TEST Engineering & Management

March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

Multi-Objective Programming Problem for Distribution Generation System based on Renewable Resources Mix

Manoj Bansal[1], Pratibha Garg[2], Mohini Agarwal[3] Neha Gupta[4]
[1] Research Scholar, Amity School of Business, Amity University Uttar Pradesh, Noida
[2,3,4] Assistant Professor, Amity School of Business, Amity University Uttar Pradesh, Noida

Article Info
Volume 83
Page Number: 9650 - 9656
Publication Issue:
March - April 2020

Article History
***ArticleReceived**: 24 July 2019*
***Revised**: 12 September 2019*
***Accepted**: 15 February 2020*
***Publication**: 11 April 2020*

Abstract:
Moving towards sustainable development, the inclination towards the use of renewable sources of energy has tremendously increased. The energy loses in transmission and distributed system can significantly be reduced by adopting the appropriate size of DG technology (renewable sources of energy) as they can benefit environment and be economical. For instance, we may need to combine the different renewable sources for satisfying the demand of the region. Here specifically focus is laid on solar energy system with different ranges of energy production. This paper presents the mathematical formulation of a multi objective optimization problem which helps in determination of optimal size of solar panels to be used which can satisfy the current demand. The problem is focused on catering two diverse objectives of attaining highest level of energy saving at the same making use of least investment. For illustration purpose, a numerical example based on different ranges of solar panels has been examined

Keywords: *Renewable Sources; Solar Energy System; DG Technology; Energy Saving; Aggregative Weighted Method; Multi-Objective Optimization Problem.*

I Introduction

Electric power is the key source for today world and is required for all activities of modern society. It should be available in right quantity and quality as life in today's society cannot be imagined without proper electricity. The quantity of the electric power delivered to consumers depends upon the transmission and distribution medium. The deviation in the transmitted and distributed electric power from the standard is due to different types of power losses is the surroundings. Adequate measures need to be taken to reduce power losses to its minimum value which should be less than 10%. In developing countries the power losses are around 20% while in developed countries it is less than 10%. In India, the T&D loss percentage of the power distribution utilities is very high and reported 20.9% during 2018-19. Therefore, Electric power generation companies are more concerned with improving the system performance using renewable distribution technologies and providing acceptable power quality by improving voltage support and increasing reliability of the electricity grid.

1.1 Renewable distributed Generation Technologies

Distributed generation is an approach with range between 1 KW to 50 MW for decentralized electric power generations units that is directly connected to the distribution networks near the demand consumption rather than high voltage transmission network. Distributed generation can be done by implementing renewable resources like solar, wind , bio mass etc and from non-renewable like gas turbines, micro turbines, internal combustion engines, diesel engine etc Distributed

March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

generation has received attention and increasingly used due to environmental problem solutions and advances in electric power generation technology. Renewable resources based distributed generation is growing more rapidly because of low cost, small size and environmental benefits. The growing environmental apprehensions and fuel cost uncertainties associated with the use of conventional energy sources; the attention has been diverted toward employing renewable DG units in distribution systems. These DG units can include the use of solar panel, biomass, wind generators and many more. Due to certain limitations attached with their uses, specifically, the researchers have focused on the use of solar based energy generators which are also referred as solar panels or solar energy system. The core of solar energy system's lies in photovoltaic panels or modules which consists of number of solar cells, they are responsible for absorbing sunlight and converting it to generate electricity. At present there exists three generations of solar panel differentiable on the basis of technology being used. As with the passage of time, newer and newer techniques are available; the same can be experienced in the field of solar panels.

The earliest generation panels were made of silicon which made them quite efficient for domestic use but with the higher temperature such panels lose their efficiency. Later, technology evolved to thin film based solar panels as they consist of few micrometers thick semiconducting material. As the amount of material utilized in their development is significantly reduced in contrast to first generation solar panels, they tend to be cheaper. In present generation, apart from using silicon it is based on variety of constituents viz. nanotubes, solar inks, silicon wires, organic dyes, and conductive plastics. Current technology is still undergoing research and are expected to increase the efficiency substantially. Figure (1) classifies solar panels into three categories: Mono-crystalline silicon solar panels, Poly-crystalline silicon solar panels and Thin-film solar panels.

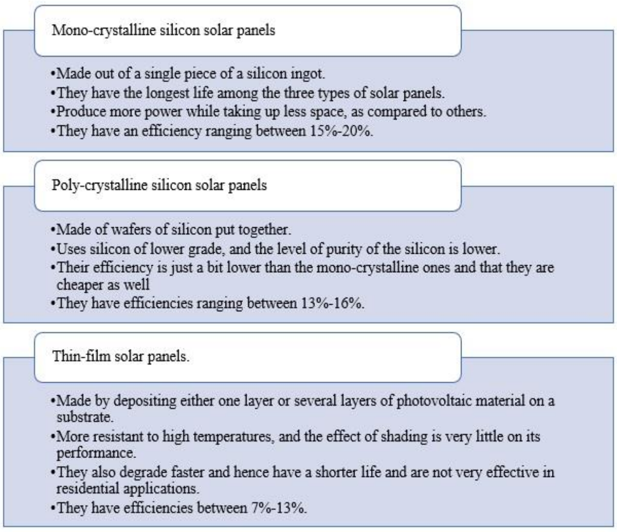

Figure 1: Types of Solar panels

Rest of the paper is organised as follows: After the brief in section 1 about the DG technology, section 2 presents the literature review. Optimization model and its relevant modeling framework is discussed in section 3. The solution procedure for multi-objective problem which is aggregative weighted method has been used as discussed in section 4. Case to find the optimal combination of number of solar panels that should be used has been elaborated and supplemented in section 5. Also, further the sensitivity analysis with respect to demand and level of energy produced is elucidated. Finally we have conclusion in section 6 followed by list of references.

2 Literature Review

Various researchers and practitioners studied the problem of distribution generation in several geographical locations and in different aspects. Some of the work done in this arena is has been examined and discussed as follows:

Griffin etal. (2000) presented an algorithm to determine optimal placement of dispersed fuel cell generation system on power grid so as to reduce losses and maximize capacity savings. Nara etal. (2001) discussed on reduction of distribution losses by proper placement of distributed

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generators. Tabu search algorithm was used for finding optimal location of installing distributed generators (DGs) on the demand side of power systems. Environmental concerns, technical and economic challenge, energy security, increased demand of electric power by reducing power losses and diversifying power resources are the factors due to which renewable distributed generations (DGs) have got greater importance at international level over traditional power plant with centralized generation (Rahman (2003); Andrews & Weiner, (2004)).

Greatbanks etal. (2003), in his study used sensitivity analysis of power flow equations for network security and reliability to found the optimal location of distributed generators. Renewable resources are popular for distributed generation as these are replenishable and available worldwide while non-renewable resources like oil, natural gas are available only in few countries. The most important aspect of distributed generation planning is to determine the optimum location for installing DG units into an existing distribution system so as to improve the system's performance. Hereford Ranch Algorithm is used to find optimal location of the renewable energy sources (photovoltaic cells, wind generation, battery storage, fuel cell, etc.) based distributed generation in a meshed network so as to minimize losses and maximize the performance index (Kim etal. (1998)and Gandomkar etal. (2005)). Wang & Nehrir (2004) presented analytical approach to find optimal location of DG units and quantified benefit in terms of reduced losses. Mithulananthan etal. (2004) used genetic algorithm to find optimal placement of distributed generator in power distribution system so as to reduce losses. Niknam etal. (2005)and Celli etal. (2005) discussed evolutionary methods to find optimal location and size of distributed generation system.

According to Phuangpornpitak etal. (2010) solar distributed generation systems can assist in generating electricity and meeting the increasing demand in India as it has abundant sunshine and can integrate solar system with electricity grid. The problem exist with the integration of distributed generators with electricity grid to decide the optimal placement and sizing of DG system on power grid during the design stage so as to improve voltage support and reliability in distribution networks. Ghosh etal. (2010) presented Newton Raphson method with conventional iterative technique for finding optimal sizing and position of renewable resources based distributed generators so as to meet ever increasing demand of electricity by improving voltages, reducing losses and cost.

Many more researchers like Rau & Wan (1994), Keane & O'Malley (2005), Gautam & Mithulananthan (2007), Singh & Goswami (2010) have discussed optimal allocation of distributed generation on distribution network so as to improve voltage and reduce losses. Ahn etal. (2015) applied least-cost and cost-risk optimization models to allocate energy sources for sustainable development in the Korean electric power generation industry. In deriving these optimal electricity generation mixes, they considered both conventional and renewable energy sources in conjunction with physical and policy constraints that realistically reflect Korean circumstances. Ogunjuyigbe etal. (2016) utilizes a Genetic Algorithm (GA)to implement a tri-objective design of a grid independent PV/Wind/Split-diesel/Battery hybrid energy system for a typical residential building with the objective of minimizing the Life Cycle Cost (LCC), CO_2 emissions and dump energy.

The above literature clearly suggests the use of DG units for reducing the loses and for determination of their appropriate size. With this aim, the work presented in this article is focused on formulation of a multi-objective optimization model which can help in achieving the same. The focus has been laid on different ranges of solar

Published by: The Mattingly Publishing Co., Inc

March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

panels, a variable for the generation of electricity by converting the solar energy.

We wish to determine the optimal combination of different ranges of solar panels that should be instilled for satisfying the demand of electricity based on two contrasting perspective of maximizing the energy saving and at the same time minimizing the investments.

3 Optimization Model

Overall energy losses are currently very high and the overall objective is to reduce these power loses. The model formulated here is based on determining the combination of solar panel (varying w.r.t their ranges) that should be installed so the energy saving is maximum and at the same time we are able to minimize the total cost of installation. These objectives are to be attained based on the fact the total production of electrical energy should be able to meet the demand.

Notations:

η_{si}- Energy saving corresponding to size of different solar panels $(i = 1,2,\dots,n)$

c_i- cost of installation of i^{th} type of solar panel

ω_i- No. of units of i^{th} type solar panel

ϵ_i- Energy produced by i^{th} solar panel per year

δ- Total energy demand per year

As η_{si} is the energy saving corresponding to ith type of solar panel and ω_i denotes the number of solar panel for ith type. Thus, energy saving for ith type of solar panel is $\eta_{si}\omega_i$. And overall energy saving is

$$\eta_s = \sum_{i=1}^{n} \eta_{si}\omega_i$$

The cost of installation corresponding to ith type of solar panel is c_i and ω_i denotes the number of solar panel for ith type. Thus, cost for ith type of solar panel is $ci\omega_i$. The total cost is

$$C = \sum_{i=1}^{n} c_i\omega_i$$

The total production according to solar panel capacity of ith type be ϵ_i and ω_i is the number of units, then $\epsilon_i\omega_i$ is the total production of ith type of solar panel and overall energy produced is given by

$$\sum_{i=1}^{n} \epsilon_i\omega_i$$

The mathematical formulation of the problem as explained above becomes:

The bi-criterion problem for finding a tradeoff solution can be expressed as follows:

$$\left.\begin{array}{ll} \max\eta_s = & \sum_{i=1}^{n} \eta_{si}\omega_i \\ \min C = & \sum_{i=1}^{n} c_i\omega_i \\ subjectto & \sum_{i=1}^{n} \epsilon_i\omega_i \geq \delta \\ & \omega_i \geq 0 \forall i \\ and & \omega_i \; are\; integers \end{array}\right\} \quad (1)$$

The above problem can be solved for different combinations by using aggregative weighted method as discussed in next section.

4 Aggregative Weighted Method

In this paper a multi objective optimization problem has been formulated as it involves more than one objective function that are two be minimized or maximized or a combination. The aim is to adopt such a methodology which can work on providing a set of solutions that define the best tradeoff between competing objectives.

In order to determine tradeoff-based solution, we scalarize a set of objectives into a single objective by adding each objective pre multiplied with a suitably determined weight.

March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

$$\left.\begin{array}{ll} \min Z = & \lambda_j C - (1-\lambda_j)\eta_s \\ subject\ to & \sum_{i=1}^{n} \epsilon_i \omega_i \geq \delta \\ & \omega_i \geq 0 \forall i \\ & \sum_{j=1}^{m} \lambda_j = 1 \\ and & \omega_i\ are\ integers \end{array}\right\} \quad (2)$$

Being the simple and parsimonious approach it is being widely used even though the determination of weights is a cumbersome task.

5 Illustrative Example

To demonstrate the proposed problem solar panel (renewable energy source) with different capacities has been considered. For the ease of simplicity, we have considered the case of three different ranges of solar panels being categorized as: small, medium and high. The data given in Table (1) has been taken from Das et al. (2017) and Zaatri & Allab (2012). The annual demand of energy production has been considered 3000 KW.

Table 1: Data of solar panel with three different range

Solar Panel	Energy Savings (KW)	Cost of Installation (Rs)	Energy Production (KW)
Small Range	1	87,000	25
Medium Range	1.5	1,30,500	66
Large Range	2	1,74,000	83

The problem (1) can be formulated by using the data given in Table (1) as follows:

$$\left.\begin{array}{ll} \max \eta_s = & \omega_1 + 1.5\omega_2 + 2\omega_3 \\ \min C = & 87000\omega_1 + 130500\omega_2 + 174000\omega_3 \\ subject\ to & 25\omega_1 + 66\omega_2 + 83\omega_3 \geq 3000 \\ & \omega_i \geq 0 \forall i = 1,2,3 \\ and & \omega_i\ are\ integers \end{array}\right\}$$

(3)

To derive the compromise optimal solution of problem (2), an aggregative weighted method discussed in section 4 has been used. As a decision maker it is a tough task to identify the importance that should be associated with different objectives, therefore, here the equal weights are assigned to energy saving and cost of installation. Hence, the weighted mathematical model of problem (2) is as follows:

$$\left.\begin{array}{ll} \min = & 0.5\eta_s + 0.5C \\ subject\ to & 25\omega_1 + 66\omega_2 + 83\omega_3 \geq 3000 \\ & \omega_i \geq 0 \forall i = 1,2,3 \\ and & \omega_i\ are\ integers \end{array}\right\} \quad (4)$$

The solution of problem (3) was obtained by an optimization software LINGO-13 as:

$\omega_1 = 0, \omega_2 = 43, \omega_3 = 2 with \eta_s = 68.5 KW and C = Rs. 59,59,500$

5.1 Sensitivity Analysis with respect to demand

In this section solution of the problem is checked for sensitivity with respect to small change in the annual demand of energy (δ). Table (2) presents the sensitivity of the solution with respect to δ.

Table 2: Sensitivity Analysis w.r.t. δ

δ	ω_1	ω_2	ω_3	η_s	C
1000	0	14	1	23	2001000
1500	0	23	0	34.5	3001500
2000	1	30	0	46	4002000
2500	0	38	0		

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March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

				57	4959000
3000	0	43	2	68.5	5959500
3500	0	52	1	80	6960000
4000	0	61	0	91.5	7960500
4500	0	67	1	102.5	8917500
5000	0	76	0	114	9918000

From the Table (2) it can be seen that with the small change in demand, cost of installation will also change. Results of sensitivity analysis shows that annual demand of energy has linear relationship with the cost of installation as with the increase in demand the cost is also increases.

5.2 Sensitivity Analysis with respect to energy produced

In this section solution of the problem is checked for sensitivity with respect to small change in the energy production by three solar panels (ϵ_i). Table (3) presents the sensitivity of the solution with respect to ϵ_i.

Table 3: Sensitivity Analysis w.r.t. ϵ_i

ϵ_1	ϵ_2	ϵ_3	ω_1	ω_2	ω_3	η_s	C
0	60	78	0	50	0	75	6525000
2	63	80	0	48	0	72	6264000
5	66	83	0	43	2	68.5	5959500
0	70	87	0	43	0	64.5	5611500
5	75	92	0	40	0	60	5220000
0	80	98	1	37	0	56.5	4915500
5	85	105	1	35	0	53.5	4654500

Also, from the Table (3) it can be concluded that with the small change in energy production by three solar panels, cost of installation will also change. Results of sensitivity analysis proves that energy production also have the linear relationship with the cost of installation as with the increase in energy production the cost is also increases.

6 Conclusion

In the electrical energy saving environment, the companies wish to use those sources of energy which can reduces energy loses but these may not be economical. At the same time looking just for economical perspective does not suffice the aim of reducing loses or conserving electrical energy. We have formulated a multi objective optimization problem for determination of optimal size of solar energy system based on varying range of electricity production. The optimal problem has been modeled as integer programming based so that solution is purely integer. To illustrate the approach, a set of assumed parameters are considered. After solving the problem, the total energy conserved will be 68.5KW and the expenditure on solar energy system will be Rs. 59,59,500. For gaining the deeper insight to problem, sensitivity analysis on demand and the energy produced has been done. The above problem is indeed beneficial to decision makes due to its flexibility and straightforward manner in determination of sizing combination of solar panels.

References

[1] Ahn, J., Woo, J., and Lee, J. (2015). Optimal allocation of energy sources for sustainable development in south korea: Focus on the electric power generation industry. *Energy Policy*, 78:78–90.

[2] Andrews, C. and Weiner, S. A. (2004). Visions of a hydrogen future. *IEEE Power*

Published by: The Mattingly Publishing Co., Inc

March – April 2020
ISSN: 0193-4120 Page No. 9650 - 9656

and Energy Magazine, 2(2):26–34.

[3] Celli, G., Ghiani, E., Mocci, S., and Pilo, F. (2005). A multiobjective evolutionary algorithm for the sizing and siting of distributed generation. *IEEE Transactions on power systems*, 20(2):750–757.

[4] Gandomkar, M., Vakilian, M., and Ehsan, M. (2005). Optimal distributed generation allocation in distribution network using hereford ranch algorithm. In *2005 International Conference on Electrical Machines and Systems*, volume 2, pages 916–918. IEEE.

[5] Gautam, D. and Mithulananthan, N. (2007). Optimal dg placement in deregulated electricity market. *Electric Power Systems Research*, 77(12):1627–1636.

[6] Ghosh, S., Ghoshal, S. P., and Ghosh, S. (2010). Optimal sizing and placement of distributed generation in a network system. *International Journal of Electrical Power & Energy Systems*, 32(8):849–856.

[7] Greatbanks, J., Popovic, D., Begovic, M., Pregelj, A., and Green, T. (2003). On optimization for security and reliability of power systems with distributed generation. In *2003 IEEE Bologna Power Tech Conference Proceedings,*, volume 1, pages 8–pp. IEEE.

[8] Griffin, T., Tomsovic, K., Secrest, D., and Law, A. (2000). Placement of dispersed generation systems for reduced losses. In *Proceedings of the 33rd annual Hawaii international conference on system sciences*, pages 9–pp. IEEE.

[9] Keane, A. and O'Malley, M. (2005). Optimal allocation of embedded generation on distribution networks. *IEEE Transactions on Power Systems*, 20(3):1640–1646.

[10] Kim, J.-O., Nam, S. W., Park, S., and Singh, C. (1998). Dispersed generation planning using improved hereford ranch algorithm. *Electric Power Systems Research*, 47(1):47–55.

[11] Mithulananthan, N., Oo, T., et al. (2004). Distributed generator placement in power distribution system using genetic algorithm to reduce losses. *Science & Technology Asia*, pages 55–62.

[12] Nara, K., Hayashi, Y., Ikeda, K., and Ashizawa, T. (2001). Application of tabu search to optimal placement of distributed generators. In *2001 IEEE Power Engineering Society Winter Meeting. Conference Proceedings (Cat. No. 01CH37194)*, volume 2, pages 918–923. IEEE.

[13] Niknam, T., Ranjbar, A., Shirani, A., Mozafari, B., and Ostadi, A. (2005). Optimal operation of distribution system with regard to distributed generation: a comparison of evolutionary methods. In *Fourtieth IAS Annual Meeting. Conference Record of the 2005 Industry Applications Conference, 2005.*, volume 4, pages 2690–2697. IEEE.

[14] Ogunjuyigbe, A., Ayodele, T., and Akinola, O. (2016). Optimal allocation and sizing of pv/wind/split-diesel/battery hybrid energy system for minimizing life cycle cost, carbon emission and dump energy of remote residential building. *Applied Energy*, 171:153–171.

[15] Phuangpornpitak, N., Prommee, W., Tia, S., and Phuangpornpitak, W. (2010). A study of particle swarm technique for renewable energy power systems. In *Proceedings of the international conference on energy and sustainable development: issues and strategies (ESD 2010)*, pages 1–6. IEEE.

[16] Rahman, S. (2003). Green power: What is it and where can we find it? *IEEE Power and Energy Magazine*, 1(1):30–37.

[17] Rau, N. S. and Wan, Y.-h. (1994). Optimum location of resources in distributed planning. *IEEE Transactions on Power systems*, 9(4):2014–2020.

[18] Singh, R. K. and Goswami, S. (2010). Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction, and voltage improvement including voltage rise issue. *International Journal of Electrical Power & Energy Systems*, 32(6):637–644.

[19] Wang, C. and Nehrir, M. H. (2004). Analytical approaches for optimal placement of distributed generation sources in power systems. *IEEE Transactions on Power systems*, 19(4):2068–2076.