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Distributed generation optimization with HOMER software and fuzzy logic control

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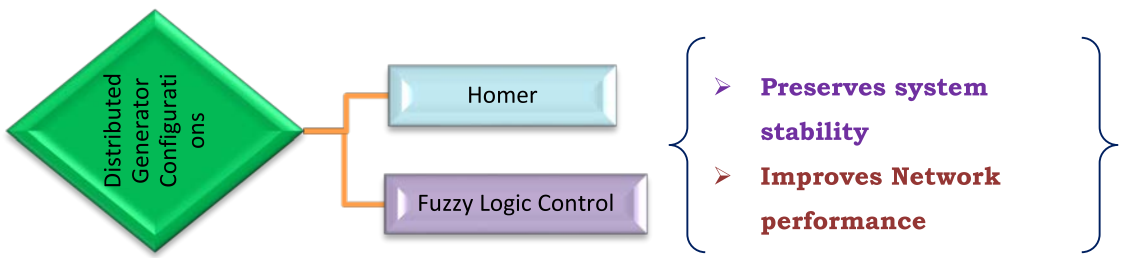
ABSTRACT



The HOMER software is described in this article in order to provide the efficient distributed generation configurations. This is based on nature of the area and its renewable energy availability. It enables the consideration of a wide range of technological alternatives in order to contribute for energy accessibility. It's a powerful tool for simulating both traditional and sustainable energy techniques. Furthermore, in distributed generation electric networks, a fuzzy-based strategy has been suggested to choose the most suitable power source and ascribe it to the appropriate load. Fuzzy Logic Control (FLC) is an effective approach to resolve complex problems using few algebraic calculations. In general, distributed generation includes network non-renewable energy sources (NRES) such as fossil as well as gas power plants along with conventional energy sources (CES) such as solar cells, fuel cells and wind generators that can operate in stand-alone mode or in grid-connection. Moreover, sustainable energy distributed generation has grown rapidly as large central power plants have become financially unviable in many provinces because of substantial decreases in fossil fuels, rising fuel costs, the global energy crunch, and the emergence of environment degradation problems. Nevertheless, the integration of distributed generation into conventional electric networks has influence on their consistency, safeness, and power feature. As a result, inoculation of distributed generation necessitates the use of adequate controllers in order to preserve system stability and performance.

Keywords: Distributed Generation, Fuzzy system, Homer, Wind, Solar

INTRODUCTION

Renewable energy sources (RES) like wind as well as solar energy are pure, budget - friendly, household and limitless.[1,2] These are non-polluting energy sources and safer sources of energy for everyone. These benefits prompted the idea of inoculating RESs into electrical networks to address the ongoing energy needs and to incorporate alternative solutions to the global energy crunch. In addition to these reasons, interest in distributed generation (DG) sources has increased recently, resulting in a rise in the quantity of generators linked to distribution network.[1-4]

DG provides atmospheric benefits, enhance reliability, reduces losses, load managements, and provides economic benefits. Notwithstanding, the integration of DG power stations into distribution networks (DNs) raises a number of concerns such as system steadiness, devices protection, serious network problems risk increment, and switching frequency.[4-10]

As a result, the need to develop appropriate control methods to enable power delivery to clients while adhering to power reliability and quality standards has grown into a significant concern in current years.[1,11,12]

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One of the key traits about loads in electrical networks is that require continuous suitable control in their ability to change. This article suggests an optimised fuzzy strategy for managing the various load demands based on the several available power sources and chooses the best possible power source relying on two primary variables: the existing power capacity as well as the distance of the power source to the load centre.[12-16,18-19] Moreover, HOMER software is utilized to investigate the most appropriate renewable DGs which may be utilised according to the ecology of the area and the abundant supply of renewable energy.[17] Because fuzzy control, unlike classical control, does not require complicated mathematical expressions, the number and variety of applications of fuzzy logic have recently increased dramatically. Furthermore, with the necessary knowledge and experience of a skilled operator, it's simple to plan a fuzzy control for nonlinear intricate systems.[20] An original family of widespread control and management tactics for micro grids in smart distribution grids is presented.[2] In addition, the paper offers an overall framework for modelling and analysing power management strategies in a micro grid with several DG sources.[21-24] The work by M.A. Azzouz et. al.[3] unveils a fuzzy algorithm to offer an intuitive reference of the on-load tape selector controller to alleviate the impact of the DG units' high permeation. The articleby G.J. Wang et.al.[4] describes a fuzzy approach that is built on a genetic algorithm for distributing power requirements between many currently offered power sources.

System Overview

Distributed generation networks use a variety of energy sources, particularly RES such as solar, wind, and geothermal energy. This system provides numerous benefits over traditional networks. "Distributed generation assurances several potential advantages, such as peak shaving, price currency swaps, energy recovery, enhanced power quality and reliability, improved productivity, and better environmental performance," according to the report. For all these causes, DG is expected to play a larger role in future electric power systems[5]. The proposed technique for DG power networks in this article can be described in the figure 1. As distributed generation, three distinct power sources are employed in this paper: wind, solar, and micro-turbine. In conversely, there is no restriction on the number of DGs. Initially, metering centres gather data from loads and sources and submit it to FLC. The FLC will then make a comparison the available and required power and send the prompt to the switching centre to allocate the optimal one.[6,7]

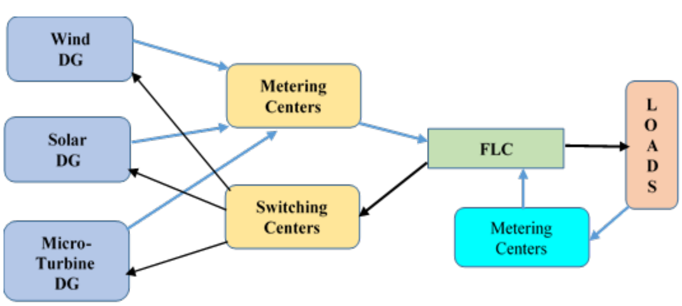

Figure 1. Designed technique block diagram

DG Power System Components Modelling

Because not all sites are proper for the setting up of an effective wind turbine, HOMER software is a useful tool for determining the feasibility of renewable energy sources. The average annual wind speed can be a suitable indicator for installation of a wind turbine at a specific site, and 5m/s above wind speed values are generally considered adequate for satisfactory results.[8] In order to have a reliable source of power from solar panels, the average radiation should have a consistent trend and the annual radiation should be greater than 4kwh/sqm/day. Furthermore, micro turbines are minor gas turbines in which gaseous or liquid fuels are burnt to generate a high energy gas flow which drives the electrical generator. Micro-turbines can start rapidly and are particularly useful in peak electrical supply for utility grid so they are more popular in recent years.[25-29]

Grid-connected Vs. stand-alone DG

As can be seen from Figure 2, DG can operate in twin modes: stand-alone and grid-connected. Stand-alone distributed system provides power to local loads straightforwardly through a low voltage bus. They are usually equipped of battery storage. However, as in the particular instance of directly coupled stand-alone systems, battery storage is not always present. Grid-connected distributed systems,[9,10] on the other hand, are integrated to regular distribution lines either through Medium Voltage (MV) or Low Voltage (LV) Networks, based on the power ratings and voltage ratings accessible for the systems; so as to provide the enhanced power needed by the loads, over and above could also be utilized to offer reactive power as well as voltage assistance to the utility grid. So the DG systems might extent around the distributed system that is linked with grid. Grid-connected systems may also be fortified with or without a power backup choice[11]. When a system is linked to a utility grid, even so, main operation and performance necessities, such as voltage, frequency and harmonic regulations, are levied.

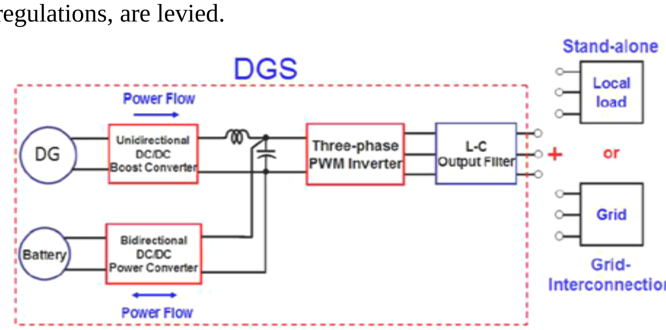

Figure 2 Modes of operation for distributed generation [7]

Controller for Fuzzy Logic

This paper discusses a fuzzy logic controller based on the Mamdani method, which has many advantages and motives to be used. For example, fuzzy logic is engage to govern intricate and nonlinear systems without the need for analysis. Second, it is adaptable to any provided system, so that if changes occur in the system, we do not have to restart from the beginning. Fuzzy logic can also be combined with traditional techniques to streamline their operation.[12]

$$R^{(k)}: IF\ x_1\ and\ x_2\ is\ F^k\ , then\ y_1\ is\ G^k, for\ k = 1,2, \dots \dots, n \quad (1)$$

Where

x_1- power capacity of altered DGs per unit (p.u.),

x_2- distance in kilometres (Km) between the altered DG sources and the loads,

y_1- priority level of assigning the optimal source to the appropriate load.

Where x_1, x_2…. x_n ε u, and $_{y1}$ ε R are the i/p & o/p of fuzzy sets in U1, U2 and R representing the kth precursor pairs and decisions pair resp. and n is the rules numbers.

Our system's I/P and O/P are an amalgamation of two types member functions. The first in triangular form as termed in equation (2) and the other in trapezoidal form as termed in equation (3). The I/P and O/P member functions are depicted in Figure 3. Defuzzification, on the other hand, employs a variety of algorithms.[12,13] lists the most commonly used algorithms.

$$trimf\ (x; a, b, c) = \max\left(min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \quad (2)$$

$$trapmf\ (x; a, b, c) = \max\left(min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right) \quad (3)$$

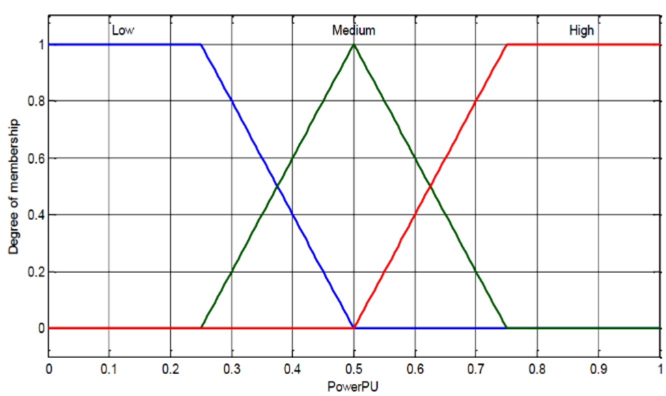

Figure 3 I/P and O/P member functions

Algorithm Proposed and Simulation Results

The proposed fuzzy algorithm for distributed generation power networks in this article can be described in Figure 4. The flowchart begins by interpretation of the power capacity levels of all accessible DGs as well as the different distances between DGs and loads using smart metering.

As previously stated, the brain of FLC is the creation of rule bases. The chief three rule bases will be as shown in equations (4), (5), and (6). Furthermore, Table (1) depicts entirely of our FLC's rule bases, with the first and second columns representing inputs and the third column representing output.

If Wind power capacity is High and Distance is Low, then Assign Wind DG

If Solar power capacity is High and Distance is Low, then Assign PV DG

If Fossil power capacity is High and Distance is Low, then Assign Fossil DG

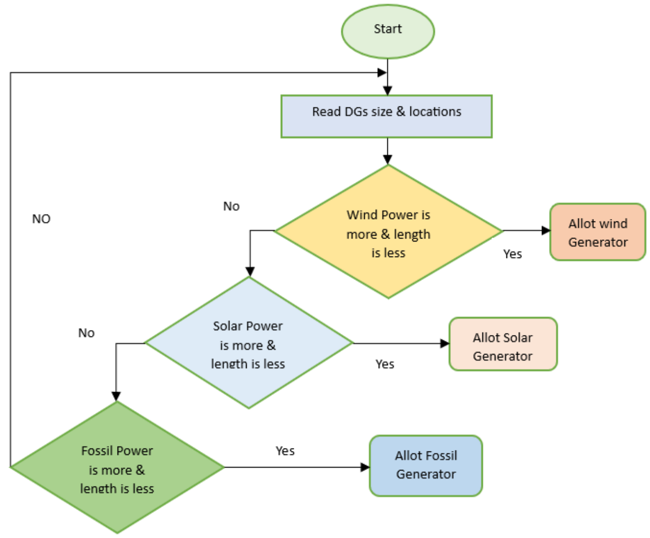

Figure 4 Flowchart for designed method

Table (1) shows that two or more DGs may have the similar power capacity and distance. As a result, the proposed technique will face another challenge which requires a suitable solution. In this state, we can improve the fuzzy controller by addition of another comparison input, such as the cost of generated power, where low cost power has a high priority.

Table 1 Rule bases for proposed fuzzy controller

Power Capability	Distance	DG Priority Allocation
Less	Less	Less
Less	Moderate	Less
Less	More	Less
Moderate	Less	Moderate
Moderate	Moderate	Less
Moderate	More	Less
More	Less	More
More	Moderate	Moderate
More	More	Less

In this case, the DG source with the more power capability, less distance, and least cost will be allocated to the load first

Benefits and Savings Estimation

Global energy consumption is expected to increase by 57% over the next two decades.[14] A significant increase in installed generating capacity is required to encounter forthcoming universal electricity demand. The global electricity generation capacity of is estimated to rise up to 5495 GW by 2025.[15]

To cover the extent of deficiency and overawed the shortcomings of orthodox electricity generation techniques, the permeation of renewable DG technologies into recent power grids improved radically, with many benefits and motives to use them. The modest competitive DG technologies are put forth in Table (2).

HOMER software is employed to analyse wind and solar energy data as shown in Figures 5a and 5b, to demonstrate the competence of this study As shown in Figure 6, our proposed system is built in HOMER.[25]

Table 2 Modest DGs technologies Comparison.

Technology	Wind Turbine	Solar Arrays	Fuel Cells	Micro-Turbine
Size (Output Produced)	0.0003 to 5 MW	0.0003 to 2 MW	0.001 to 10 MW	0.025 to 0.5 M41W
Installation Cost (□/KW)	80000-4,00,000	4,80,000-80,00,000	80,000-4,00,000	1,00,000-1,40,000
Operation & Maintenanc e Cost (□/Kwh)	4-13	12-15	4	16
Electrical Efficiency	25-35%	35-65%	25-45%	05-20%
Overall Efficiency	75-80%	80-90%	25-45%	05-20%
Type of fuel	Wind	Sunlight	Natural gas, Hydrogen and Hydrogen based fuels	Natural gas, liquid fuels

After simulating our system with HOMER, we generated a list of distinct arrangements, sorted by the maximum operative total net present cost (NPC).[25-30] The proposed example formed thirty-six different configurations organized by the most active total NPC. Conversely, as shown in Table 3, the program presented the best four configurations.

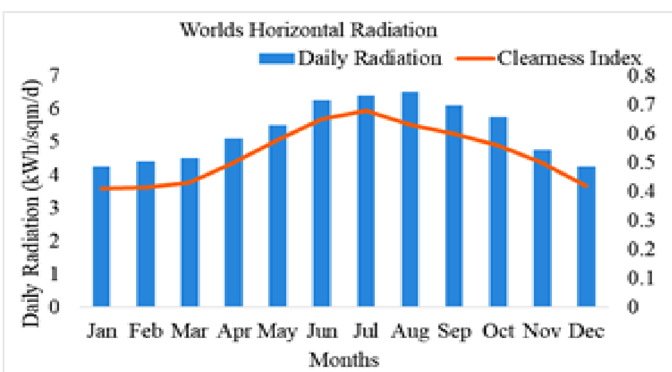

Figure 5a Data of daily Solar radiation (one year)

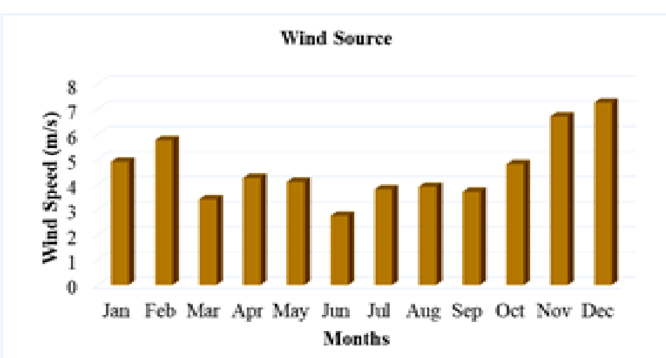

Figure 5b Data of Wind speed (One Year)

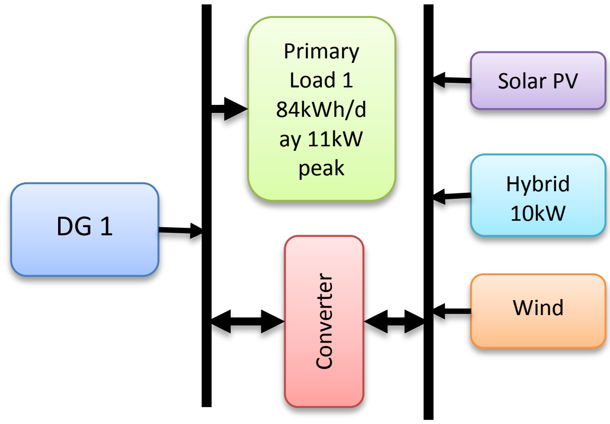

Figure 6 DG construction using HOMER

We compared the first and second configurations to investigate the efficiency of these configurations. It was discovered that the total NPC of the first simulated system is 1,16,97,940/- while the total NPC of the second simulated system is □1,11,37,776. The comparison between electrical production power and sustainability of configurations A and B is given in table 3.

Table 3 Proposed DGs configuration A & B comparison

Phase	Configuration A	Configuration B
Used DGs	Wind + Solar + MT (Diesel Gen.) + Batteries	Wind + MT (Diesel Gen.) + Batteries
Total NPC (□)	1,16,97,940	1,11,37,776
Wind (%)	70	74
Solar (%)	6	0
Diesel (%)	24	263
COE/KWh(□)	33	31
Excess Elec. (%)	30	28
CO_2 emission (Kg/yr)	@18,000	@ 20,000

Conclusion

In conclusion, the optimum fuzzy approach for DG can efficiently by applied in electrical power distribution systems that incorporates wind and solar resources into traditional electric networks. The fuzzy controller intended to select the appropriate DG source and assigned it to the load. Compared to previous reports, DG technologies present very different research challenges than traditional centralized power sources. Lower cost, higher efficiency, and longer life-time DGs are cummulative targets for development of efficient systems. The HOMER software employed to determine the best DG configurations based on total NPC provides optimum required parameters.

Conflicts of Interest

The authors declare that they have no known competing appeared to influence the work reported in this paper.

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