^{\min}$ and $V^{\max}$ are the minimum and maximum values of voltage at bus i; normally the bus voltage lies between $0.95 \le V_i \le 1.05\, pu$.

(iii). Fuel cell constraint

The fuel cell constraint mainly consists of the allowable capacity for the buses and the corresponding power factor of the fuel cell. The capacity of the fuel cell is described in the following equation (11).

$$P_{DGi}^{\min} \le P_{DGi} \le P_{DGi}^{\max} \tag{11}$$

The proposed method utilizes the constraints to find the minimum power loss attaining bus during the faulty condition, which is known as optimum location. Depending on the loss function the corresponding capacity of fuel cell is identified and added to the particular location. The brief process about the determination of fuel cell location and capacity using the proposed method is described in the following section 4.

4. Optimal Location and Optimal Capacity of Fuel Cell using Hybrid method

The optimal location and capacity of the fuel cell are formulated as multi-objective constrained optimization problems. This paper uses a novel combined GA and RNN for solving the optimal location and capacity of the fuel cell. Here, the proposed hybrid method utilizes GA in two stages, such as the GA first phase and GA second phase with the combination of RNN technique. The process to identify the training dataset using GA first phase is explained in the following section 4.1.

A. GA First Phase Based Optimal Location Determination

Of late, GAs have assumed supreme significance as the universal purpose optimization algorithms in accordance with the procedure of natural selection and genetics. They function on string structures such as chromosomes, characteristically a concatenated list of binary digits symbolizing a programming of the control constraints like phenotype of a specified dilemma [21]. In the proposed method, GA first phase is utilized for attaining the optimum location of the fuel cell. Here, the objective of the GA first phase is focused on minimized power loss attained bus during the different types of loading conditions. The backward sweep and forward sweep technique of supply load flow is effectively employed to perform the preferred target [22]. The crossover and mutation is negligible for the optimum location determination process. The steps to identify the optimum location for radial distribution network are described below:

Steps of the GA first phase

Step 1: Run the load flow equation for normal condition and different types of loading conditions.

Step 2: Initialize the required parameters of GA such as radial distribution network bus data set as N number of buses, bus voltage (V_i), real power loss and reactive power loss $(P_L^i \text{ and } Q_L^i)$ etc.

Step 3: Generate the random population of load value and apply it to the buses. The required random population chromosomes are described in the following equation (12).

$$X = [X_i^1, X_i^2 \dots X_i^d] \tag{12}$$

Where, $i = 1,....n$, and d is specified as the dimensions of the population space.

Step 4: Set the count k =k+1

Step 5: Find the fitness as follows

$$fitness = Min(P_L) \tag{13}$$

Step 6: Select the chromosome X_i^{best}, which has the minimum fitness.

Step 7: Apply the load changes and go to step 4, until the required termination criteria is achieved.

At the end of the process, the GA first phase develops the optimum location to place the fuel cell. Then RNN gives the capacity of the fuel cell to solve the problem. The process to get the fuel cell capacity using RNN is explained in the following section 4.2.

B. RNN Based Fuel Cell Ratings prediction

Recurrent neural network (RNN) is, in fact, analogous to feed-forward neural network (FNN), though RNN comprises feedback loop around neuron. Feedback loop, on the other hand, also comprises unit delay operator (z^{-1}) [24]. The presented neurons have the interior connections and each neuron in RNN receives a number of inputs, depending on the activation functions of the RNN results in the output level of the neuron. The learning task is given in the form of examples, which is known as training examples. Normally RNN has three layers like input layer, hidden layer and output layer. Here, the RNN is trained by the target fuel cell capacity with the corresponding inputs such as load variation and the bus number. The RNN structure is explained in the figure 1. The supervised learning process is utilized for training the RNN, which is briefly described as follows.

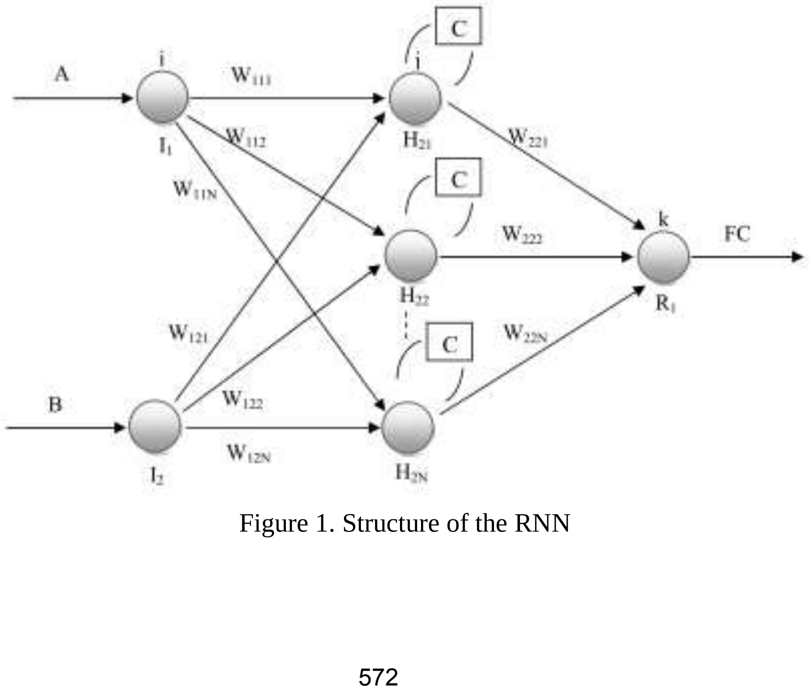

Figure 1. Structure of the RNN

Supervised Learning and Training Process

This section describes the training process of the RNN. Here, the supervising learning law of the gradient descent is used to train the RNN during the end of the initialization process. The derivation is similar to the back propagation algorithm. It is used to ensure the weight adjustments w_{bc}^{3}, w_{b}^{2} and w_{ab}^{2} of the RNN by using the training datasets. By using the chain rule, error between the actual output and target output is calculated and updated. The main purpose of the supervising learning algorithm is to minimize the error function, which is explained in the following equation (14).

$$E=\frac{1}{2}(W_a-W_t)^2=\frac{1}{2}e_s^2 \tag{14}$$

Where, W_a is the actual output of the network, W_t the target output of the network and E the error function. The error calculation and weight updating are explained as follows:

Layer 1:

This layer is used to update the weight of the w_{bc}^{3}. Here the updated weight is given by the following equation (15).

$$w_{bc}^{3}(N+1)=w_{bc}^{3}(N)+\eta_{bc}\Delta w_{bc}^{3}(N) \tag{15}$$

Where, $\Delta w_{bc}^{3}=-\frac{\partial E}{\partial R_c^3}=\left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial Net_c^3}\right]=\delta_c R_b$ with $\delta_c=\frac{\partial E}{\partial R_c^3}=\left[-\frac{\partial E}{\partial e_s}\frac{\partial e_s}{\partial R_c^3}\right]$ is propagates the error term, η_{bc} is the learning rate for adjusting the parameter w_{bc}.

Layer 2:

This layer performs multiplication operation and the updated rule for w_b^2 and w_{ab}^2 is given by the following equation (16) and (17).

$$w_b^2(N+1)=w_b^2(N)+\eta_b\Delta w_b^2(N) \tag{16}$$

$$w_{ab}^2(N+1)=w_{ab}^2(c)+\eta_{ab}\Delta w_{ab}^2(N) \tag{17}$$

Where, $\Delta w_b^2=-\frac{\partial E}{\partial w_b^2}=\left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial R_b^2}\frac{\partial R_c^3}{\partial R_b^2}\right]=\delta_c w_{bc}^2 P_b^2$ a

$$\Delta w_{ab}^2=-\frac{\partial E}{\partial w_{ab}^2}=\left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial R_b^2}\frac{\partial R_b^2}{\partial w_{ab}^2}\right]=\delta_c w_{bc}^2 Q_{ab}^2$$

With η_b and η_{bc} are the learning rates for adjusting the parameter w_b^2 and w_{ab}^2 respectively, w_b^2, w_{ab}^2 and w_{bc} are the tuning parameters. We can derive a learning algorithm that drives E to zero. Once the process is finished, the RNN is ready to give the fuel cell capacity. But the optimum capacity of the fuel cell to improve the voltage profile and minimize the power loss of the system is determined by the GA second phase. The detailed process of the fuel cell optimum capacity determination is described in the following section 4.3.

4.3. Fuel Cell Capacity Optimization Using GA Second Phase

This section describes the fuel cell capacity determination using GA second phase. The optimum location parameters are used as the inputs of the GA second phase. Here, the fuel cell capacity [25] is randomly generated and applied for the obtained optimum location. From the applied capacities, we can find the optimum capacity of fuel cell by using the multi-objective function, i.e., minimization of both power loss and voltage deviation. The step by step process to obtain the optimum capacity of the fuel cell is explained below:

Steps to find the capacity of fuel cell

Step 1: Initialize the input parameters like required radial distribution system bus data such as bus voltage (V_i), power loss (P_L^i), fuel cell capacity limit etc.

Step 2: Set the time counter *t=0* and randomly generate the *n* chromosomes, i.e., fuel cell sizes within the searching space dimension $[Y_{\min}, Y_{\max}]$.

$$Y = [Y_i^1, Y_i^2 \ldots Y_i^d] \tag{18}$$

Where, $i = 1,\ldots.n$, and d is specified as the dimensions of the population space.

Step 3: Evaluate each chromosome in the initial population using the objective function (1) and search for the best value of the objective function J_{best}. This step finally Sets the chromosome proportionally to the J_{best} as the best.

Step 4: Update the time counter t = t+1.

Step 5: Create a new population by repeating the following steps until the new population is completed.

Selection: select the two parent chromosomes from the population according to the fitness function.

Crossover: The crossover operation is achieved between the two chromosomes, leading to generation of a new set of chromosomes.

Mutation: By using the mutation probability, the method mutates a new child at each chromosome.

Acceptance: Place new child in a new population.

Step 6: Run the algorithm with the new set of population.

Step 7: If one of the stopping criteria is achieved, stop the operation,. else go back to the step 3.

Once the above mentioned steps are finished, the system is ready to give the optimum capacity of the fuel cell with improved voltage profile and minimum power loss. The proposed method working structure is given in the following figure 2. The proposed method is implemented in the MATLAB platform through IEEE standard bench mark system and the performance is evaluated by using the comparison studies, which is described in the following section 5.

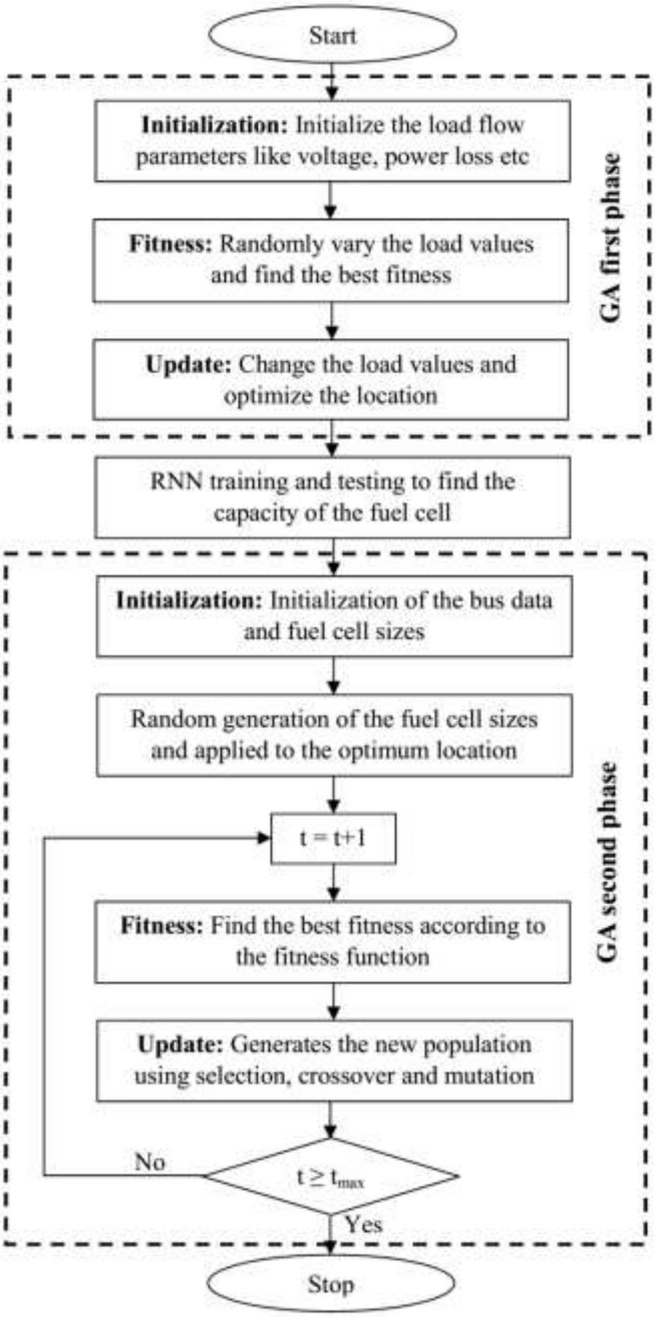

Figure 2. Structure of the proposed hybrid technique

5. Numerical Results and Discussion

The proposed mutual method is implemented in MATLAB/simulink R2013a platform, 4GB RAM and Intel(R) core(TM) i3-2100 CPU with 3.10 GHz. The IEEE 33 bus radial distribution system with 3.72 MW and 2.3 MVAr is utilized for the testing of the proposed hybrid method [27,28]. The mentioned testing system consists of 33 nodes and 32 branches. Here, the backward sweep and forward sweep method of distribution load flow [29] is used to fulfill the desired objective. The effectiveness of the proposed method is identified by using the comparative analysis with the GA, PSO and hybrid PSO techniques. The results are displayed as follows.

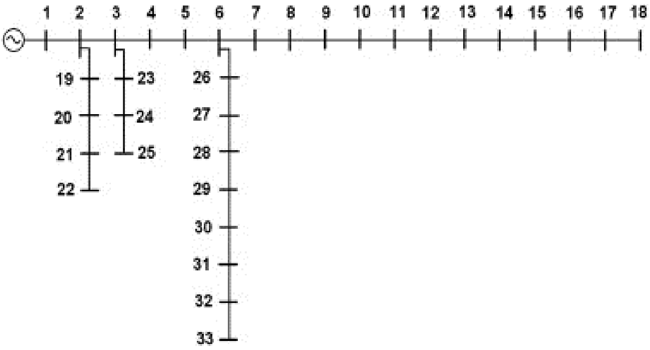

Figure 3. Structure of the IEEE 33 bus distribution system

The following figure 4 describes the IEEE 33 bus radial distribution system normal voltage profile. It is seen that the radial distribution network maintains the bus voltage within the specified limit at all the 33 buses, i.e., the nominal voltage of the substation is 1 pu. The testing system line loss at normal condition is described in the figure 5. The maximum line losses are present in the bus system at normal condition is 58 kW. The figure 6 shows the bus voltage of the radial distribution system at fault time. Due to the load increasing at the range of 20%, the bus voltage is violated from the normal condition. The power loss of the IEEE 33 bus radial distribution system at fault time is given in the figure 9. It is observed that the power loss is increased due to the load variation of the distribution system. In the faulty condition the bus power loss is likely to go up to 62kW, which is a high loss compared to the normal condition. So it is essential to find the optimum location to place a fuel cell at right capacity. The proposed method is utilized for determining the optimal location to achieve minimum power loss by placing the optimum capacity of fuel cell. The bus voltage profile after locating the fuel cell is explained in the figure 8, at the same time the line losses of the system are described in the figure 9. Form the figure, it is crystal clear that the proposed method voltage profile is effectively maintained near the normal condition and the power loss is minimized at 58kW. The figure 10 describes the proposed method fitness at 20% load variation, which is dependent on the iterations.

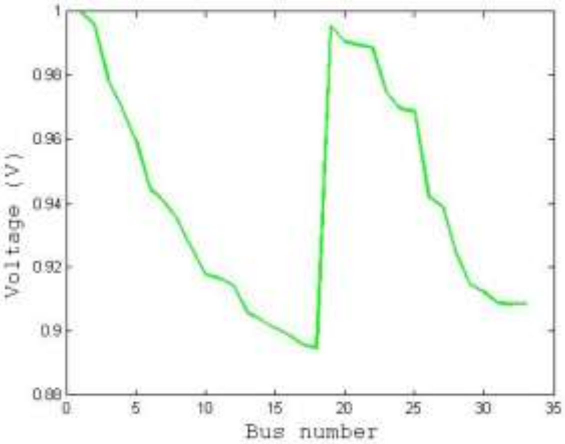

Figure 4. Normal bus voltage

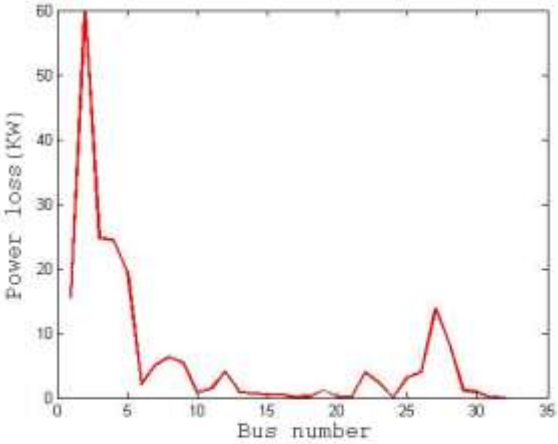

Figure 5. Normal power loss

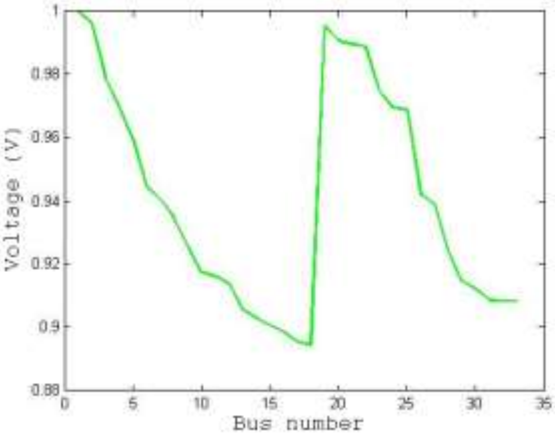

Figure 6. Bus voltage at 20% load variation

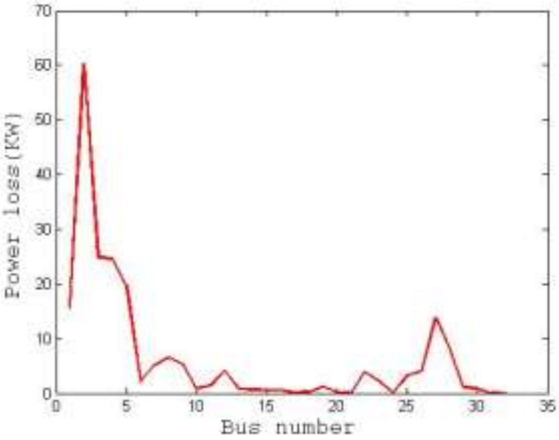

Figure 7. Power loss at 20% load variation

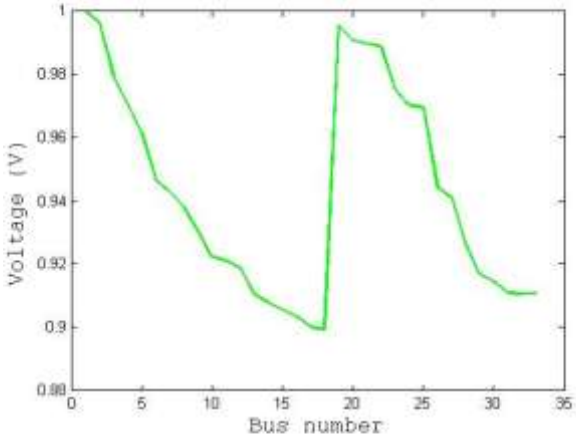

Figure 8. Bus voltage using proposed method at 20% load variation

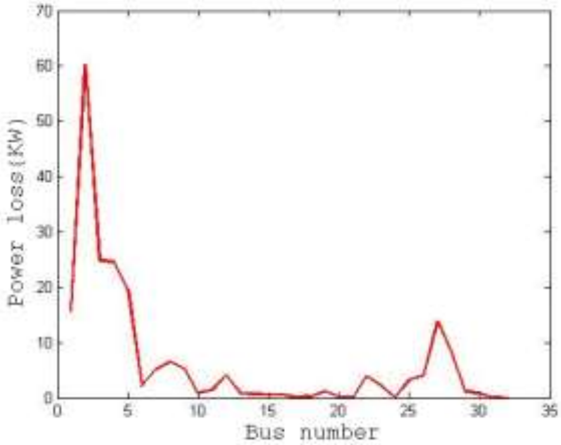

Figure 9. Power loss using proposed method at 20% load variation

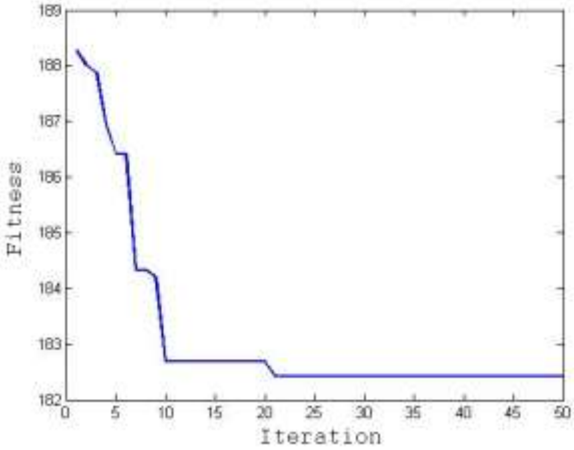

Figure 10. Fitness of the proposed method at 20% load variation

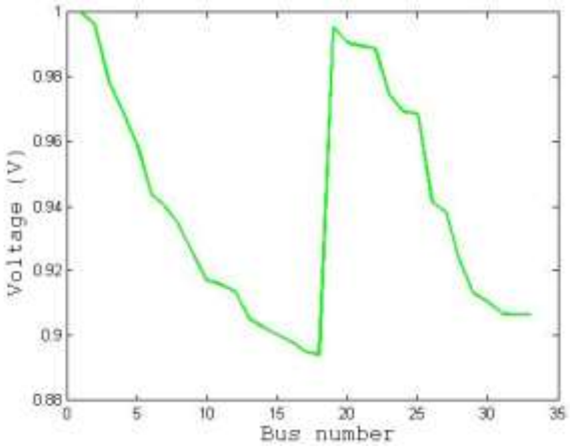

Figure 11. Bus voltage at 30% load variation

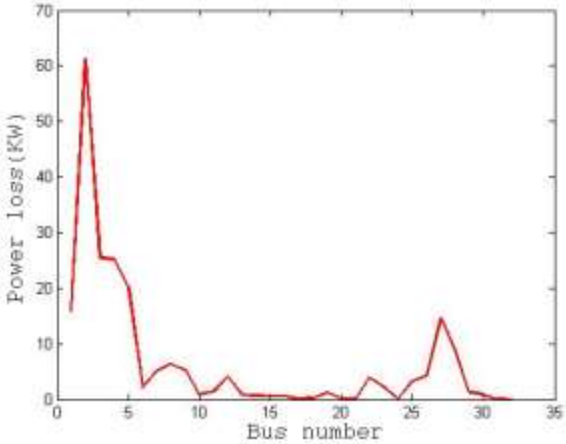

Figure 12. Power loss at 30% load variation

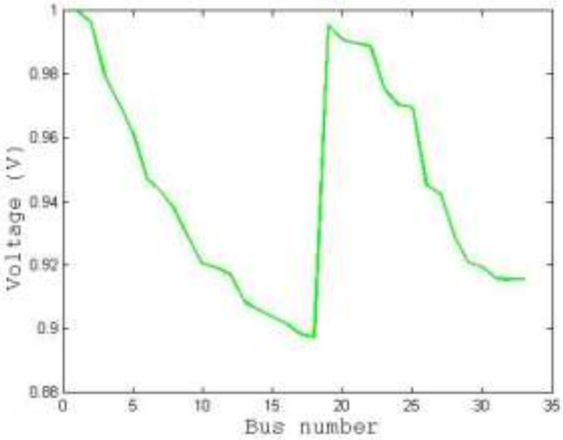

Figure 13. Bus voltage using proposed method at 30% load variation

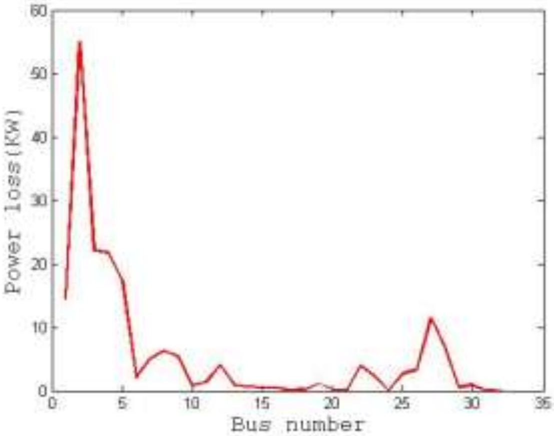

Figure 14. Power loss using proposed method at 30% load variation

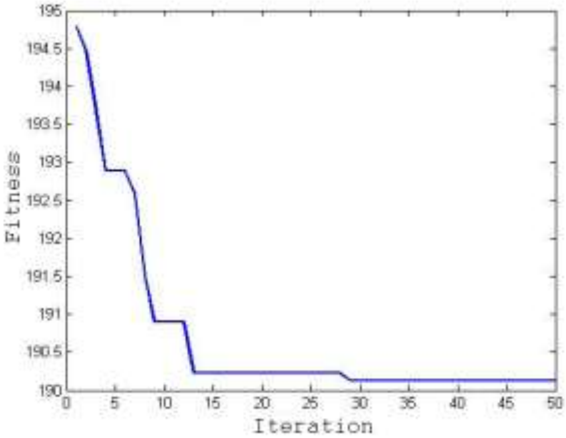

Figure 15. Fitness of the proposed method at 30% load variation

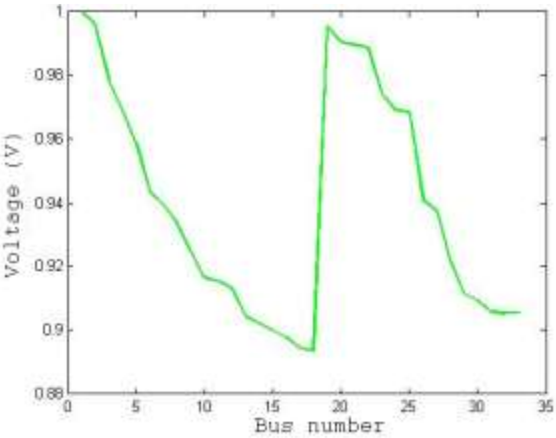

Figure 16. Bus voltage at 40% load variation

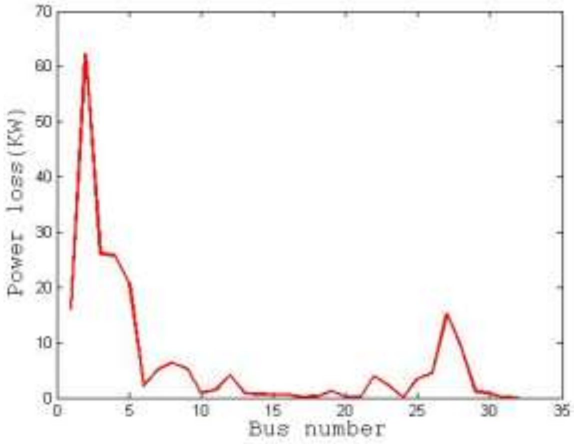

Figure 17. Power loss at 40% load variation

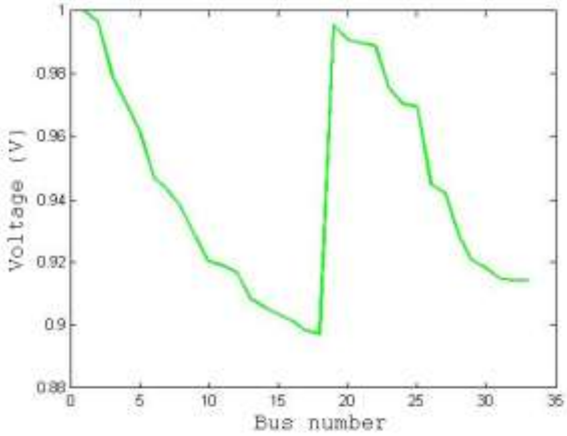

Figure 18. Bus voltage using proposed method at 40% load variation

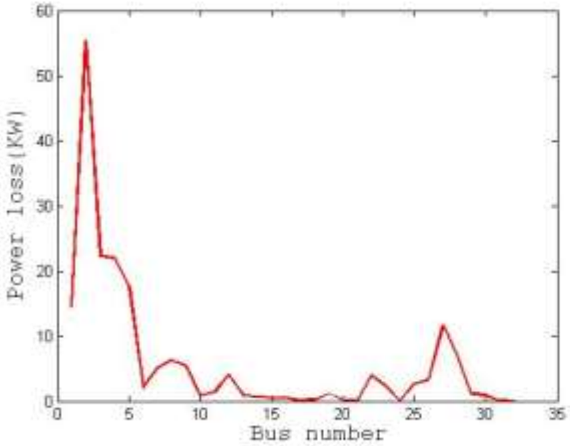

Figure 19. Power loss using proposed method at 40% load variation

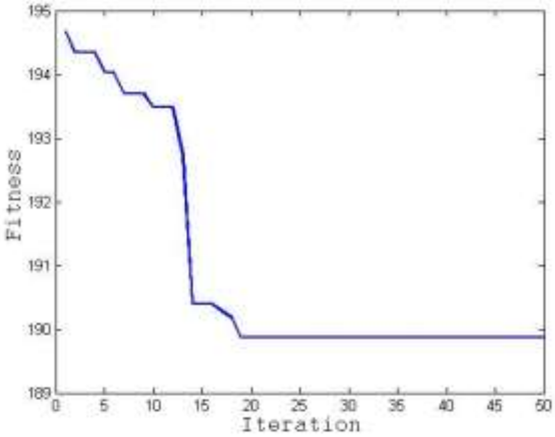

Figure 20. Fitness of the proposed method at 40% load variation

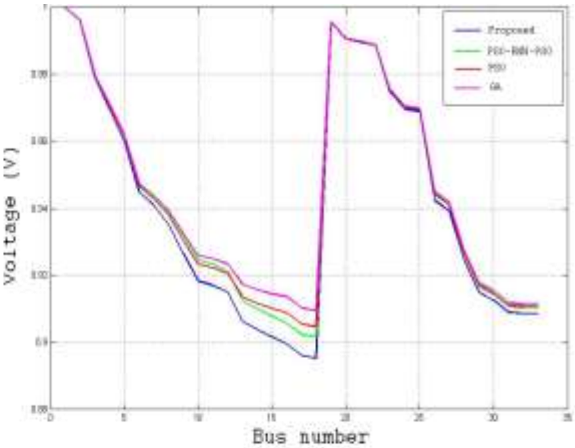

Figure 21. Bus voltage comparison at 20% load variation

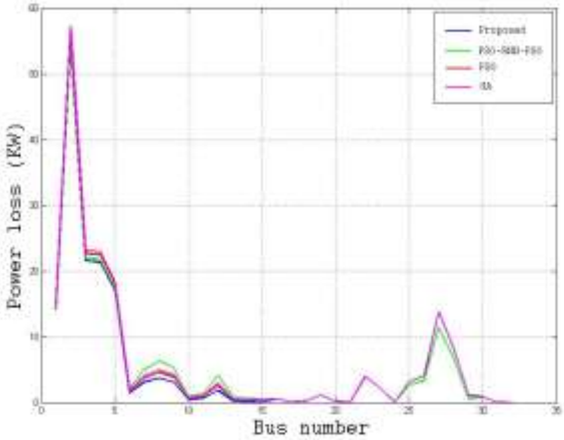

Figure 22. Power loss comparison at 20% load variation

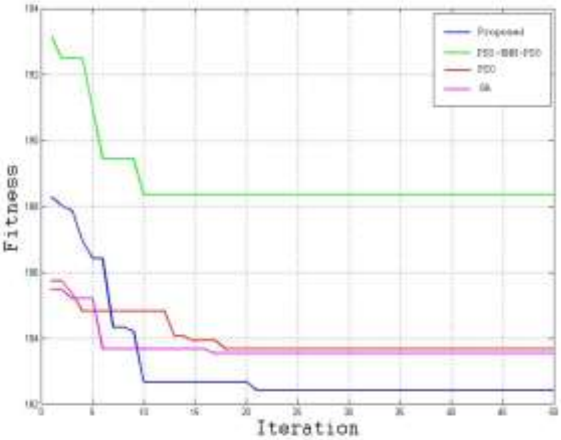

Figure 23. Fitness comparison at 20% load variation

The IEEE 30 radial distribution system bus voltage at 30% load variation is described in the figure 11. It clearly shows the voltage deviation on account of the load variation compared to the normal condition. Also the power loss at the 30% load increment is described in the figure 12, which shows that the maximum power loss of this load condition is 64kW. In this condition the proposed method optimized results are applied and the corresponding voltage and power loss are explained in the figures 13 and 14. After the arrangement of fuel cell, it improves the voltage profile in the specified limit and reduces the power loss into 55kW. The proposed method fitness evaluation dependent on the iteration is explained in the figure 15.

The IEEE 33 bus system is allowed to meet the 40% load increment, which affects the power flow quantities of the system. During the load increment period the system normal voltage profile gets collapsed, which is shown in the figure 16. Similar load condition the system power loss is described in the figure 17. In the situation, to restore the normal condition of the bus system with the help of optimum rating of fuel cell at the optimum location, the proposed method finds the location and capacity of the fuel cell at the 40% load increment. After the fuel cell placement the bus voltage profile is analyzed, which is shown in the figure 18. Due to the voltage stability the constraints are maintained in the stable limit, which reflects minimum power loss. The attained minimized power loss is explained in the figure 19. The fitness of the proposed method during the 40% load variation of the bus system is explained in the figure 20. Then the proposed method results are compared to the other optimization techniques such as GA, PSO and hybrid PSO. Here, we find the optimum location and capacity of the fuel cell using the above mentioned techniques for 20% load variation. Initially the proposed method bus voltage profile for 20% load variation is compared with the above mentioned techniques, which is described in the figure 21. From the comparison, we observe that the proposed method voltage profile is well improved near the normal voltage profile compared to the other techniques. The power loss of the different methods is compared in the figure 22. Here, the proposed method effectively reduces the power loss by selecting the optimum location and capacity of the fuel cell. Finally the proposed method fitness evaluation during the iteration process is compared with the other techniques, which is described in the figure 23. For attaining the optimum location and capacity of fuel cell it is essential to minimize the voltage deviation and power loss.

Table 1. Performance analysis of the GA technique

Load in %	Bus no.	Fuel cell capacity	Power loss in kW			Voltage		CPU time (sec)
			Normal Power loss	After fault	After fuel cell placement	Min	Max	
20	15	163	210.859	212.814	198.080	0.9055	1	85.3367
30	15	144	210.859	213.803	191.964	0.9061	1	97.1982
40	15	173	210.859	214.798	194.342	0.9047	1	118.6004

Table 2. Performance analysis of the PSO technique

Load in %	Bus no.	Fuel cell capacity	Power loss in kW			Voltage		CPU time (sec)
			Normal Power loss	After fault	After fuel cell placement	Min	Max	
20	15	169	210.859	212.814	187.764	0.9095	1	89.53124
30	15	134	210.859	213.803	193.356	0.9049	1	107.3599
40	15	176	210.859	214.798	194.767	0.9047	1	123.2981

Table 3. Performance analysis of the hybrid PSO technique

Load in %	Bus no.	Fuel cell capacity	Power loss in kW			Voltage		CPU time (sec)
			Normal Power loss	After fault	After fuel cell placement	Min	Max	
20	30	172	210.859	214.725	191.182	0.9095	1	7.1567
30	28	181	210.859	214.851	193.013	0.8975	1	11.2743
40	28	168	210.859	216.202	194.559	0.8974	1	8.1074

Table 4. Performance analysis of the proposed method

Load in %	Bus no.	Fuel cell capacity	Power loss in kW			Voltage		CPU time (sec)
			Normal Power loss	After fault	After fuel cell placement	Min	Max	
20	16	161	210.859	212.868	187.208	0.9101	1	6.9216
30	9	141	210.859	212.913	190.801	0.8949	1	5.0253
40	29	162	210.859	220.950	193.509	0.8973	1	6.2556

The above tables explain the performance analysis of the different techniques like GA, PSO, hybrid PSO and the proposed method. Table 1 and table 2 show the performance analysis of both the GA technique and PSO technique respectively. The hybrid PSO performance is analyzed in the table 3 and the proposed method effectiveness is analyzed in the table 4. The above mentioned techniques are tested against various load conditions like 20%, 30% and 40% load variations. During the respective load conditions the power loss, voltage deviation and time for attaining the optimum results are tabulated. From the tables we can conclude that the proposed method effectively attains the minimum power loss and improved voltage profile, thereby, optimally selecting the location for fixing the fuel cell effectively.

5. Conclusion

This paper introduces a hybrid technique for locating the capacity of fuel cell in the distributed generation system. In the proposed method, the optimal location for fixing the fuel cell is determined by the GA first phase and the fuel cell capacity is predicted by the RNN. The optimum capacity of the fuel cell to reduce the power loss and voltage deviation is attained by using the GA second phase. The advantage of the proposed method is its enhanced capacity to achieve improved bus voltage profile, reduced power loss, transmission and distribution relief capacity for both utilities and the customers. This process is tested in the IEEE standard radial distribution benchmark systems and the effectiveness is analyzed with different algorithms. Here the comparison analysis is made between the radial distribution system power loss and voltage at various conditions like normal condition, during the fault time, GA, PSO, hybrid PSO and proposed techniques. From the comparison results we are convinced that the proposed method is the well effective technique to identify the optimum location and capacity of the fuel for the radial distribution system, which is superior to the other techniques.

6. References

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