CAREER EPISODE 3

OPTIMUM SIZING AND ALLOCATION OF DISTRIBUTED GENERATOR USING HYBRID OPTIMIZATION TECHNIQUE

INTRODUCTION

CE 3.1

I worked on a technical project during my degree in Electrical Engineering as my final year project (EL-499). The title of this project was "Optimum sizing and allocation of distributed generator using hybrid optimization technique". I completed my Bachelors in Electrical Engineering from [redacted] I started working on this project in my last semester in [redacted] and finished it in month of [redacted]. I was fortunate to have had this great opportunity to apply my theoretical expertise that I gained throughout my studies to a real-world problem while developing important skills that will serve me well in my future career.

BACKGROUND

CE 3.2.1

Distributed generation refers to the installation of small-scale generators within the distribution system, positioned in close proximity to the point of electrical demand. There are numerous benefits to it including improvement of voltage in distribution networks, minimization of power losses etc. The placement of DGs can be flexibly determined based on suitability, and their size can be adjusted according to the demand of the load on the distribution end. There was a need to find an optimal location and sizes for DGs as there are many possible ways of placing them. In this project, I worked on determining an optimal location and sizing technique of DGs considering the minimization of active power loss. I applied some techniques for the propose of optimization and compared their results for verification.

CE 3.2.2

I started working on my project by first defining my research topic, afterwards I developed search strategy, gathered relevant literature, developed a structure for my literature review and wrote my literature review by summarizing main points of every paper and book. I carried out this literature review for getting an overview of current state of knowledge on this topic, I was able to identify the literature gaps and highlighted the areas where more research was required. After gathering all the data, I started with planning my project and set clear goals and timelines for my project. I used Gantt project software for planning and managing of my project by developing a timeline with assigned task for the other member of the team which improved my project planning and efficiency. Following this helped me in ensuring the timely achievement of my project goals.

CE 3.2.3

I planned meetings with my supervisor on weekly basis for providing feedback and ensuring progress. I served as a team leader and was responsible for organizing and leading meetings with my team members as well. Through these meetings, we discussed progress, share ideas, and highlighted issues and challenges that required attention. By planning these meetings, I ensured that my team members were aware of the project goals, timelines, and expectations. These meetings also played a critical role in keeping the project on track and ensured that we were working together towards a shared goal. I was also responsible for all the documentation related to this project which included project proposal and project report. I also prepared a presentation at the end for communicating my project objectives and results in a best way to my faculty members for their assessment of my work.

PROJECT REPORTING HIERARCHY

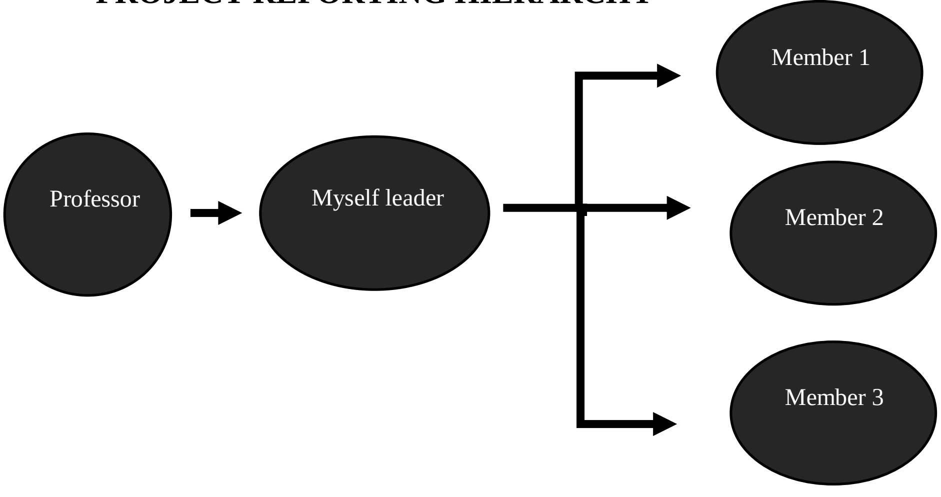


Figure 1 Hierarchy of the project

PERSONAL ENGINEERING ACTIVITY

CE 3.3.1

Distribution systems are experiencing a rapid increase in load demand due to continuous economic development and progress resulting in depletion of energy resources. The generation of electrical energy greatly benefits from the use of RE sources, particularly distributed generating units. Integration of DG into the current network can help in enhancing the voltage profiles, power quality, minimize losses, and aid in frequency control. Also, it is cost-effective as it is an addition to the power reserves. Moreover, if the location and size of DG are not correct it can result in excessive loss of power.

CE 3.3.2

The problem here was to manage the RE resources as they are available for limited time range like solar energy is available only at day time. For all the above-mentioned reasons in this project I focused on determining the optimal location and size (in MW) of DG for integration into a conventional radial distribution network. Electrical power networks operate on different levels of voltage. The equipment which is used in grid goes through abnormalities throughout the lifetime like a failed bearing, lightening strokes etc. Insulators may also be degraded as a result of pollution. There was a pressing need for a faster and less costly approach for enhancing the reliability and stability. The problem was the integration of DG into the systems effectively for improving the system performance. Also, my research was motivated by the desire to achieve a decrease in peak demand, an increase in energy efficiency, and the capacity to accommodate RE.

CE 3.3.3

The aim of this project was to develop tools for better understanding of integration of DG in the distribution networks. I determined the optimal location, size and no's of DGs and minimized the objective function. I formulated the objective function in this project including few parameters of the system which needed to be minimized. The objectives were minimization of voltage fluctuations, minimization of power loss etc. Thus, to address this optimization problem some optimization techniques were required. My problem was a multi objective optimization as it involved two objective functions that needed to be minimized. There were constraints in the problem too which needed to be satisfied including range of DG unit reactive & active powers, ranges of voltage fluctuation, power loss of a branch as well as total power loss of the system.

CE 3.3.4

In order to obtain the preliminary outcomes for the given electrical network, such as the overall power loss and voltage profile, I first performed an initial load flow analysis and determined the initial voltage profile. However, in electrical systems, the values of power are known while the currents are unknown, causing the power flow equation to be nonlinear. Hence, I utilized iterative methods for solving this problem. There are numerous techniques for solving this problem however, I adopted NRM as it gave better results compared to other techniques reason being the smaller number of iterations and the number of repetitions were independent of the size of the network.

CE 3.3.5

I designed a research methodology for this project in form of a flow chart. The results I obtained justified the optimum location and size of DG in distribution system. I achieved development in voltage profile with decrease in both reactive and active power losses. The method I adopted was two times faster than the PSO algorithm used for optimization. This adopted method resulted in decrease of total power losses in system compared to the base case scenario.

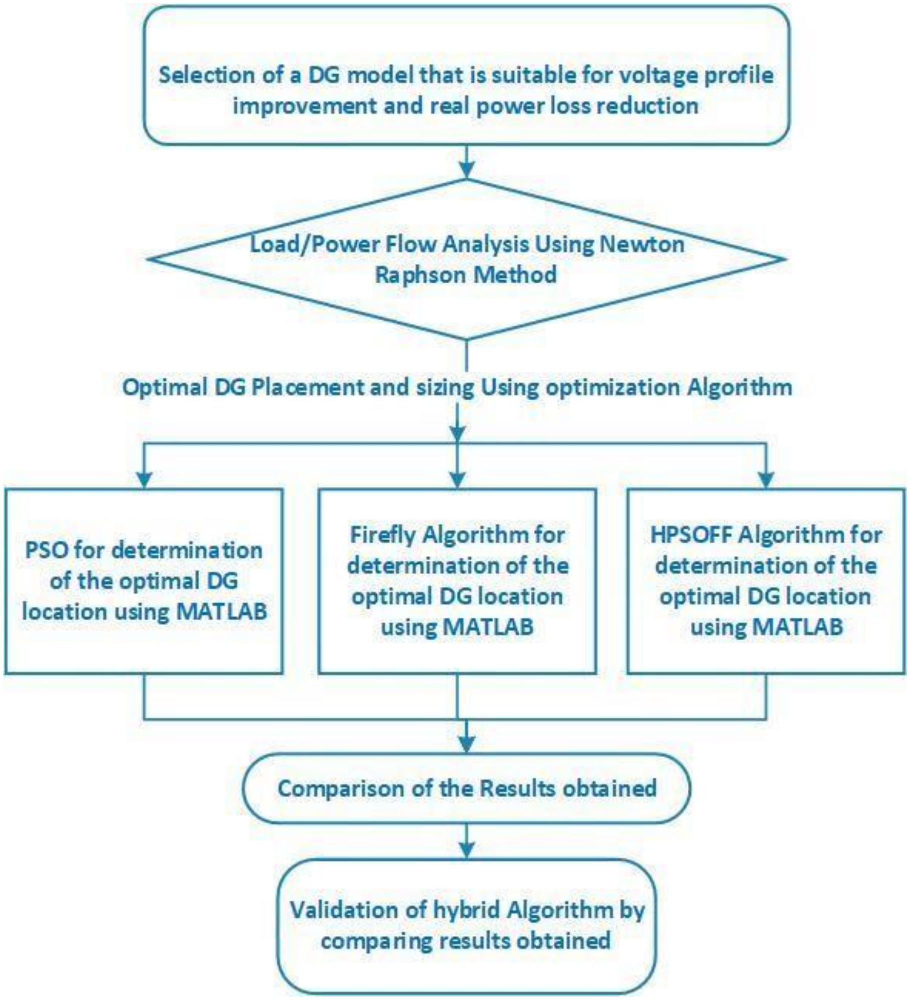


Figure 2 Project methodology

CE 3.3.6

I formulated my optimization problem, where objective function was to find best position (no. of bus) and size of DG in distribution networks minimizing the total loss in performance of the system.

$$P_{loss} = \sum_{line(i,j)=1}^{m} P_{line(i,j)}$$

The constraints involved in this problem were that the value of node voltage at every bus has to be between max and min limits, the value of the conductors current has to be less than the conductor's ampacity after DGS insertion on network, the total active losses of power have to be less than the losses before DG was inserted, similarly, the total reactive power losses have to be less than losses before DG was inserted, the total sun of all DG sizes have to be less than the total loads of the systems and lastly that the voltage fluctuations have to be less than the defined limit.

CE 3.3.7

In this project, I used different optimization techniques PSO, firefly algorithm and HFPSO algorithm for finding optimal size and location of DG. The PSO algorithm I considered begins by generating a cloud of particles and assigning initial velocities. It then calculates the objective function value and identifies the best location with the minimum value. The algorithm updates particle velocities and locations iteratively based on the current velocities, best individual locations, and their neighbors' best locations until an optimal solution is achieved. I also designed a flow chart for this PSO algorithm based on my project.

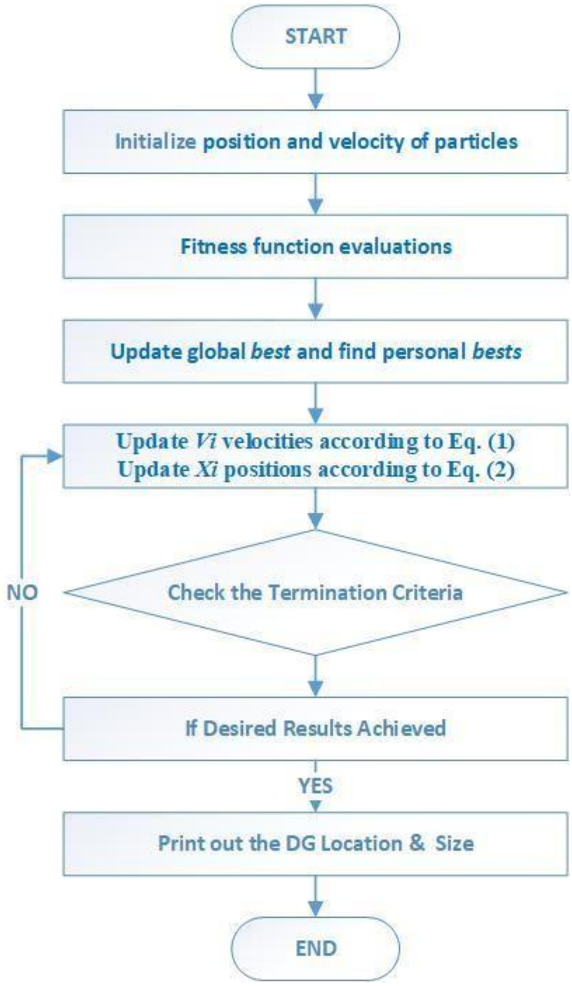


Figure 3 PSO Flow Chart

CE 3.3.8

A Firefly Algorithm (FA) I considered is based on the behavior of these insects and is designed to optimize target ability by adjusting the separation increment and accounting for the absorption of light by air. I also designed its flow chart as per my project. Hybrid PSO algorithms I used to aim at balancing exploration and exploitation and overcome PSO's flaws, while Firefly Algorithm (FA) has benefits such as no distinct global best and no speed attribute. A combination of PSO and FA can achieve a balance between exploration and exploitation, with PSO used for global search and FA for local search. Dynamic inertia weight has also been successful in improving the hybrid algorithm's performance. I also deigned flow chart for this algorithm as well.

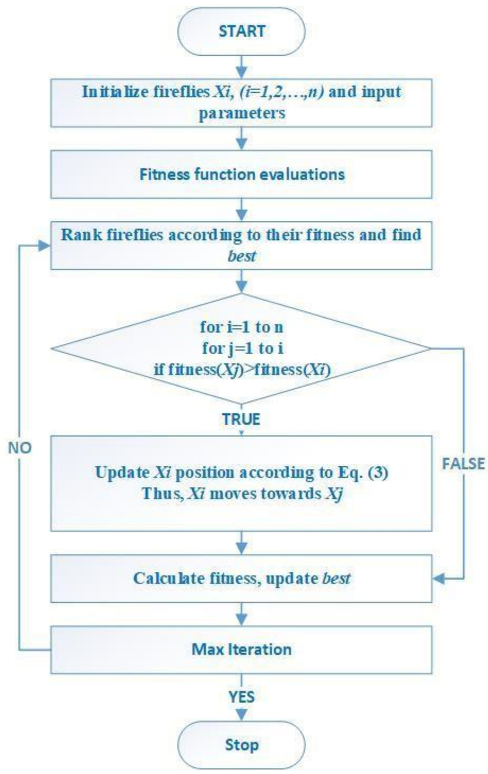


Figure 4 Firefly Algorithm

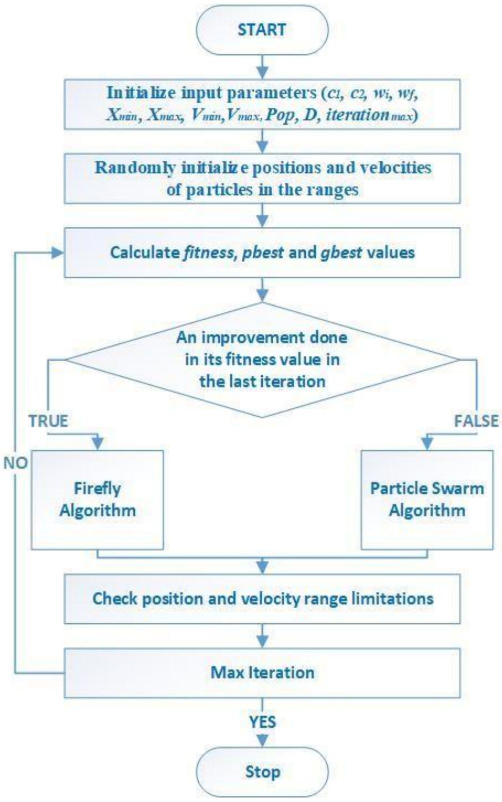


Figure 5 Hybrid Firefly PSO Algorithm

CE 3.3.9

The procedure I followed for optimization using above mentioned techniques was generating the size and location pairs of DG randomly. The range of sizes was defined as per the available capacity. I ran the network-Raphson power flow program for incorporating DGs in its load flow equations, as I learnt during the literature review. I recorded the total losses of active power and size location pair which corresponded to the calculation of power loss. I then checked if all the constraints were in the defined limits, when they were not in the range I rejected that size and location pair and moved to the next iteration. I repeated all the above steps until I reached an optimal solution with min power loss.

CE 3.3.10

I formulated the optimization problem using equations of load flow and then solved it using different techniques for IEEE 30 bus system for comparison. I also compared the results with load without DG. I optimized the both single and two DGs at the same time. I observed that power losses were reduced and voltage profiles were also improved. I also observed that the utilization of multiple DGs, in contrast to a single DG, resulted in a significant reduction of power losses and enhanced voltage profiles.

CE 3.3.11

I also plotted the results of both with and without DG for comparison as well as with single and two DGs. From the results a significant decrease in active power losses was observed when DG was inserted. PSO and HFPSO both optimized the problem as per the objective function which was to minimize the active power losses. From the voltage profiles graph, I observed that both the algorithm applied, kept the max and min values of voltages within the defined limits of 0.9 to 1.1 pu. The deviation in voltage was increased to a minute value in both the algorithms, however, it was not of any concern as I performed the optimization w.r.t active power losses.

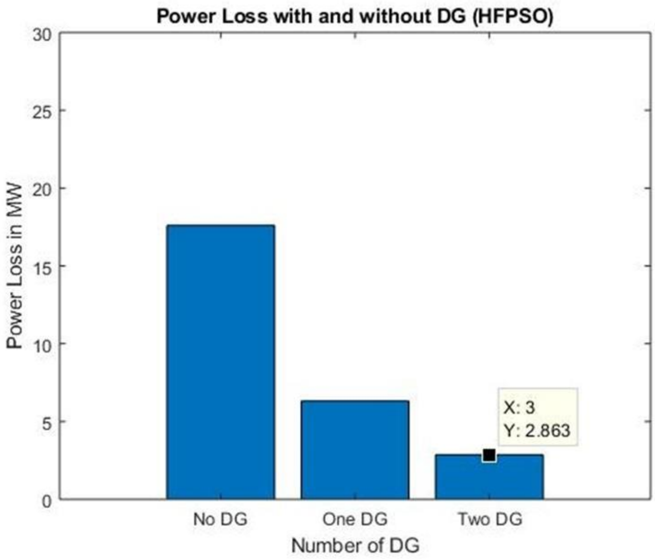
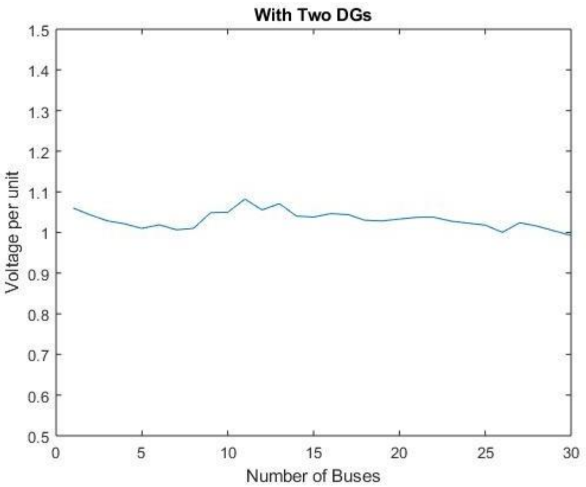


Figure 6 Comparison of Power Loss with and without DG



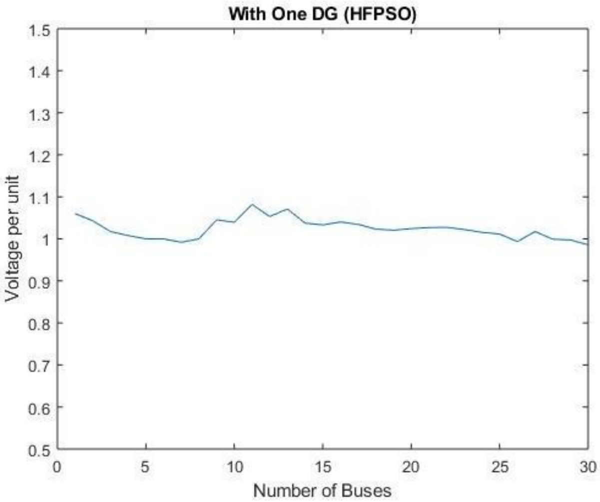


Figure 7 Voltage Profile

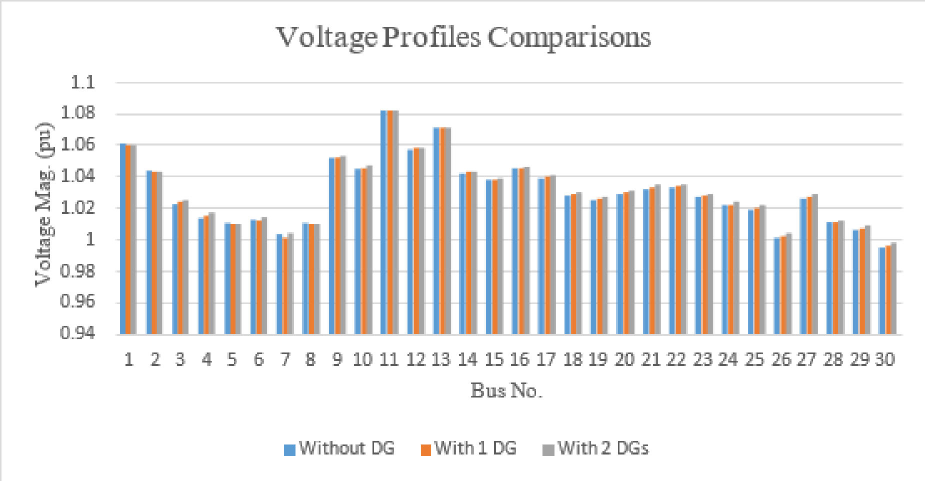


Figure 8 Comparison of Voltage Profiles with & without DG

SUMMARY

CE 3.4.1

Distributed generators have become increasingly important in modern energy systems due to their numerous benefits. The integration of DG in present network helped in improving the voltage profiles, quality of power and loss minimization. However, improper placement of these DG can lead to excessive loss of power. Considering all these issues, I proposed an idea for optimizing both the location and size of DGs to obtain improved quality of power as well as supply reliability. I used the IEEE 30 bus system as a basis for formulating the optimization problem using load flow equations and constraints. This optimization problem was solved using various techniques to obtain an optimal solution. I compared the results of both the techniques. The results showed that the optimal sizing of DGs reduced the power losses and improved the voltage profiles. At the end of this project I was able to gain practical skills in optimization techniques, it helped me in developing critical thinking skills as well. I completed a course on ethical conduct under the title of professional and social ethics during my degree that equipped me with the knowledge and skills necessary to comply with all engineering regulations throughout the duration of my projects. I received appreciation from all the faculty members, as the project I chose was more challenging than the topics I covered in class, requiring me to expand my knowledge and research skills beyond what was taught in the course.