

PAPER • OPEN ACCESS

An enhanced fuzzy logic based strategy for non-disruptive load shedding and the predictive energy management system

To cite this article: W Waheed *et al* 2021 *J. Phys.: Conf. Ser.* **1736** 012035

View the [article online](#) for updates and enhancements.

You may also like

- [Load shedding analysis on microgrid during island mode](#)
Nur Najihah Abu Bakar, A'lia Najwa Muhamad Azmi, N. Rosle *et al.*
- [Overload handling of IBT using load and capacitor shedding](#)
F M Rabbani, I M Ardita, D R Aryani *et al.*
- [Adaptive Underfrequency Load Shedding design based on generation losing estimation using Artificial Neural Network method](#)
J Hartono, K M Tofani, D R Jintaka *et al.*



The Electrochemical Society
Advancing solid state & electrochemical science & technology

243rd ECS Meeting with SOFC-XVIII

More than 50 symposia are available!

Present your research and accelerate science

Boston, MA • May 28 – June 2, 2023

[Learn more and submit!](#)

An enhanced fuzzy logic based strategy for non-disruptive load shedding and the predictive energy management system

W Waheed¹, X Qingshan¹ and M P Abdullah²

¹ Southeast University, Faculty of Electrical Engineering, Nanjing 210096, China

² Universiti Teknologi Malaysia, Faculty of Electrical Engineering, Johor Bahru 81310, Malaysia

waqarwaheed10@seu.edu.cn

Abstract. Electrical energy capacity mismatch and immense power shortages due to energy deficit in the power system keep on increasing because of inadequate power capacity, insufficient investment, demand growth, and the rise in living standards. To maintain a balanced relationship between production and consumption, several load shedding schemes have been implemented for load management in the last few years, but their inconsistency poses a challenge. This research work will apply the fuzzy logic algorithm (FLA) and optimise the existing conventional power systems with and without dispersed generators (DGs). In critical circumstances, the algorithm will find node sets or desired locations where limits are violated and system operators may request the utility or industrial customer to shed a required amount of load by operating distributed generators to maintain its system integrity. The performance and suitability of the proposed scheme are demonstrated and proved by testing on a standard 33-bus radial distribution system in MATLAB Simulink having an objective function of minimising its total load curtailed and reducing power system losses by improving its system stability.

1. Introduction

Energy resources are one of the most precious assets all around the globe. They are indispensable in the daily life of every single individual in the world but governments are responsible for them. Developed countries were aware of the importance of energy potential, mainly electrical energy and took keen measures at the right time to provide sufficient electrical energy to fulfil the needs and capitalise on energy forecasting for future demands [1], while underdeveloped countries face energy deficit due to the electricity supply-demand gap, i.e. power supplied to the system is less than power demands [2,3]. This keeps on increasing day by day due to insufficient investment and demand growth as well as the rise in living standards. This lack of resources and inefficiency of the power distribution system will affect consumers to face rolling blackouts daily and leave them in a state of despair. This will also cause a downfall in the development of any country because rapid industrialisation and increasing urbanisation in developing countries need a huge amount of electrical energy which cannot be fulfilled with their available generating capacities despite continuously growing power generation as compared to the conventional power system and after the addition of new power resources such as renewable energy [4], [5]. The energy supply-demand gap is also increasing because of increasing power demand. An energy crisis is one of the major setbacks for a country to develop and power shortages are a fact of life all over the world due to lack of investment and rapid demand growth in the energy sector. This will create a serious critical condition for their economic growth and development. The energy supply-demand gap



keeps increasing, while utilities fall shorter in their generation capabilities and strongly demand a new enhanced future smart grid, which is depicted in Figure 1 [6].

Notable electrical power shortages for many years in the developed or under developing countries will be solved by optimised solutions consisting of energy distribution systems supported by an efficient distribution system and divided into sub-areas with the help of dispersed generation. This will result in achieving maximum energy efficiency, improving network voltage profiles, minimising network loss, and reducing operational costs. Islanding prevents a complete blackout of the system and cascading failures due to network weaknesses [7]. Controlled islanding in the dispersed radial distribution system also prevents failures from extending and affecting other power network areas and provides stability to the power distribution system, while the fuzzy logic algorithm (FLA) based optimal load balancing scheme has been proposed for an efficient electrical power distribution system with and without dispersed generators (DGs). Also, this strategy will provide complete assistance in constant and variable energy capacity deficit caused by unscheduled power cut in the power distribution system. Several optimisation schemes have been proposed during the last couple of years to improve the power distribution system and provide an optimal solution to overcome the power deficiency problem due to excessive load demand and limited power supply. Many well-known optimisation techniques such as a heuristic approach, linear programming, fuzzy algorithm, genetic algorithm approach [8], particle swarm optimisation [9], time approach optimisation and many different combinational techniques have been used to reach the most efficient solution. The impact of demand response (DR) application at the residential house has been discussed by using load shifting under certain conditions when electricity tariff charges are set to be higher than in another period by the utility and shifted forward to some other less tariff time frames for balancing the peak demand of the house [6]. The artificial intelligence technology is one of the fittest techniques for this type of problem, but the only problem is the huge database for the training of datasets in smart grids and buildings [10].

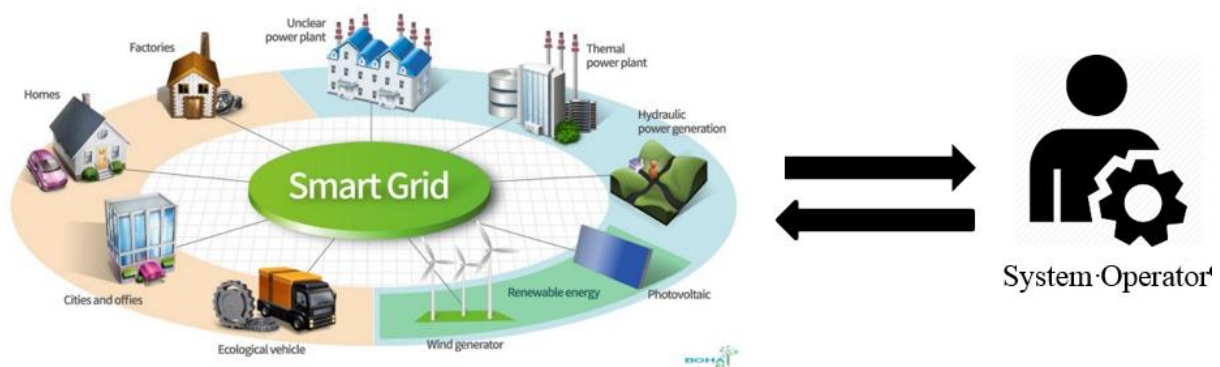


Figure 1. Future smart grid.

In some conditions, however, the same method can be used to find and eliminate unintentional islands that disturb the network and create its instability. This technique will be helpful for countries whose power systems suffer from routine electricity shortages and will reduce the risk of wide blackouts on the end-user side. A computational intelligence technique is considered as one of the most prominent techniques for engineering optimisation [11]. The radial distribution system (RDS) has been considered after the effective analysis of multiple reconfiguration in the radial distributing system network which provides maximum operating performance, reliability, voltage enhancement, and minimisation of losses [12]. The evaluation mainly focused on active power losses (kW), reliability in terms of interruption cost and voltage profile whether it is done by particle swarm optimisation [13] or by artificial intelligence technique [14]. This is the most prominent solution to the modern problem. Different characteristics of buses in the power system network have been considered with linear programming

(LP) and the particle swarm optimisation (PSO) method for a shorter period and all constraints, respectively [15]. Another research, however, has used load shedding strategies to investigate distribution system reliability cost indices to evaluate weight factor for a different type of feeder in which capacity and cost match are used to determine load shedding priority among feeders [16]. A fuzzy logic-based algorithm was introduced for tackling emergency conditions in a power system due to a sudden increase in load, losses in transmission lines, generation, or any other failures of components in the system [17,18]. Another efficient solution involves applying load forecasting techniques for monitoring the future demand in the country and being well prepared for it in advance for a time span of single hour to the tenure of many years [19,20]. The demand-side prediction system for scheduled power cuts in which irregularity of scheduled power cuts can be resolved by statistical data measured for about a year has been introduced. In this data analysis, the beginning of power cut as well as its frequency outage have been monitored during a certain time frame [21]. The discussed optimal placement of DGs describes location and capacities provided by DGs in the distribution network and its main objective is to minimise network power losses. A DG model consists of its location and sizing required for fulfilling the required demand by considering different voltage-dependent load models such as industrial, residential, and commercial loads [22].

The contribution of this paper mainly focuses on electrical energy capacity mismatch and immense power shortages due to increasing energy deficit in the power system resulting from insufficient power capacity, insufficient investment, demand growth as well as the rise in living standards. This lack of resources will affect consumers to face rolling blackouts daily due to the increase in the demand-supply gap which causes a frequency deviation problem. This research work will apply the fuzzy logic algorithm (FLA) and optimise the existing conventional power systems with and without dispersed generators (DGs). In critical circumstances, the algorithm will find node sets or a desired location where limits are violated and system operators may request the utility or industrial customer to shed a required amount of load by operating distributed generators to maintain its system integrity.

2. The theoretical aspect of the research

This proposed scheme has been employed for an optimal load shedding strategy in a 33-bus power distribution network to examine distributed generators (DGs) in the constant and variable modelling of power distribution network simulated in MATLAB Simulink. The electrical power distribution system usually consists of unidirectional power flow in a radial network, but with the advent of dispersed generation, the distribution system has a locally looped network and bidirectional power flows. The on-site generation has been used during excessive peak demands in certain critical areas during critical situations [23]. The expected objective function is set as:

$$\text{Min} (\sum_{N=1}^{Kbus} W_N P_N + \sum_{N=1}^{Kbus} R_N I_N^2) \quad (1)$$

where

$I_N^2 R_N$ = Power system losses at the Nth branch.

$W_N P_N$ = Total curtailed load at the Nth branch.

K=Total number of buses.

2.1 The Impact of Dispersed Generation in the Power System

Several distributed generators (DGs) will be placed in a distribution system that will provide bi-directional power flows and maximum stability to the system. The planned and more effective distributed generation network is a key to cope with growing demand for industrial, domestic, and commercial loads. These DGs will operate when demand exceeds the power supplied by the utility. A required DG will shed the total load supplied by the utility and maximum possible load will be provided

in the disturbing network in a certain period of time-region through optimum load shedding according to the voltage magnitude and load priority set by the utility supplier.

In this distribution system, each branch connected with different buses comprises multiple end user's RLC load. Each branch will be continuously under observation and runtime values for each branch will be fetched and measured separately for different parameters like P, Q, V, and I. These parameters act individually as input variables for the relay controlling system by the specified set point. The relay subsystem comprises three-phase inputs connected with each branch individually and a load flow analysis will be performed to easily trace and compare that branch load input with the specified threshold value by relational operators connected with each phase input and generating high and low signals for the S-R flip-flops. These flip-flops will compare that high signal with a constant zero value for further NAND gate operation. Finally, that value will be converted into two types of signals: high (1) and low (0) which can control a circuit breaker connected with each DGs. When the limit violation occurs at any branch of the system against the specified value of input parameter, the relay system will operate and generate an input signal or high pulse for the circuit breaker connected with a distributed generator (DG) of that individual branch where demand increased as compared to the limited supply, which results in capacity falls below the specified threshold level. Thus, the system stability will be maintained by DGs operation. The electric distribution system is a central focus nowadays due to growing penetration by distributed generators (DGs) or integration of distributed generators into the network which changes the basic structure from a passive system to an active one. Generating electrical energy on-site, except the main utility system, eliminates interdependencies and complexity of the network and reduces inefficiencies associated with transmission and distribution, which is also cost-effective. This will provide certain benefits as compared to the conventional power distribution system. The main technical advantages are:

- reduced power line losses,
- voltage profile enhancement,
- reduced pollution due to emissions,
- increased overall efficiency,
- improved security and reliability,
- better power quality,
- relieved transmission and distribution congestion.

2.2 Fuzzy logic algorithm (FLA)

Due to the increase in nonlinearity, coupling, and complexity of the object, people cannot efficiently solve critical problems by the existing law. It is necessary to solve them by using a natural language to define multiple objects and express them through qualitative, imprecise, and fuzzy logic conditional statements. Fuzzy logic can be defined as a superset of conventional logic which is either right or wrong and can be described by how much of its importance is exactly right if it is compared with a rough answer. In other words, fuzzy logic defines the relative importance of precision. This fuzzy logic concept was proposed by Lotfi Zadeh, researcher and professor emeritus at the University of California, Berkeley from the 1960s. This system was implemented in the 1970s due to the lack of computational capabilities in the control system.

Although this modern technique of fuzzy logic algorithm is still young, the concepts of fuzzy logic algorithm reach right down to our bones. Fuzzy logic is termed as an efficient algorithm for its immense capability of merging artificial intelligence (AI) and a mathematical description of the experimental system which can be understood by fuzzy logic representation for the controlling of complex structure blended with multiple controlled conventional techniques like fault diagnosis. Fuzzy logic is also very convenient in terms of mapping from the input space onto output space. This can be achieved by inserting a black box between input and output like a fuzzy logic algorithm (FLA). The fuzzy method has a serious advantage over other techniques because it is fast and cheap. Its flexibility enables easy variations in the system without starting from scratch. In the last few years, fuzzy logic has been used in a variety of applications like process control, decision support modules, camcorders, cameras, medical

instrumentation, microwaves, washing machines, portfolio selection, industrial and multiple consumer products and the demand for fuzzy logic has increased tremendously. The fuzzy logic algorithm is an intelligent control technique that can be combined with human intelligence, which can be done in the following four steps: fuzzification, establishing a fuzzy rule, fuzzy inference, and defuzzification. This process can be done directly in MATLAB Simulink where these steps will be run at the background by using a graphical user interface (GUI) of the Matlab fuzzy logic toolbox and follows in five different steps summarised in the form of the fuzzy inference system (FIS). The fuzzy inference system can be defined in five basic GUI tools for building, editing, and observing of the system: FIS Editor, membership function editor, rule editor, rule viewer, and surface viewer.

3. Implementation of the Fuzzy Logic Algorithm (FLA)

A fuzzy logic algorithm has been employed for finding node sets or disturbing branches where load shedding has been required with the help of connected generators (DGs). The distributed generators will assist the utility to shed some load in response to the total power increment at any branch after certain violations of critical threshold limits, which results in the stabilised power system as shown in the block diagram in Figure 2.

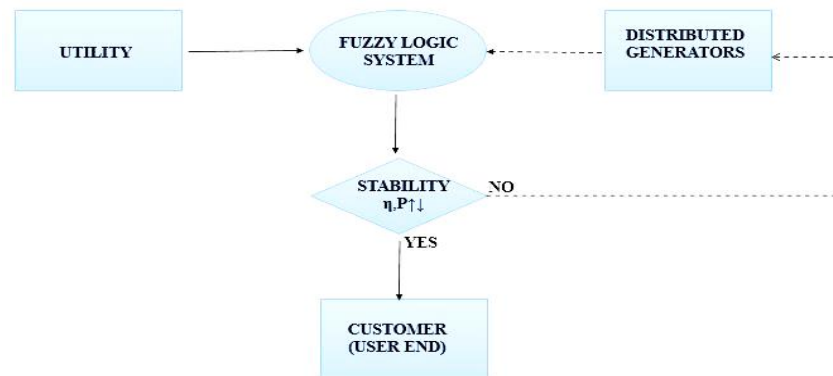


Figure 2. Basic flowchart of the fuzzy load balancing system.

DGs output in the fuzzy logic algorithm-based system cannot be fixed and can be varied between 0 and 1.2 MW due to the variation in demand at the disturbing connected branch where increment in load above certain threshold limits is also variable. The main problem is that demand cannot be fulfilled due to the corresponding parts of the network which are exceeding their limits as compared to the main source. For balancing the network in terms of generation and distribution momentum, load may be shed to avoid the following constraints:

- power loss in the system,
- overloaded branch currents,
- voltage deviation in the busbar,
- operational switch costs.

3.1. Experimental Setup

To resolve power generation shortages and minimise the supply-demand gap, the fuzzy logic algorithm-based load shedding scheme has been implemented if the utility system is unable to fulfill the demand required by the user side, and then the load with low priority will be shed due to limit violations that occur at a certain region or branch. This scheme will be able to minimise power distribution losses with efficiently dispersed generation. In the fuzzy logic-based system, the 33-bus network which was already divided into four branches is connected with multiple RLC loads at the end-point. Each branch load data (P, Q, V, I) is separately measured and fetched with the oscilloscope. After that, Voltage (V) and Current (I) act as an input parameter to fetch phasor real power output at different branches through load flow

analysis. These phasor's real power outputs act as an input parameter for a fuzzy logic toolbox for the implication of an efficient load shedding strategy through the fuzzy logic algorithm. Therefore, the fuzzy logic algorithm will perform in line with the pre-defined rules and membership functions with the specified different conditions and provide an efficient solution that can be seen by surface and rule viewers of the optimised fuzzy logic inference system. This proposed solution is used for defining the membership function and its threshold limits as well as the functioning of the system as compared to the input and output values with certain specified limits. In this system, there are four phasor's real power inputs which can be set between threshold limits specified by a load flow curve within a certain time frame and can be set as a Trapezoidal membership function with one input of available generation at the main utility side which can show the condition of available generated power on a scale of 0-100% and can be set as a Gaussian Membership function. The overall operation of the system is depicted in Figure 3.

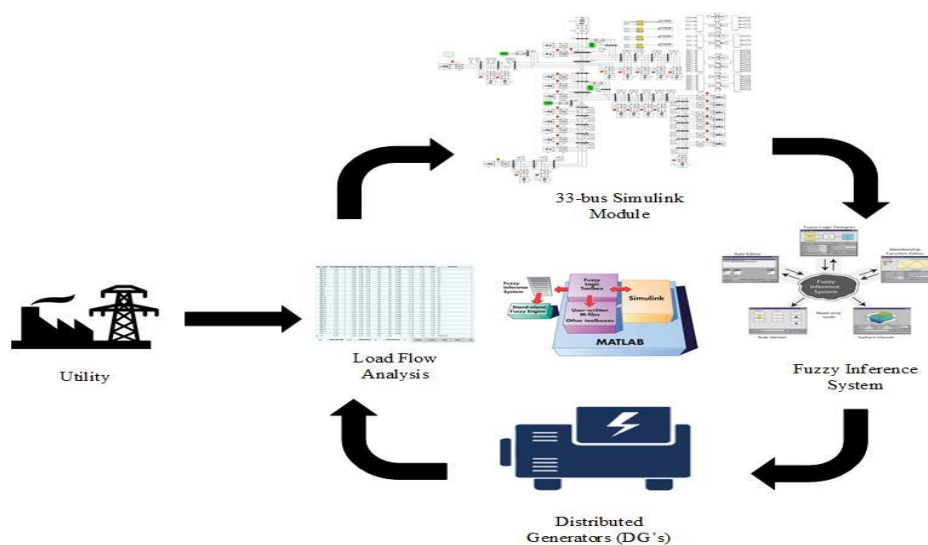


Figure 3. The overall working of the improved system.

The output of the system consists of four DGs connected with each branch which can be used for the efficient load shedding strategy as demanded by critical situations. The fuzzy logic algorithm works as a decision-making module where any branch violating the limits against specified threshold values results in emergency distributed generator interconnection as a parallel operation with the main utility system. The output membership function can be set as a Triangular membership function.

4. Results and Discussions

The fuzzy logic algorithm has been implemented by a specific membership function and a set of rules for obtaining the desired objective. The rule viewer will act as the main interfacing system in which real power measurement of all branches and total generation capacity act as an input parameter and variable DGs connected at each branch will be considered as the output of the fuzzy logic system. The system operator will monitor and apply the desired action based on the fuzzy logic algorithm. If, as it has been seen, all input real power of all four connected branches is under certain threshold limits as defined by the operator and generation is at a medium level of 50% of the total generation, there is no need for load shedding at any branch because the system is already in stable condition. The corresponding “if-then” rules of the designated system are given below:

1. $(Pb1==low) \ \& \ (Generation==High) \Rightarrow (DG1=low_load \ shedding)$
2. $(Pb2==low) \ \& \ (Generation==High) \Rightarrow (DG2=low_load \ shedding)$
3. $(Pb3==low) \ \& \ (Generation==High) \Rightarrow (DG3=low_load \ shedding)$
4. $(Pb4==low) \ \& \ (Generation==High) \Rightarrow (DG4=low_load \ shedding)$

5. (Pb1==High) & (Generation==Medium) => (DG1=medium_ load shedding)
6. (Pb2==High) & (Generation==Medium) => (DG2=medium_ load shedding)
7. (Pb3==High) & (Generation==Medium) => (DG3=medium_ load shedding)
8. (Pb4==High) & (Generation==Medium) => (DG4=medium_ load shedding)
9. (Pb1==High) & (Generation==Low) => (DG1=critical_ load shedding)
10. (Pb2==High) & (Generation==Low) => (DG2=critical_ load shedding)
11. (Pb3==High) & (Generation==Low) => (DG3=critical_ load shedding)
12. (Pb4==High) & (Generation==Low) => (DG4=critical_ load shedding).

There are five input functions of which four are phasor’s real power inputs of the four different branches of the IEEE 33-bus system and one is a utility (generation) membership function which can be set between threshold limits specified by a load flow curve within a specified time frame. The available generation at the main utility side can show the condition of available generated power on a scale of 0-100%. The output of the system consists of four DGs connected with each branch which can be used for efficient load shedding as demanded by critical situations. The fuzzy logic algorithm works as a decision-making module that decides which branch violates the limits against the specified threshold values where the distributed generators interconnect in parallel with the main system. The four output membership functions can be set as a Triangular (trimf) Membership function of the interconnected generators on the four different branches of the 33-bus system due to its capability of retrieving threshold limits from low, medium and critical load conditions.

If two of the four branches are still under certain threshold limits and the other two violate the threshold limits (for example branch-02 and branch-03), distributed generators DG₂ and DG₃ need to operate and supplying almost 0.87MW to the system to maintain its integrity, and utility generation is only 20% as compared to the total load in a certain branch. In another case, when all four branches violate the threshold limits of real active power, while utility power generation is at almost 27% of the total generation, all four DGs will operate at 0.77MW of the total capacity to normalise the power distribution system as shown in Figure 4. If the available generation capacity declined to 16.3% of the total generation, distributed generation capacity would increase almost up to 1MW of the total capacity.

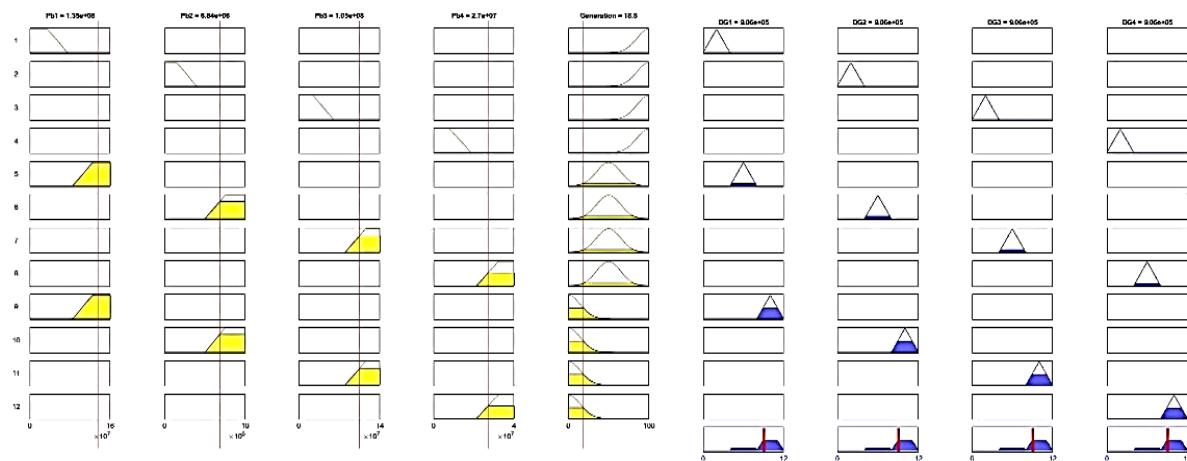


Figure 4. Power normalising under critical load forecasting.

Now, consider the surface viewer which also shows the operation of the system by the three-dimensional plot as seen in Figure 5. The surface viewer shows a three-dimensional plot where the total utility generation is at the X-axis, the phasor’s real power input is at the Y-axis and the distributed generator output is at the Z-axis of the three-dimensional plot.

If one branch is constant in terms of its input real power and another branch violates its threshold limits, the disturbing branch allows the distributed generator to increase power supply to maintain the power system integrity as shown in Figure 6.

Concerning the surface viewer, it is clear that with the increase in the real power input of the branch and violated threshold limits against the available generation resulting in distributed generators (DGs) operation, DGs will operate and increase linearly in terms of the increment in the input real power of the disturbing branch and, consequently, can reduce power system losses with a huge impact on the controlled power system with distributed generation (DGs) as shown in Figure 7(a) and 7(b), respectively.

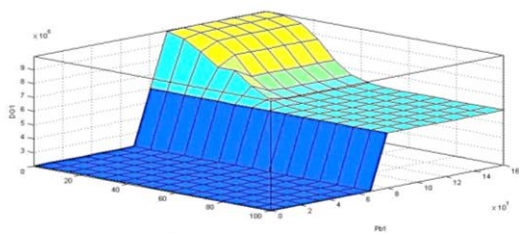


Figure 5. Surface viewer operation of the fuzzy logic algorithm.

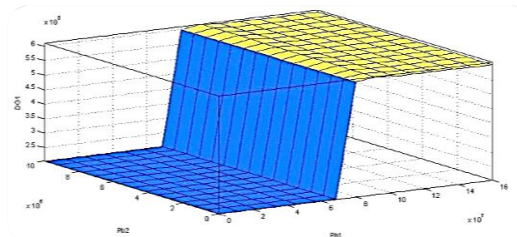
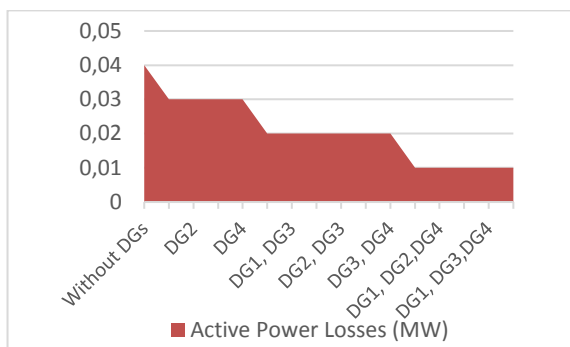
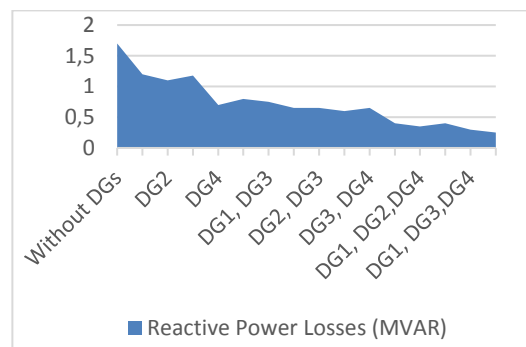


Figure 6. Comparison of the two operational power system branches.



(a)



(b)

Figure 7. Impact of the distributed generation in terms of power losses: (a) active power losses; (b) reactive power losses.

This is how the system can get back to the normal condition from the failure that occurred in the power distribution system. Hence, this will increase system efficiency and maintain its integrity during critical situations as shown in Table 1.

Table 1. Impact of fuzzy logic operation in the power system.

	Before DGs		After DGs	
	Active Power	Reactive Power	Active Power	Reactive Power
Total Generation	P=4.35 MW	Q=4.57 MVAR	P=6.25 MW	P=4.42 MVAR
Power System Losses	P=0.04 MW	Q=1.67 MVAR	P=0.01 MW	Q=0.22 MVAR

5. Conclusion and Recommendations

The energy deficit originated from the failures in the power distribution and transmission system that promotes load curtailments into the distribution system. Power system losses will be minimised and the

total load will be shed by efficient load curtailment by a fuzzy logic algorithm where this proposed scheme will find a node-set or desired location where limits are violated. If a certain disturbance occurs in the network, the system operator may request the power distribution utility or industrial customer to shed load to maintain the system integrity. The system can thus be normalised by an on-site generation where connected DGs in high priority geographical areas will be in operational standby condition due to excessive demand during peak load. This will make the system more efficient by minimising power system losses. Another advantage is the cost-efficiency of the fuzzy decision-making module with distributed generators (DGs) activated in critical situations only as compared to very expensive DGs operation with continuously running distribution generators.

It is also concluded that there are several areas needed to be addressed along with the accuracy of the fuzzy logic system, convergence rate, and the false triggering of relay-controlled operation. The implementation of an accurate scheme after filtration can save a significant amount of energy and normalise mismatch in the power system and keep a balanced relationship between production and consumption.

References

- [1] Apergis N and Payne J E 2011 A dynamic panel study of economic development and the electricity consumption-growth nexus *Energy Econ.* **33**(5) 770–781
- [2] ADB 2013 *energy outlook Energy Outlook no. October* 2013
- [3] Alam M M and Murad M W 2020 The impacts of economic growth, trade openness and technological progress on renewable energy use in organization for economic co-operation and development countries *Renew. Energy* **145** 382–390
- [4] Paterakis N G, Erdinç O and Catalão J P S 2017 An overview of Demand Response: Key-elements and international experience *Renew. Sustain. Energy Rev.* **69** 871–891
- [5] Kinhekar N, Padhy N P and Gupta H O 2014 Multiobjective demand side management solutions for utilities with peak demand deficit *Int. J. Electr. Power Energy Syst.* **55** 612–619
- [6] Elma O 2017 *An Overview of Demand Response Applications under Smart Grid Concept* 104–107
- [7] Shahmohammadi A and Ameli M T 2014 Proper sizing and placement of distributed power generation aids the intentional islanding process *Electr. Power Syst. Res.* **106** 73–85
- [8] Lujano-Rojas J M, Dufo-López R, Bernal-Agustín J L, Domínguez-Navarro J A and Catalão J P S 2019 Probabilistic perspective of the optimal distributed generation integration on a distribution system *Electr. Power Syst. Res.* **167** 9–20
- [9] Abdeltawab H H and Mohamed Y A R I 2017 Robust operating zones identification for energy storage day-ahead operation *Sustain. Energy, Grids Networks* **10** 1–11
- [10] Raza M Q and Khosravi A 2015 A review on artificial intelligence based load demand forecasting techniques for smart grid and buildings *Renew. Sustain. Energy Rev.* **50** 1352–1372
- [11] Abdullah N R H, Musirin I and Othman M M 2010 Computational intelligence technique for solving power scheduling optimization problem *Power Eng. Optim. Conf. (PEOCO), 2010 4th Int.*
- [12] Bhujel A K M D and Adhikary B 2012 A Load Flow Algorithm for Radial Distribution System With Distributed Generation 2012 *IEEE Third International Conference Sustainable Energy Technologies (ICSET)* **2** 375–380
- [13] Club Y R, Branch P M, Moghan P, Club Y R and Branch A 2013 *Distributed Generation Allocation in Radial Distribution Systems Using Various Particle Swarm Optimization Techniques* **1** 261–265
- [14] Venkatesh B, Chandramohan S, Kayalvizhi N and Kumudini Devi R P 2009 Optimal reconfiguration of radial distribution system using artificial intelligence methods *TIC-STH'09 2009 IEEE Toronto Int. Conf. - Sci. Technol. Humanit.* 660–665
- [15] Hagh M T and Galvani S 2011 *Minimization of load shedding by sequential use of linear programming and particle swarm optimization* **19**(4) 551–563
- [16] Leite Da Silva A M, Cassula A M, Billinton R and Manso L A F 2001 Optimum load shedding strategies in distribution systems 2001 *IEEE Porto Power Tech Proc.* **2** 398–403

- [17] Ben Hessine M Load Shedding Strategy Application Using Fuzzy Logic 2013 *International Conference on Electrical Engineering and Software Applications* (Hammamet)
- [18] Kaewmanee J, Sirisumrannukul S and Menaneanatra T 2013 *Optimal Load Shedding in Power System using Fuzzy Decision Algorithm* pp. 43–51
- [19] Mordjaoui M, Haddad S, Medoued A and Laouafi A 2017 Electric load forecasting by using dynamic neural network *Int. J. Hydrogen Energy* **42(28)** 17655–17663
- [20] Jamaaluddin J *et al.* 2018 Very Short Term Load Forecasting Using Interval Type - 2 Fuzzy Inference System (IT- 2 FIS) (Case Study: Java Bali Electrical System) *IOP Conf. Ser. Mater. Sci. Eng.* **384(1)**
- [21] Kogo T and Nakamura S 2014 *A Demand Side Prediction Method for Persistent Scheduled Power-cuts in Developing Countries* pp 1–6
- [22] Hosseini M and Baghipour R 2013 *Optimal Placement of DGs in Distribution System including Different Load Models for Loss Reduction using Genetic Algorithm* **4(3)** 55–68
- [23] Malekpour A R, Seifi A R, Hesamzadeh M R and Hosseinzadeh N 2008 An optimal load shedding approach for distribution networks with DGs considering capacity deficiency modelling of bulked power supply 2008 *Australas. Univ. Power Eng. Conf.* 143–151