OMAINTEC CONFERENCE EXHIBITION 2020

International Operations & Maintenance Conference in the Arab Countries

Under the theme of
The Integration of Maintenance and Asset Management

15-16 December 2020

18TH EDITION VIRTUAL

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Optimal Sizing and Location of PV Distributed Generation in Transmission System Using Particle Swarm Optimization: Layla Town Case Study

Outline

- Introduction
- What are the benefits of DG?
- Objective
- Problem Formulation
- Particle Swarm Optimization
- Layla Town Network
- Execution Procedure
- Results and discussion
- Conclusion

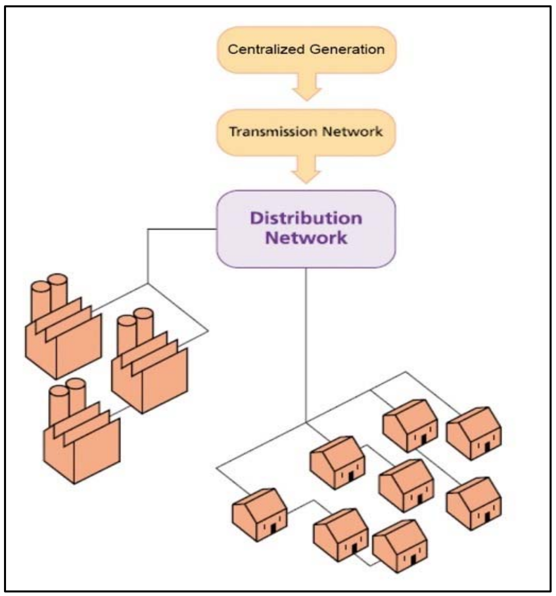
Introduction

- The idea to produce electricity in large-scale power plants came up in the twentieth century. Originally, electricity was produced by small, combined heat-and-power-plants (CHP) in urban areas.[1]

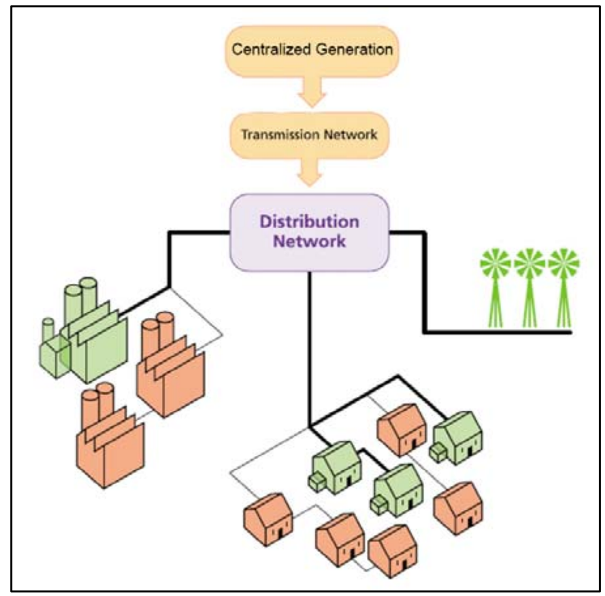
- As electricity demand increased, it was cheaper to centrally produce electricity in remote areas while investing in transmission and distribution networks to deliver electricity to households and consumers.

- Distributed generation (DG) is a small generation source that is connected closely to the load. DG source could be conventional fuel or renewable-based small generation source.

Introduction

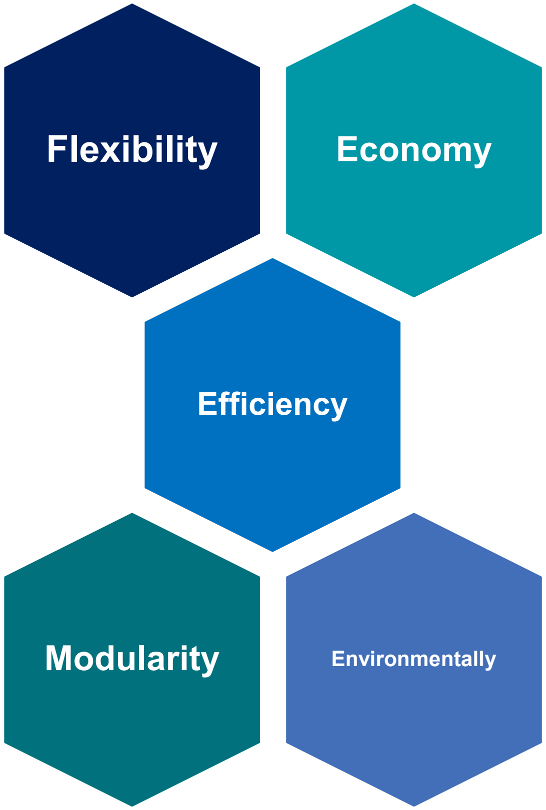


Conventional structure of power system depending on Centralized Generation[2].



Distributed Generation arrangement in the power system[2].

What Are the Benefits?



Objective

Image Credit: www.smart-energy.com

- **The objective of this study is to reduce the real power losses while improving the system voltage profile by optimally integrating DG in transmission system (Layla Town Network) by using complex integrative optimization technique (Particle Swarm Optimization (PSO)).**

Problem Formulation

- **The objective function of the model will focus on real power losses minimization, and improving voltage in the network as follows [2]:**

$$F = f_1 + f_2 + f_3$$

$$f_1 = \frac{\sum_{i=1}^{L}(P_{Loss}(i))_{with\ DG}}{\sum_{i=1}^{L}(P_{Loss}(i))_{without\ DG}}$$

$$f_2 = \frac{\sum_{i=1}^{B}|V_i - V_{ref}|_{with\ DG}}{\sum_{i=1}^{B}|V_i - V_{ref}|_{without\ DG}}$$

$$f_3 = \frac{B}{\sum_{n=1}^{B}(VSI_n)_{with\ DG}}$$

Problem Formulation

- Apart from the technical formulation, the constraints that decide the optimality of the solution are formulated below:

➢ **Power flow constrains**

$$P_{slack} + \sum_{i=1}^{DG} P_{DG}(i) = \sum_{i=1}^{L} P_{loss}(i) + \sum_{i=1}^{B} P_{Load}(i)$$

$$Q_{slack} + \sum_{i=1}^{DG} Q_{DG}(i) = \sum_{i=1}^{L} Q_{loss}(i) + \sum_{i=1}^{B} Q_{Load}(i)$$

➢ **Bus voltage profile limits**

$$V_{min} \le |V_i| \le V_{max}$$

➢ **DG capacity limits**

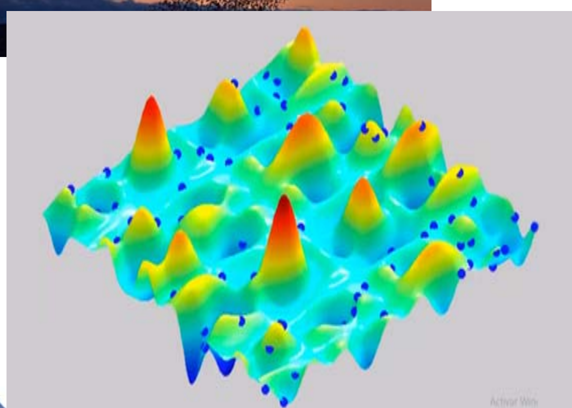
$$P_{DG}^{min} \le P_{DG}(i) \le P_{DG}^{max}$$

$$Q_{DG}^{min} \le Q_{DG}(i) \le Q_{DG}^{max}$$

➢ **Thermal limits**

$$S_{Line} \le S_{Line\ (rated)}$$

Particle Swarm Optimization



Images Credit: www. blog.stratio.com

- Particle Swarm Optimization (PSO) is an algorithm developed by James Kennedy and Russell Eberhart.
- It is a robust optimization technique based on the movement and intelligence of swarms with social interaction for problem solving.

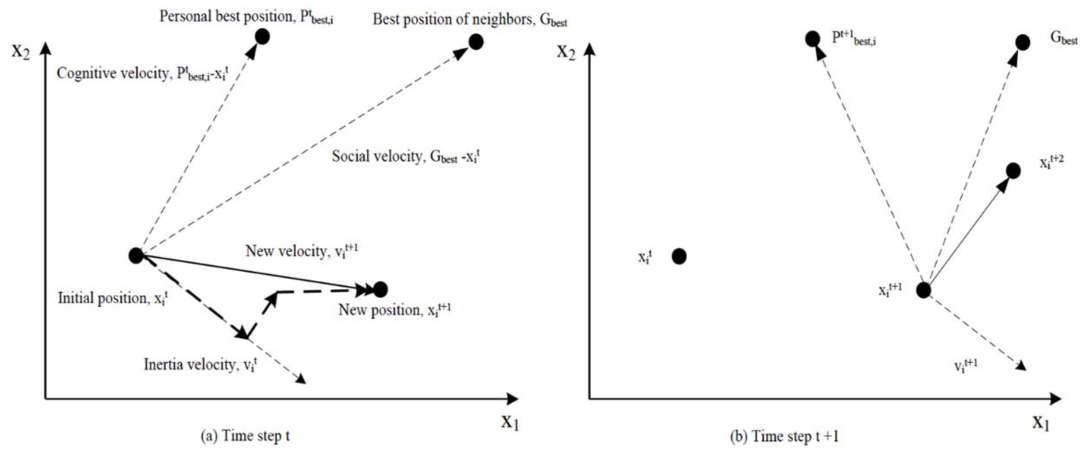
- In every iteration each particle keeps track of their personal best attempt, know as **pbest**, and also the neighboring best and global performance, know as **gbest**.
- The main concept of PSO lies in the essence that each particle in the space is accelerated towards the **pbest** and **gbest** locations with a random weighted acceleration in each iteration.

Particle Swarm Optimization

- **Assume x_i^t indicate particle i position vector search space at time step t, then the updated position of that particle in the search space is given by[3]:**

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

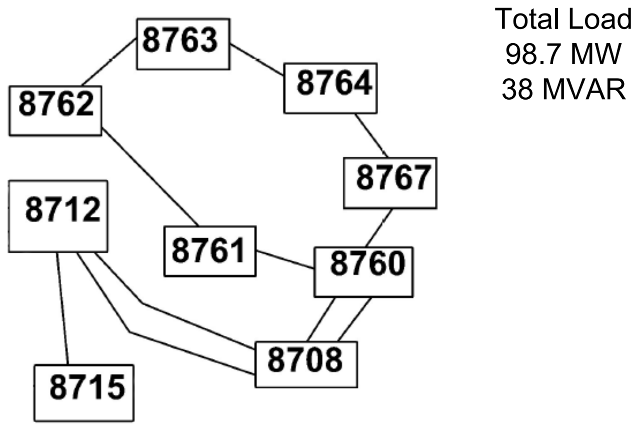
$$v_{ij}^{t+1} = wv_{ij}^t + c_1 r_{1j}^t \left[P_{best,i}^t - x_{ij}^t\right] + c_2 r_{2j}^t \left[G_{best} - x_{ij}^t\right]$$



Layla Town Network

- **Layal town transmission system was nominated as a case study for several reasons:**

- The load of the town considered critical due to industrial factories located nearby.
- The transmission system of the town fed from single switching substation and small power plant.
- It is been noted that there are many voltage violations on some buses during peak time.
- The average daily global horizontal irradiance is 6482 Wh/m^2 , thus the location has a great potential for installing PV DG.



Execution Procedure

- Target the values that will be optimized.
- Run the power flow analysis to obtain system real power losses and voltage profile of the base case.
- Set all the parameters according to the table below.

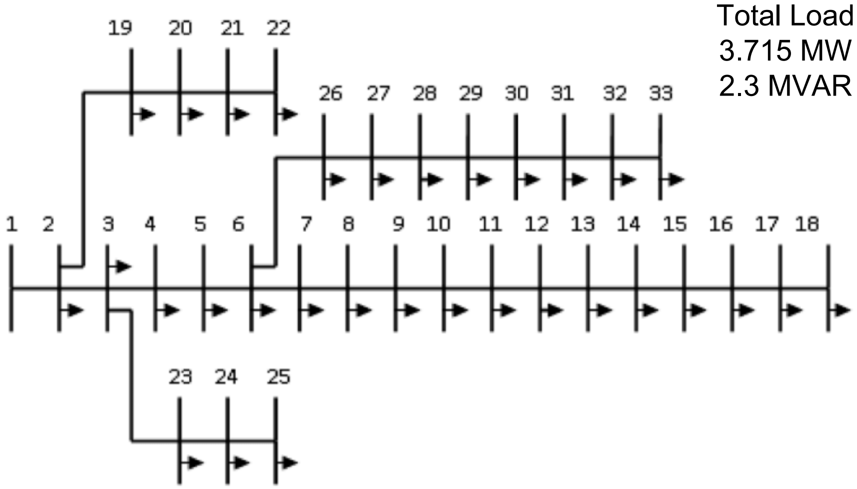
Parameter	Value
Number of DG's	2-3
DG Size	0-2 MW
Swarm Size	50
Number of Iterations	50
Acceleration Coefficient 1	2
Acceleration Coefficient 2	2

- Formulate the fitness function.
- Initialize the swarm randomly (i.e. position and velocity of each particle).
- Find the global best value according the fitness value of each particle.
- Initialize the loop with respect to the iteration count. In each time step, update the velocity and position of each particle.
- Update the personal best value for each particle. Also, identify the global best value among all the swarm.
- Global best value will be the achievable optimal size and location of the DG's.

Results And Discussion

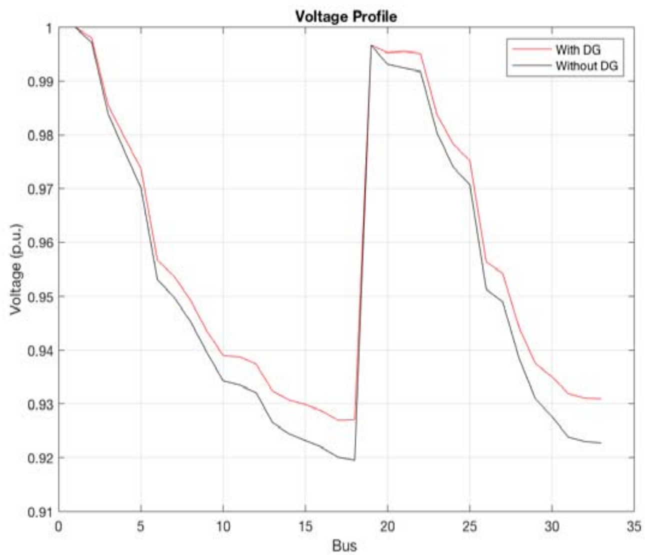
- **IEEE 33 Bus Radial Distribution System Results**

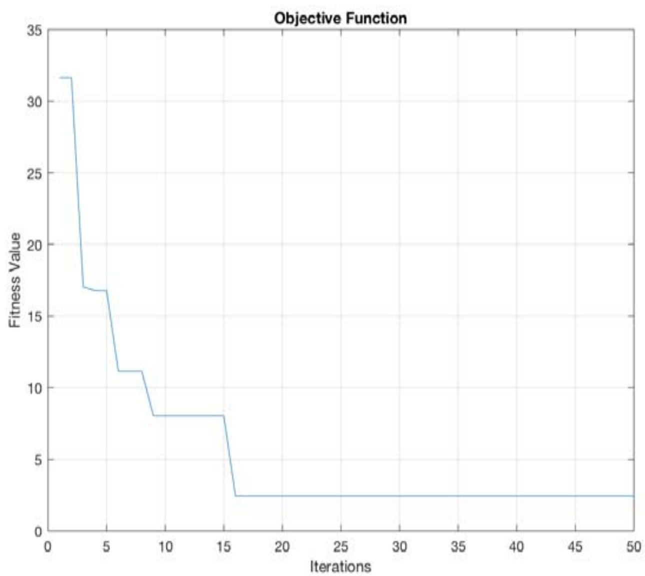
➢ The results indicated two DG's will be inserted in the most sensitive buses 15 and 13 with an optimal total size of 2.81 MW. As a result, the total real power losses reduced from **0.176 MW** to **0.103 MW** with a reduction of around **41%.**



Images Credit: www.researchgate.net

Results And Discussion

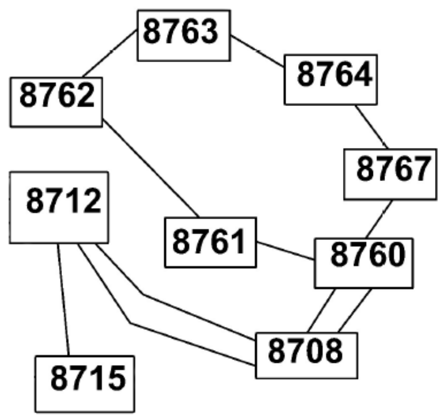




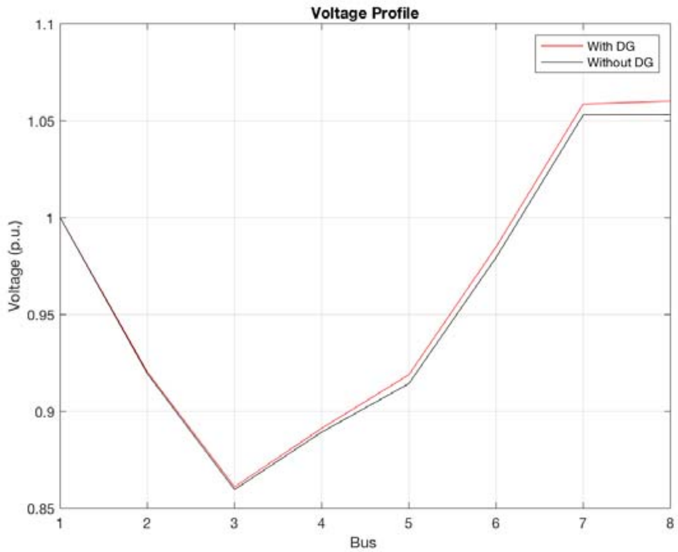
Results And Discussion

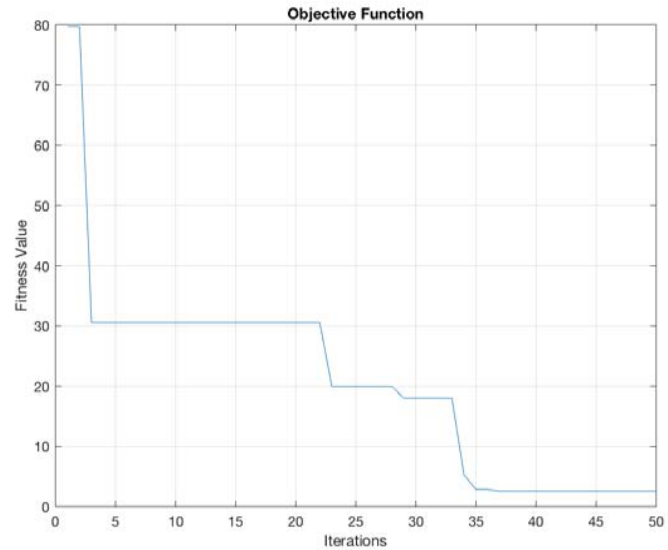
- **Layla Town System Results**

➢ The results show the two DG's will be placed on S/S 8761 , and 8763 respectively with an aggregated size equal 3.22 MW. The total real power losses initially were **0.206 MW** and decreased to **0.146 MW** after DG integration with an approximate reduction of **29%.**



Results And Discussion





Conclusion

- In this study, IEEE-33 bus radial distribution system and Layla town transmission system was selected for placing PV DG with optimal size and location.

- The PSO global best optimization algorithm used in this case with an objective function focuses on real power losses reduction and improve bus voltage profile.

- From the results obtained in this research it can clearly notice the optimal allocation of multiple PV DG's would reduce the real power losses up to 41% in IEEE 33 bus system and 29% in the Layla network, and bus voltage profile generally improved with the optimal PV DG integration.

Thank you