Integration of Distributed Energy Resources in the Distribution System Using Dragonfly Algorithm

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Abstract: *To fulfil the load requirement and enhance the system performance, it is imperative to use renewable distributed generators optimally in the DS. In the present scenario, minimization of power loss is a prominent research issue. Different researchers solved the power loss reduction and voltage profile improvement problem in DS. Exact location and size determination of DERs are two crucial factors for identifying the exact location and capacities in two crucial factors affecting the DS performance. This research aims to reduce the power loss in the DS and facilitate an improvement in the voltage profile of the system. First, the vulnerable nodes for placement of RDGs are identified by the LSF method. Next, the sizes of DERs at determined places are found using optimisation techniques. Various constraints of the DS are included to solve the problem. Various cases are considered to analyse the performance. Further, most of the literature authors considered the allocation of these sources independently. In this paper, an integrated approach is proposed to solve the DG and SC allocation problem mutually. Finally, the potency of the developed method is tested on 83 IEEE buses, and also real test system (83-bus Taiwan systems) is also considered. The obtained show its dominance of the developed methodology in terms of better loss reduction and voltage profile improvement.*

Keywords: *Distributed, Capacitor, Distribution system, Energy, Sensitivity factor*.

1. INTRODUCTION

Allowing numerous involvements of different utility services and provider in the electric market, help to achieved by bringing down the effect of over increasing load demand which is commonly the major problems faces by the power system utilities are some of the main encounters faced by utility companies in this contemporary period. The creation of a new transmission station to boost the transfer capability or an advanced station will not solve the issue of over-increasing load demand. Since only the capacity generated will be transmitted, therefore, the continuous use of DREs to supplement the existing conventional generating plants is the only way that both the transmission stations and distribution stations will function effectively. Dispersed generating mechanism (DGs) connected close to the end users, with the addition of shunt capacitor banks, without the financial implications of sending and sharing, will reduce the cost of transfer and sharing, and hence power loss through the processes will be minimised, thereby improving the voltage stability or profile in the system. DREs can be a mini hydro, solar plants, wind energy plants, a small diesel generator, a micro-turbine run on natural gas, fuel cells, etc. DERs such as mini hydro, solar, and wind energy plants ensure supplementary help with zero eco-friendly discharge. Additionally, the coming out of innovations of modular DGs demands smaller space, less building or constructing time, and less financial implications have necessitated the use of DERs. Traditionally, conventional plants ought to be a basic part of the electric grid, in which bulky generating facilities are closely sited either neighbouring energy resources or else placed in remote locations from occupied capacity centres, these at the end supply the old-fashioned transmission and distribution network that allocates greater majority of power to load centres and from there to end users. These were established when the expenditures of moving fuel and incorporating generating tools into settled areas far surpassed the cost of rising sending, delivery facilities, and charges. Fundamental plants are habitually considered to take advantage of minimising the financial problems, and are constructed as "unrepeatable." Consequently, the interwoven generation is the central cause of remote purchasers' power charges and power quality difficulties, which became more severe as digital tools required enormously reliable electricity. Competence gains no longer come from growing generating size, but from smaller units situated closer to sites of ultimatum. To fully achieve the potential benefits of DGs, it is essential to rethink the key idea leading the electricity supply system. The imminent active system will outstandingly and efficiently connect all the utility electric power sources with customer needs. DG is frequently used as supplementary power to boost reliability or as a way of complying with ventures in transmission and distribution networks, reducing network charges, minimizing line losses, deferring building of huge generation facilities, dislodging costly grid-supplied power, providing substitute sources of supply in markets, and generating conservational profits. In recent years, DG has grown into an efficient and clean alternative to the old-fashioned electric energy sources, and fresh technologies are making DGs increasingly feasible. The key motivating forces behind the larger penetration of DGs can be branded as eco-friendly, profitable, and governing features. There are quite a lot of small generators that create very small or no greenhouse gas discharges. One eco-friendlier driver is to ease the sending and delivery increase, along with the prevention of bigger power plants. In the viable driver, the ambiguity in electricity markets helps small generation systems, and DGs are now cost-effective to recover the power quality and dependability. The smooth scheme of DGs is that it is circulated the linkages near to customers, and DGs signify different skills and major energy sources.

3.0 OBJECTIVES

- To introduce innovative technologies for optimal utilization of existing resources and resolution of reported issues to meet the targeted load demand.
- To minimize the distribution system power losses
- To enhance the voltage profile of the distribution systems

3.1 **Preferred Methodology**

- Network Reconfiguration
- Conductor grading
- Distribution transformer allocation and sizing
- High voltage distribution system
- Automatic Voltage Booster
- Capacitor placement
- Distributed Generation placement
- All the above-mentioned methods are used to minimize the power loss and improve the voltage profile of the system. But to meet the load requirement, improve the loss reduction, and maintain a good voltage profile during peak time, the most commonly employed method is;
- Distributed Generation placement

3.2 Problem Formulation

In this research work, notable techniques are adapted to highlight the best way to overcome the DERs integration constraints in DS. The significance of this presentation is to curtail or alleviate the losses to reasonable stages and, at the same time, to enhance the power quality or voltage profile proportionally.

The corresponding applied relation is given in equation (1), below;

$$P^{DER}_{TLoss(\mathrm{u,u+1})} = \sum_{m=1}^{nb} P^{DER}_{LossI(\mathrm{u,u+1})}$$

(3.1)

The given above applied relation fulfills the different requirements and constraints of DS, which is represented in the equation. (2) to eqn. (5)

$$\sum_{u=1}^{N_{DG}} P_{DG,u} \le 0.5^{*} \sum_{u=1}^{n} P_{Lu}$$

(3.2)

Constraints of the capacitor;

$$\sum_{u=1}^{N_C} Q_{C,u} \le \sum_{u=1}^{n} Q_{Lu}. \qquad (3.3)$$

Constraints of voltages;

$$V_{\min} \le |V_u| \le V_{\max} \qquad (3.4)$$

Constraints of thermal;

$$|J_{u,u+1}| \le |J_{u,u+1(\max)}|. \qquad (3.5)$$

2.0 LITERATURE SURVEY

The principal goal of the electricity supply coordination is to see that customers' demand for energy is fulfilled. The sending or transfer coordination is to send bulky quantities of energy from the leading generation areas to key load centres. The bidirectional power flow and the intermittent nature of renewable DERs (like solar and wind) introduce significant operational challenges for Distribution System Operators (DSOs). Delivery structures convey the drive further to end users, consuming the maximum suitable voltage level. Conversely, with system deregulation, new small producing facilities, which are branded as Distributed Generation (DG), are predictable to appear as the most important suppliers to power generation. New planning and operational tools are required to handle increased complexity and uncertainty. Optimization frameworks, such as those based on Genetic Algorithms (GA) or deep learning models, are being developed to optimize DER set points, network reconfiguration, and short-term load forecasting for enhanced efficiency, resilience, and loss minimization (Zhou Tao and Bruno François, 2011). Nevertheless, DGs can send rich advantages to the supply utility system, such as power loss reduction, auxiliary services, enhanced consistency, and better effectiveness.

Decades ago, many factors have facilitated the drive to drive DGs to the front of electricity generation: new modernisations in DGs know-how, growing worry about climate variation, and swelling consumer demand together with ecological and social limitations on the creation of new spreading infrastructure, which combine to make DGs and precisely renewable types a feasible substitute to meet the ceaseless growth in electricity proposition.

A study of the significant literature has revealed that there is no commonly accepted definition of DGs. Several countries defined DGs based on the root of the voltage level, while others start from the principle that DGs are coupled to circuits from which consumer loads are supplied directly. This segment reviews the descriptions and some methods of DERs engagement and quantifying the future by diverse societies, families, and researchers. The IEEE states DERs as the production of electricity by facilities that are suitably smaller than principal generating plants as to allow interconnection at any point in an energy coordination.

The International Council on Large Electricity Systems (CIGRE) describes all generation units with a maximum size of 50 MW to 100 MW, which are generally linked to the distribution network and which are neither centrally scheduled nor transmitted.

Abdullah Bin Humayd and Kankar Bhattacharya (2017) proposed that apart from considering the usual demand profile, the future framework considers unrestrained and restrained (smart) PEV charging demand, as well as demand response options operating cost. A new iterative method is proposed, which involves post-processing the plan judgments to meet effective adequacy levels for each year of the planning limit.

Meng and Wang (2017). This paper investigates the problem of distributed energy control for both generation and demand sides in a smart grid by formulating the economic dispatch and demand response in a united framework. The main role is to formulate a social welfare maximization problem for a more practical scenario by taking wind power and temporally coupled constraints of the demands into account.

Mahmpoud, Dang Huya, and Vigna (2017) DGs' contribution to power systems includes improvement in energy efficiency and power quality, to reliability and security. These benefits are only achievable with optimal allocation of distributed resources that considers the objective function, constraints, and employs a suitable optimization algorithm. It can be stated.

Adefarati and Bansal (2017) Reliability technique is one of the strategic performance indicators to measure the influence of renewable DG resources in the national power distribution system. A reliability assessment method in the presence of the DER units is proposed to economize the cost that is associated with the power outage. There is a considerable drop in the cost that is associated with the power outage with the application of renewable DERs.

Zhi-Hui Wang, Bao-Zhu Liu, Xing-Wei Liu and Ze-Chen Wei (2017), the research delivered the harmonised charging approach of plug-in electric vehicles to give the required distributed energy accommodation capacity. Based on the demand-side management, the time interval of peak-valley charging demand is found.

Biswasa, Suganthana and Amaratunga (2017), the real and reactive power play a significant role in power systems and distribution systems. Active power does the useful work by providing real power supports, while reactive power backs the voltage that necessitates control from the system reliability phase, as deviation of voltage from the nominal range may lead to abnormality.

Satish Sharma and Abhyankar (2017), this research expected a variant of the Shapley value loss allocation method called the sequential Shapley value (SSV) method. The technique is essential for loss allocation on radial distribution systems, as the process exploits the radial features of distribution systems.

Lokesh Gupta and Sivasubramani (2018), this paper suggests a combined model of Multi-Objective Dynamic Economic and Emission Dispatch (MODEED) with Demand Side Management (DSM) to find out the assistance of DSM on the generation side. This model considers a day-ahead based load instable DSM approach. In order to analyse the effect of DSM on the generation side, the intents of the dynamic economic and emission dispatch problem were minimized individually and simultaneously with and without DSM.

Suresh Kumar Sudabattula et al (2018) established a DFA technique with other optimization assertions to allocate DERs in DS. The effective allocation of DERs in DS presented the best solution to alleviate the real power loss by enhancing the voltage quality.

4.0 LSF METHOD FOR DERs PLACEMENT

The knowledge of LSF examination in the distribution system (DS), which commonly functions to prevent away repetition of calculations to manage the time and space of the power flow solutions. The employment of DERs in a proper situation in radial structures includes two features that need to be examined: the position of DERs to be fixed and the capacity of the DERs. To effectively position the DERs is the most important than their capacity. The fundamental formulations consist of isolated variables indicating their site. Some reflection in determining the finest position for fresh DERs is the effects of power loss and voltage stability. The voltage quality enhancement is computed by manipulating the modification of voltage strength in relation to per unit (pu).

$$P_{loss} = \left(\frac{P^2_{u+1,eff}\, Q^2_{u+1,eff}}{|Vu+1|^2} \right) Ru, u+1$$

(4.1)

Nevertheless, the real and reactive power losses noted are analyzed, and related equations are shown in eqn. (7) and (8). The buses that are liable to real and reactive power loss are taken as the candidate buses for fixing the DERs.

$$APLSF(\mathrm{u,u+1}) = \frac{\partial P_{loss}}{\partial P_{u+1,eff}} = \left(\frac{2P_{u+1,eff} R_{u,u+1}}{|V_{u+1}|^2} \right)$$

(4.2)

$$RPLSF(\mathrm{u,u+1}) = \frac{\partial P_{\ loss}}{\partial Q_{u+1,eff}} = \left(\frac{2Q_{u+1,eff} R_{u,u+1}}{|V_{u+1}|^2} \right).$$

(4.3)

4.2 Dragonfly Algorithm

The Dragonfly Algorithm was used, which was designed by SEYEDALI MIRJALILI by the year 2015, and the putting into practice of this algorithm is influenced by the swarming actions of dragonflies.

3.1 Important steps of the dragonfly algorithm for solving the DGs and SCs sizing problem

1. Read the data related to test systems
2. Run base case load flow
3. Optimal locations of DGs and SCs are identified using the LSF approach
4. Parameters of the DFA are specified
5. Identified locations are given as input to the DFA, further setting the dimension of the search space, lower and upper bounds
6. Initial population is generated
7. If a particular no of evaluations is reached, the further end condition is fulfilled, stop the procedure
8. Attraction towards the food sources is given using the equation below gives DG and SCs sizes in Eqn. (9)

$$F^i = X^+ - X \qquad \text{………… (5.1)}$$

9. Distraction outward enemy gives the worst possible sizes of DERs, which is represented in Eq.(10)

$$E^i = X^- + X \qquad \text{……… (5.2)}$$

10. Further, velocity and position vectors are updated using below equation. (5.3) and eqn. (5.4)

$$\Delta X_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i + wW_t)$$

………. (5.3)

$$X_{t+1} = X_t + \Delta X_{t+1} \qquad \text{………. (5.4)}$$

11. While ended
12. Results related to DG and SC sizes are stored and further evaluated power loss of DS.

5.0 DISCUSSION AND INTERPRETATION OF 83 IEEE

Bus Systems in DS.

A rapid increase in load demand and solving the power shortage problem in peak times connecting distributed generators to the distribution system, is a viable solution. Moreover, DG also offers the environmental, economic, and technical advantages, i.e., voltage profile upgrading, curtailment in power loss, power stability, and quality improvement. To make these advantages feasible, it is necessary to select the correct size and location for the DG unit. Inappropriate size and location give a negative result. So, the optimal allocation problem of DGs in DS has been a significant problem in recent years.

Further, the nature of the loads in DS is inductive. So, there is a need to add shunt capacitors (SCs) in suitable places for reactive power compensation. These actions improve the voltage profile and reduce power loss. Further, allocation of DGs and SCs improves the overall performance of the system. So, effective utilization of both sources is a prominent issue nowadays. The integration of renewable DGs and SCs gives the preferred solution in terms of better loss reduction, voltage profile, and voltage stability of the system. The DGs may be diesel generators, mini hydro power, solar, wind, micro turbine, etc. In addition, solar, wind, and mini hydro power contribute to the benefits of environmental issues. Since they are less hazardous environment. The DGs and SCs can be important only when they are allocated properly in the system. In the present work, a methodology is employed to provide a prominent solution to place DGs and SCs simultaneously in suitable locations and achieve significant results.

6.0 RESULTS AND DISCUSSION:

The technique employed in MATLAB and the IEEE 83 bus is selected. Before the allocation of DERs, the active and reactive power loss at the base case is 0.531 MW and 0.8458 p.u. Various cases are analysed and the observations of the power loss and voltage profile in noted.

Case 1: 1 DG
Case 2: 1DG and 1 Capacitor
Case 3: 2 DGs
Case 4: 2 DGs and 2 Capacitors
Case 5: 3 DGs
Case 6: 3 DGs and 3 Capacitors
Case 7: 4 DGs
Case 8: 4 DGs and 4 Capacitors
Case 9: 5 DGs
Case 10: 5 DGs and 5 Capacitors

Case 1: The DGs were placed on 6 buses, and they inject real power into the system. After the allocation of the DG, the power loss is reduced to 0.446 MW from 0.531 MW, and the voltage profile improved to 0.947 p u. The injection of a single DG on a bus yields only a real power, which results in reducing the active power losses. Conversely, the addition of DGs will also increase the voltage profile, as a result of the reduction of real power loss through the employment of DGs.

Case 2: In this case where both the DGs and the capacitor were considered for placement and injected real and reactive power to the system. After adding these sources, the power loss reduced to 0.406 MW and the enhanced voltage profile to 0.947 p.u. For any allocation of GDs + Capacitor banks clearly shows the advantages over just a single DG, because in any case, the loads present must accumulate both real and reactive power. Therefore, it's a good decision to place both the DERs simultaneously in the distribution system.

Case 3: 2 DGs were considered for injecting active power on 6 and 82 buses. After allocating these sources loss is reduced to 0.407 MW, and increases the voltage profile to 0.948 p.u. The use of only a DG in this case has highlighted the need, in any case, to test the DERs against the actual constraints present in that particular bus. The reason is the placement of DERs in an effective position, and also the sizes of the DERs matter a lot. Because when there is improper placement or ineffective sizing of DERs, the result normally gives negative impacts instead of positive impacts. In this mode, the utilisation of only DGs gives an eminent achievement by reducing the active losses and helps in improving the power quality of the voltage.

Case 4: 2 DGs and 2 capacitors are employed to provide both real and reactive power, by placing the DERs on the candidate or best buses power loss was reduced to 0.345 MW, and the voltage profile is enhanced to 0.948 p.u. Localising both the DERs in the 6 and 82 buses to improve the losses in the buses, the effectiveness of this combination results in the best options in this case, where the percentage shows there is drastic power minimisation and power quality enhancement. The developments in this case have given a percentage of power loss reduction of 35% in this combination; hence, there is a huge achievement in the simultaneous integration of DERs in DS.

Case 5: only 3 DGs were chosen to inject only active power to the system. The DERs were placed to support or compensate for real power losses in DS. The DERs were allocated to 6, 69, and 79

Table 1.0 showing cases 1-6 of 83 IEEE bus systems;

Different Cases	**Power loss in MW**	**DGs size in MW**	**Capacitor size in MVAr**	**DGs/Caps. Locations**	**% Reduction of power loss**	**V_{min} p.u**	**Power factor**
Case 1	0.446	3.1400		6	16.15	0.9472	NA
Case 2	0.406	3.1486	2.284	82	23.67	0.9472	0.81
Case 3	0.407	3.1756		6	23.48	0.9482	NA
		2.6264		82			NA
Case 4	0.345	3.1484	2.2841	6	35.14	0.9482	0.81
		2.6412	1.9127	82			0.81
Case 5	0.372	3.1753		6	30.06	0.9548	NA
		2.6615		69			NA
		3.6437		79			
Case 6	0.290	3.1486	2.2838	6	45.48	0.9599	0.81
		2.6412	2.0907	69			0.78

buses. It was found that the power loss is reduced to 0.372 MW. The employment of only DGs in the bus shows that the placement was done appropriately, since the aim is to decrease the active power loss and help in making the voltage quality stable. The most vital aspects of the injection of only DGs are supplementing or supporting the actual power required, which is necessary for any power system to be achievable. Whenever the designed power quality is met, the voltage stability or voltage profile enhancement will reach the expected results. The power loss minimisation observed is quite significant, since the development is a 30% reduction from the actual power loss at the base case level (where there is no engagement of DERs. In most cases, when the placement of DERs is made effectively tends to be promising even if the responsive power is not compensated; the power reduction helps the improvement of the voltage quality, making the load increase properly managed in the radial distribution networks. The case is considering the DGs alone to verify the significant loss present in the respective buses used in the location. The power loss has been reduced to 30%; therefore, this combination has minimised the real power loss, and also the power quality has been enhanced. Case 6: In this case, 3 DGs and 3 Capacitors are considered for placement, after assigning these sources in 6, 69, and 79. The power loss is minimized to 0.290 MW, and the voltage profile is improved to 0.959 p.u. In this case, the injection of 3DGs + 3capacitor banks using 6, 69, and 79 buses to alleviate the constraints of both real and reactive losses. The capacitor banks were used to suppress the effects of induction motors used by the consumers or end users, which contributed the highest losses in DS. The capacitors, banks, or shunt capacitors which applied here to compensate for the reactive power requirements where necessary. Furthermore, the compensation helps in building a good power quality, thereby stabilizing the voltage quality, hence leading to voltage profile enhancement. The combination with the DGs has given the required achievement, showing a reduction in real power loss percentage and the voltage profile advancement of 45%; therefore, this combination has been achieved.

Table 2: 83 IEEE bus items 7-10 simulated results;

Different Cases	**Power loss in MW**	**DGs size in (MW)**	**Capacitor size in MVAr**	**DGs/Caps Locations**	**% Reduction in power loss MW**	**Vmin P.U**	**Power factor**
Case 7	0.339	3.1756	NA	6	36.27	0.9548	
		2.4231	NA	54			
		2.5676	NA	71			
		2.6263	NA	82			
Case 8	0.243	3.1482	2.2844	6	54.31	0.9599	0.81
		2.4208	1.5927	54			0.835
		2.552	1.9782	71			0.79
		2.6413	1.9126	82			0.81
Case 9	0.307	3.1757		6	42.28	0.9548	
		3.1932		19			
		2.423		54			
		2.5671		71			
		3.6438		79			
Case 10	0.193	3.1485	2.2838	6	63.71	0.9599	0.81
		3.1832	2.3922	19			0.7994
		2.4204	1.5926	54			0.8353
		2.5525	1.9779	71			0.7904
		3.6208	2.6161	79			0.8105

Case 7: In this case, 4 DGs were employed to supply active power into the system. Buses 6, 54, 71, and 82 are considered for allocation after placement. The losses are reduced to 0.339 MW. a The localization of 4DGs supports real power in the radial distribution networks to reduce the active power losses and which help in enhancing the voltage stability in the DS. The real power loss was minimised to 36% in the buses used. Whenever there is proper placement and sizing of DERs, the desired needs are always obtainable in the DS.

Case 8: In this case, 4 DGs and 4 capacitors are considered and inject both active and reactive power into the system. The best buses are 6, 54, 71, and 82. The solution obtained after placement, power loss is reduced to 0.243MW, and an improvement of the voltage profile to 0.959 p.u. Considerably, in this case large amount of DGs and capacitor banks are injected to support the deficiencies of the system, by providing or reducing the active power loss and expanding the power quality, making the voltage profile stable and increasing. The localization of 4DGs supports real power in the radial distribution networks to reduce the active power losses and which helps in enhancing the voltage stability in the DS. The real power loss was minimised to 36% in the buses used. Whenever there is proper placement and sizing of DERs, the desired needs are always obtainable in the DS.

The presence of both the DERs signifies the test to which the basic needs of actual power loss reduction and the reactive power compensation are to be attained, making the impacts positive in the case. The notion behind the use of both DGs and capacitor banks is to supply the requirement appropriately, so that the issue of real power and reactive power will be over.

Case 9: 5 DGs were considered to supply only real power to the system. The candidate buses for allocation are 6, 19, 54, 71, and 79. The solution obtained after allocation of DGs is 0.307MW, and the voltage profile is improved to 0.954 p.u. The inclusion of DGs alone in this case has yielded the benefits where the localising of the DGs supports the active power of the system, which reduces losses and thereby making or helping the advancement of voltage stability.

Looking at the percentage reduction in loss gained, it shows the system reduced its losses by about 42% making it reliable to be implemented.

Case 10: In this case, 5 DGs and 5 Capacitors are considered. The suitable buses are 6, 19, 54, 71, and 79. Power loss is minimised to 0.193MW, and the voltage profile is enhanced up to 0.959 p.u. Further, significant loss reduction is achieved in this case compared to all other cases. Finally, the voltage profile is improved to the maximum extent. This is the only examination with the highest number of standard buses to determine the requirements in DS. The initial base case is 531Kw power loss, which, after the placement it was improved to a reduction in losses of 63%. Therefore, whenever the appropriation was done simultaneously the level of loss or used to be eminent compared to the placement of DERs separately

7.0 CONCLUSION AND FUTURE SCOPE

The purpose or objectives of this research are to integrate DERs in DS, minimize power loss, and enhance the DS voltage to a considerable extent. Further, the method was employed on an 83 IEEE bus practical test system. Further, the optimization procedures DFA are used to solve the mentioned. It shows a promising result, where in all the cases or items treated the actual power loss has been minimized and also the voltage stability has been expanded. Further, the developed method is extended to place battery storage devices along with renewable resources. Also, the integration of electric vehicles along with renewable sources gives more practical consideration.

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