ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

Fuzzy based multi-line Power Outage Control System

Emad Hussen Sadiq[1], Shahzad Ashraf[2], Zeeshan Aslam[3], Durr Muhammad[4]
[1]Duhok Polytechnic University, Duhok Iraq
[2]Hohai University Changzhou, Jiangsu China
[3]Petroweld Kurdistan Erbil, Iraq
[4]Pakistan Steel Mills Karachi Pakistan
E.Mail: emad.sadiq@dpu.edu.krd

ABSTRACT: Transmission lines are among the most important power grid equipment in which their removal can lead to subsequent outages. One of the situations which lead to blackouts is multiple line outages. Therefore, multiple line outage detections (MLOD) are a necessity in the power system for protection actions. This paper proposes a fuzzy inference system (FIS) to identify multiple line outages. The proposed FIS can determine multiple line outage conditions by continuously monitoring the lines circuit breakers (CBs) status. For this purpose, by introducing the line CBs status as inputs, the status of the predefined line outage scenario is determined as the output of the proposed FIS. This study is helpful for the power system researchers to make decisions about power system protection. The proposed fuzzy MLOD system has the advantage of high precision in applying the fuzzy system as an artificial intelligence tool. For the reason of problem dimensions limitations, in this paper, just single and multi-line outage contingencies are considered for the MLOD problem although the proposed method can be extended to detect triple and more line outage contingencies by definition the additional fuzzy rules. The proposed fuzzy MLOD system is tested on IEEE 5-bus system and the results are presented.

KEYWORDS: Multiple line outage, detection, fuzzy system

1. INTRODUCTION

Getting the smooth and uninterrupted power supply from power houses to the home or the vicinity is much crucial. It is also important to have sufficient transmission line protection arrangements. Nowadays, extraordinary computer tools are available to model the power system network in every aspect.The power systems have numerous protection challenges which are been seriously considered, as power transmission lines are inevitably exposed to a variety of extreme weather disturbances, equipment aging, human error and even malicious attacks. In fact, due to unexpected contingencies and the evolving nature of power grids, the completely reliable and safe operation cannot be achieved.because power system engineers try to design a reliable system.

The development of the protection system for power transmission lines can be divided into three stages. Specifically, conventional protection is mainly based on an electro-mechanical protection relay for the separation of overloading branches[1]. Despite the high reliability and simplicity of the construction, these relays need to be calibrated periodically in the absence of directional features. With the advent of computer features, the second protection stage as the advanced intelligent control algorithms can be applied to protect power grids[2]. In addition, the use of the Global Positioning System (GPS) is a remarkable milestone that enables engineers to synchronize time precisely and obtain global phase information for the protection of the wider area. The availability of global information on power systems makes it possible to establish a systematic approach to dealing with catastrophic scenarios in large-scale power grids. The Special Protection Scheme (SPS) is therefore proposed to reduce global stress by separating power systems from several islands and isolating faulty areas according to predetermined actions.

Hundreds of transmission lines can be connected to the corresponding generating stations by a single line, including every system supporting component. There are a variety of real-time technologies in power and energy systems. The issue of line outage in power system whether planned such as network maintenance operations or unplanned such as fault situations may cause some problem for the protection system. In other words, if these outage conditions are not included in the protection plan, it is likely to cause outage of other system elements i.e. loads or resources. If the protection system operates properly, after removal of multiple lines, the rest of the system will remain stable, otherwise some miscoordination may occur between system protective elements and consequently the system will

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

encounter regional or wide blackouts. Therefore,the detection of these situations has significant impact on preventing the protection miscoordinations and blackouts[3].

This study is being conducted to investigate the maleficent impairments in Multi-line Power Outage Control system using a fuzzy based sagacious approach through IEEE 57-bus system with the help of IEEE 5- bus sten.We adopted the Line Breaker (LB) [4], switches and the status of all LBs for all lines is expressed in fuzzy set notations. We conducted MATLAB simulation to ratify the performance of the proposed system similar to the realtime scenarios. Further, a balanced phase power system is also modeled in theSimulink performance.Figure 1, illustrates the overall power outrage mechanism accordingly.Initially, a flooded decision identifies the status of the transmission lines. The analog signals are obtained from the power lines. It is considered that a power line meter is associated with each pair of LBs in the single line. For clarification, a line with two LBs is shown in figure 2, along with the corresponding power flow meter.

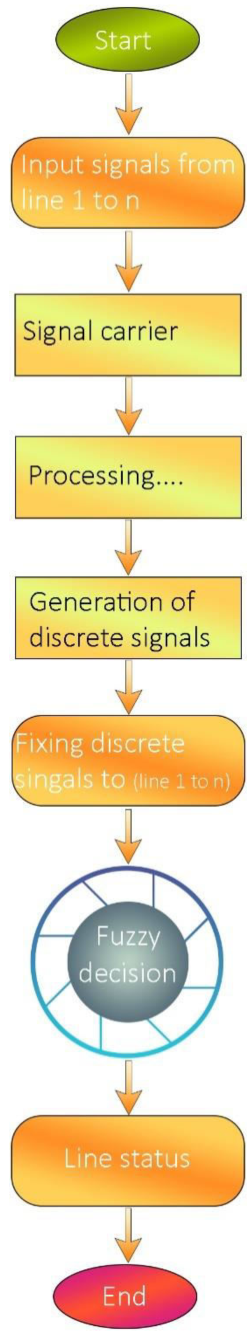


Figure 1. Information flow chart of fuzzy basedmulti-line Power Outage Control System

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

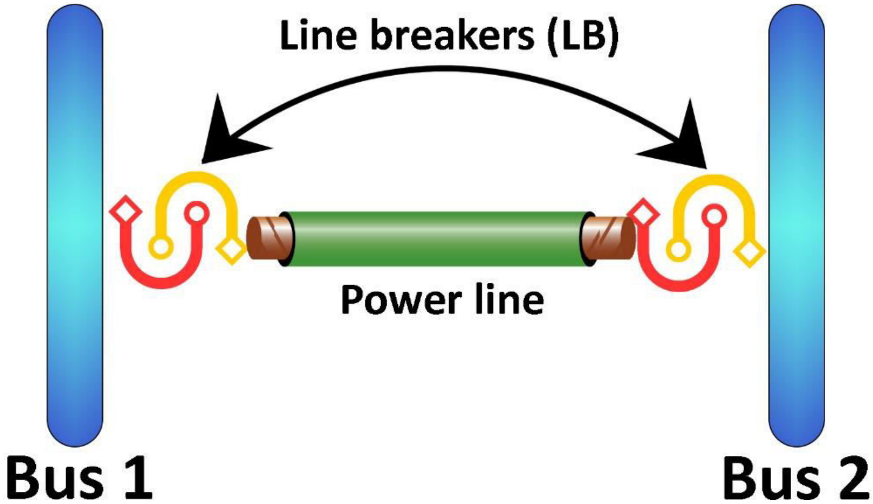


Figure 2. Line breaker

Initially, the analog signals will be initially transmitted to the central system via the TCP / IP network, allowing all protection, control, measuring and monitoring functions within the power supply system to be integrated.The analog signals are then converted into digital values and used to determine the current line status for the system. The converter is used for structural analysis to generate and transmit digital data. The further discussion is given in the proposed section.

2. RELATED WORK

The numerous researches are available in literates which issued multiple line outage detection (MLOD) methods [5], in the power systems. Most of the researches have focused on power flow measurements analysis for MLOD problem.The author [6], proposed a double-line outage detection method in the power systemmainly based on AC power flow equations and injected power. This system has some limitation during operation. The changes are declared using the AC model by power injections and consequently the outage can be detected. Another author in [7],introduced a double-line outage detection scheme based on load flow. For this purpose, initially a reactance model of system is derived. Afterward, the outage contingencies are detected through analysis and the reactance matrix values are obtained from performing load flow. The status of the connection lines can be declared through the reactance matrix.

In [3] and [4] the probability and estimation techniques are used for MLOD problem. In [3], first the system is modeled and load flow is performed. Then estimation of distribution algorithm is used to estimate the outage of lines based on threshold between outage and normal status of lines. In [4] first the probability of occurrence for each multiple line outage configuration is calculated based on overloading index and skip the outage configurations with too low probability. Then, the lines which are in outage conditions are detected by monitoring the modifications in reactance matrix for remained set of outage configurations. The MLOD problem [8], has been discussed depends on phase angles analysis. Data from phasor measurement units (PMUs) is analyzed, and the status of lines is calculated as a result of the analysis.

Despite of substantialoutcome, most of the existing approaches for line outage detection suffers from two drawbacks which are high computational complexity and the difficulty of analyzing the results for the users. The high computational complexity especially in wide grids limits the MLOD only for the case of single line or double-line outages. On the other hand, the speed of analyzing data and making subsequent decisions in central system are much important. Considering these drawbacks, the present paper proposes a fuzzy system which overcome both mentioned drawbacks. The proposed fuzzy system can be extended for wide grids to detect more line outage contingencies and can be used as a comprehensive graphical user inference (GUI) in central system for more simple and fast decision making by users.

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

2.1 Architecture of IEEE 57 bus system

It is an American based power system and the bust network consists of 63 transmission lines, 7 generators, 42 loads and 17 tap-setting transformers[9]. According to the available data, the transmission line does not have any active and reactive power limits.The power system consists of two segments, the first is the Transmission segment and the second is the Distribution segment. The first segment consists of generators, 1 to 17 voltage busses of 138 kv (line-line) and the Tap Setting Transformers, while second segment incorporates 18 to 57 voltage busses of 69kv (line-line) and distribution loads as shown in figure 3.This model has three major liabilities; First, review the structure of a power system and the original data to estimate the number of components required and the rating.

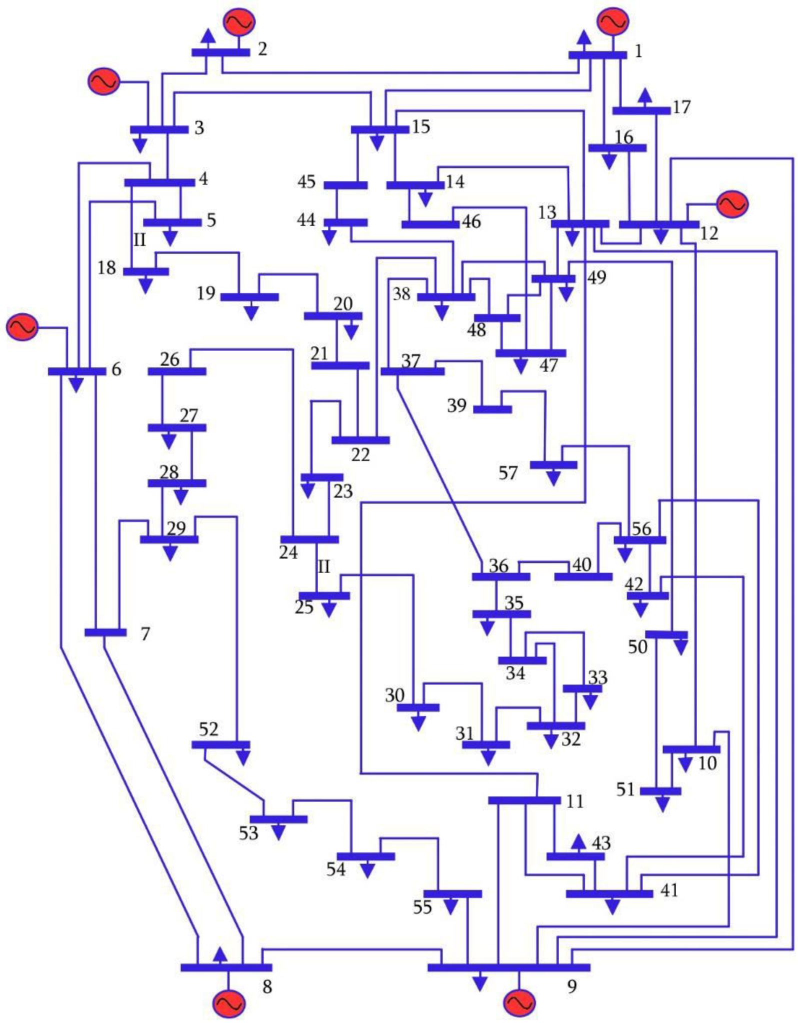


Figure 3. TheIEEE 57 bus architecture system

3. MULTI LINE OUTAGE ANALYSIS

A protection system is neededmaking the power system monitored and set plans to help it encounter the likely scenarios that would happen. Cascade outages [10], are usually uncontrollable and can be very wide. Therefore, it is necessary to make the protection system for special preparations. One of these situations which might leads to cascade outages is the multi-line outage. The importance of multi-line outage is considered as the voltage magnitude at buses under single line and multi-line outage contingencies in IEEE 5-bus system can be taken therefore, the multi-line outage has more effect on voltage magnitude than single line outage. It can be observed that there is an obvious voltage drop in multi-line outage scenarios versus single line outage. Multi line outage can be occurred in the situation when two lines are disconnected due tofaults or maintenance operations. In such situations, the other

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

lines would encounter overloading and then may disconnect since the control system are not planned to action in overload and low-voltage situations. Eventually, the other lines are disconnected one after another and a cascading outage would happen.

4.PROPOSED LINE OUTAGE DETECTION

In order to conduct our finding, the multi-line outage detection mechanism mainly based on interface between the lines CBs status and central system has been considered. The main functional blocks of our proposal isshown in Figure 4.

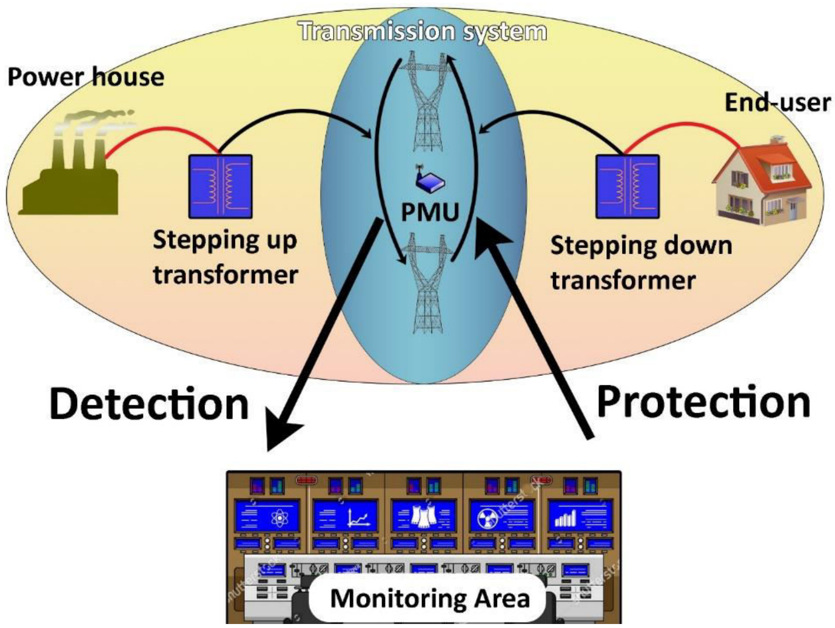


Figure 4. The proposed system architecture

The lines statusis identified mainly by the fuzzy logic block and thereforethe analog signals are being obtained from the power flow meters whileeach pair of CBs in the single line are associated with power flow meter. Initially, the line with two CBs and the corresponding power flow meter is being monitored then the analog signals are sent to central system using high speed Ethernet through IEC 61850 TCP/IP protocol[11]. The IEC 61850 is a global standard for Ethernet-based communication in power system. It enables integration of all protection, control, measurement and monitoring functions within the power system. Therefore, providing a real times communication in IEC 61850 protocol, guarantees the speed of the transferring data obtained from the CBs to central system for further actions.The analog signals in central system converts to digital values by converter to be used as inputs for the fuzzy system determining the scenario status. Structurally, the converter is used to generate and transfer digital data for further analysis. Further, the details of our proposed system have been structured with every thick and thin as

4.1.Line CBs Status

In this paper, the line CBs status are used as an index for line outage detection. Therefore, in order to model the two possible status for CB, first the active power flow passing through a CB is modeled using a dc approximation as follows [12]:

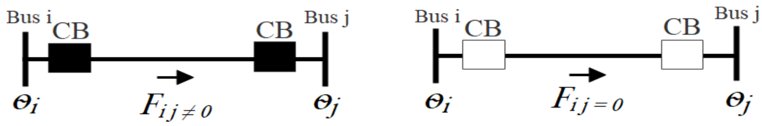
$$F_{ij} = B_{\varepsilon}(\theta_i - \theta_j) \qquad (1)$$

Where$F_{ij}$is the active power flow through the considered CBs; θ_i *and* $\theta_j$are the voltage angle at bus i and j, respectively andB_{ε} is the susceptance. Then, a binary variable is used in Equation (2) to model the two status of CB that becomes [13]:

$$F_{ij} = U_{ij} B_{\varepsilon}(\theta_i - \theta_j) \qquad (2)$$

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

A value of U_{ij}equal to 0 identifies an open CB, whereas 1 value indicates a closed CB. The CB status consider the power flow through the line isgiven in figure 5:



(a) (b)

Figure 5. CB status (a) closed (b) open

It can be observed that$U_{ij} = 0$ implies null flow i.e., the open CBs conditions. On the other hand,$U_{ij} = 1$ implies the closed CBs conditions. In other word, there is a small voltage angle difference between buses i and j and consequently apower flow between two buses.

Therefore, according to the definition of one binary variable asU_{ij} with two status, the line CBs status can be detected. Depending on the binary variableU_{ij} which is determined by the power flow passing through the CBs, status of the line can be detected. Therefore, for a power system with n lines, the $n$binary values are defined for the lines CBs status such that n indicates a set of CBs in each individual line at each side of the line. A decision making system is crucially required to receive the binary values from the converter and detect the lines status. Fuzzy inference system (FIS) is a powerful decision making tool for this purpose. The FIS is simulated in MATLAB fuzzy toolbox.

4.2.Fuzzy Inference System

The fuzzy interface system (FIS) is being used to detect the line outage contingencies as a decision making tool. A typical fuzzy logic system consists of a fuzzification component, an inference engine, and a defuzzificaton component.

The inference engine is a set of IF–THENrules which are made up of linguistic variables and whose consequences are associated with fuzzy membershipfunctions[14]. In fuzzification block, the input convertsto linguistic variables by assigning proper membershipvalues which is required in order to activate the rules. The inference engine matches all the rules with the inputs, aggregatesthe weighted output of the rules, and generates a possibility distributionof the values in an output space. The defuzzification block, convertthe distribution into a single crisp value using some defuzzification methods.

The most important types of FIS are Mamdani fuzzy inference and Takagi –Sugeno (TS) fuzzy system[15]. Considering the linear dependence of each rule on the input variable of the system, the Sugeno method is ideal for multiple linear functions. Also, flexibility in system design and adequate for multiple input multiple output (MIMO) systems[16], are the main reasons adopting the Sugeno method for proposed system. The typical fuzzy rule in FIS has the following format:

IF x *is* A and y *is* B THEN $z=f(x,y)$ (3)

Where $A$and B are fuzzy sets and z is polynomial or a constant. Such fuzzy rule bases are described by membership functions in which the input fuzzy sets are form the left hand sides and the output fuzzy sets are form the right hand sides. Thus, the line status is detected by the measurements obtained from power flow meters continuously. All theinformation is being converted to binary values and utilize for defining the membership functions in the proposed fuzzy system. The main steps of our proposed fuzzy system are listed as:

- Binary values of CBs status are expressed in fuzzy set notations.
- Define fuzzy "IF-THEN" rules for lines CBs status.
- If the CBs of any line are identified as open, the line is determined in outage condition.

The FIS is simulated in MATLAB fuzzy toolbox. The components of the FIS are membership function, rule base and fuzzy designer which are described in the following.

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

4.2.1 Membership Function

The proposed fuzzy multi line outage detection system includes inputs which are the lines CBs status and outputs which are the status of the scenario. For both input and output it is needed to define membership functions. The line CBs status namely *LBK-ST* is the FIS input and consists of triangular membership functions. Also, the *LBK-ST* has *Tripped* (0) and *Not-Tripped* (1) membership functions. The range of *Tripped* and *Not-Tripped* membership functions are $(-1, 0, 1)$ and $(0, 1, 2)$ respectively. When the line CBs are open, membership function is considered as *Tripped* which related to outage of line. Also, for closed position of the line CBs, membership function is considered as *Not-Tripped* which is related to normal status of line and means the power is passing through the line. The output of the proposed FIS is *SCENARIO-INDEX* and indicates the index of the predefined line outage scenarios. Also, the *SCENARIO-INDEX* is a constant membership function[17].

4.2.2 Rule Base

The most important part of the proposed fuzzy system is the line outage scenario mechanism. For this purpose, the fuzzy rules are used for single line and multi-line outage scenarios. Therefore, based on the status of predefined membership functions, the rules are formulated. Table 1 shows the rules used in the proposed fuzzy-multi line outage detection system which already has applied to IEEE 5-bus system.

The special letters*T* and *NT*in Table 1 represents the *Tripped* and *Not-Tripped* status of the line CBs. As it can be seen from Table 1, each scenario is corresponded to one network topology including single line or multi line outage[18]. Using the signals obtained from the CBs by power flow meters, the status of the lines is detected and the index of related predefined scenario is identified by applying the proposed fuzzy line outage detection system.

Table 1: Fuzzy Rules bus system

Scenario Index	Lines CBs status							Scenario Status
	1-2	1-3	2-3	2-4	2-5	3-4	4-5	
1	T	NT	NT	NT	NT	NT	NT	Line 1-2 outage
2	NT	T	NT	NT	NT	NT	NT	Line 1-3 outage
3	NT	NT	T	NT	NT	NT	NT	Line 2-3 outage
4	NT	NT	NT	T	NT	NT	NT	Line 2-4 outage
5	NT	NT	NT	NT	T	NT	NT	Line 2-5 outage
6	NT	NT	NT	NT	NT	T	NT	Line 3-4 outage
7	NT	NT	NT	NT	NT	NT	T	Line 4-5 outage
8	T	NT	T	NT	NT	NT	NT	Line1-2 and 2-3 outage
9	T	T	NT	NT	NT	NT	NT	Line1-2 and 1-3 outage
10	T	NT	NT	T	NT	NT	NT	Line1-2 and 2-4 outage
11	T	NT	NT	NT	T	NT	NT	Line1-2 and 2-5 outage
12	T	NT	NT	NT	NT	T	NT	Line1-2 and 3-4 outage
13	T	NT	NT	NT	NT	NT	T	Line1-2 and 4-5 outage
14	NT	T	T	NT	NT	NT	NT	Line1-3 and 2-3 outage
15	NT	T	NT	T	NT	NT	NT	Line1-3 and 2-4 outage
16	NT	T	NT	NT	T	NT	NT	Line1-3 and 2-5 outage
17	NT	T	NT	NT	NT	T	NT	Line1-3 and 3-4 outage
18	NT	T	NT	NT	NT	NT	T	Line1-3 and 4-5 outage
19	NT	NT	T	T	NT	NT	NT	Line2-3 and 2-4 outage
20	NT	NT	T	NT	T	NT	NT	Line2-3 and 2-5

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

								outage
21	NT	NT	T	NT	NT	T	NT	Line2-3 and 3-4 outage
22	NT	NT	T	NT	NT	NT	T	Line2-3 and 4-5 outage
23	NT	NT	NT	T	T	NT	NT	Line2-4 and 2-5 outage
24	NT	NT	NT	T	NT	T	NT	Line2-4 and 3-4 outage
25	NT	NT	NT	T	NT	NT	T	Line2-4 and 4-5 outage
26	NT	NT	NT	NT	T	T	NT	Line2-5 and 3-4 outage
27	NT	NT	NT	NT	T	NT	T	Line2-5 and 4-5 outage
28	NT	NT	NT	NT	NT	T	T	Line3-4 and 4-5 outage

4.2.3 Fuzzy Logic Designer

A fuzzylogicdesigner is used to design and test the FIS for modeling the system behaviors. The fuzzy logic designer which used for multi-line outage detection is consist of the status of lines CBs as inputs and the index of predefined line outage scenario as output. This is done by de-fuzzification of the membership functions. The fuzzy logic designer for multi-line outage detection is shown in figure 6.

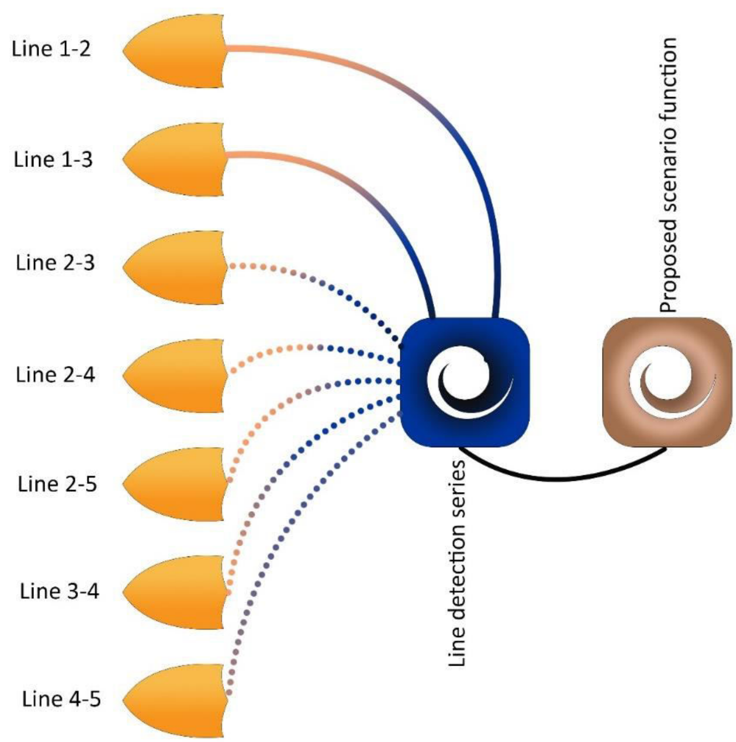


Figure 6. Fuzzy logic designer for line outage detection

5.SIMULATION RESULTS

The proposed FIS identifying themulti-line outage scenarios is tested on IEEE-5 bus system. It consists of 2 generators, 3 load buses and 7 lines. Based on the predefined rules given in Table 1, the output which is the index value of predefined scenario has been selected. Finally, the selection scenariosand the outcome of the various profile for our proposed Fuzzy based multi-line Power Outage Control Systemare shown in figures 7-10.

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

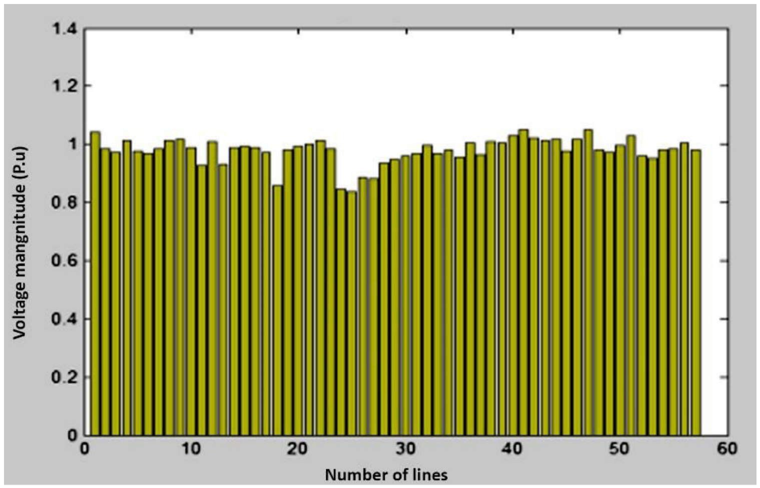


Figure 7. Voltage magnitudes

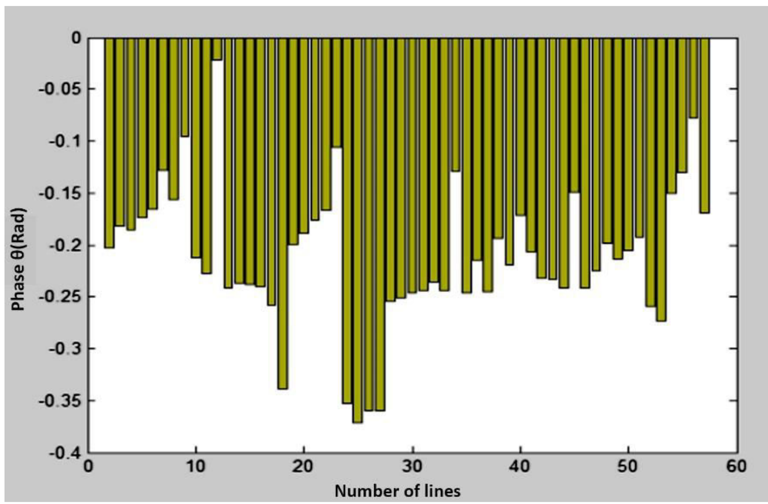


Figure 8. Voltage phase angle

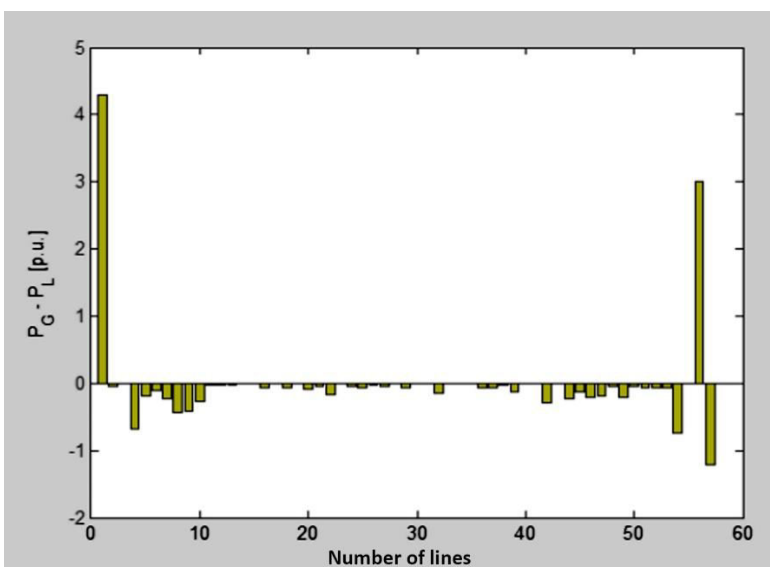


Figure 9. Active power

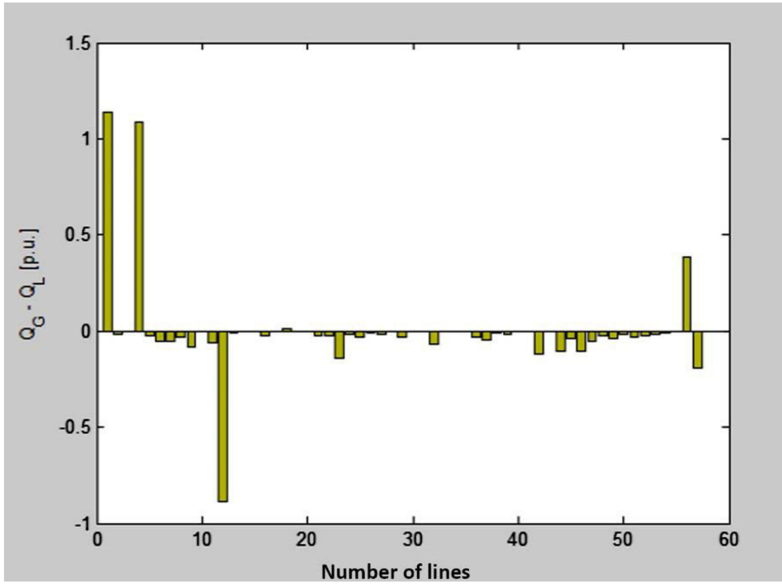


Figure 10. Reactive power

The outcome of all these figure presages that the overall network is balanced. The result statistics has determined the voltage and the currents at all the buses. However,it also showed that phases have equal in magnitude and shifted by 120^o with respect to the each other. Nonetheless, the results have been verified in the current scenarios. The powers at the buses presages total power pass through the connected transmission lines, thus the capability of the bus can be assessed. All the results are tabulated without loads and with loads are shown in TABLE 1. it is very useful to examine the parameters change at all the lines from no-load case to Full load case. The results acquired after this experiment are useful to presage the performance of model with the actual power system.

6.CONCLUSION

The fuzzy based multi-line Power Outage Control System was one of the best outcome performance measuring mechanism for the power system. The line CBs status are considered as an index for line outage purpose.The line is determined in outage condition when the CBs are open. A fuzzy system is used to detect the predefined line outage scenario based on the lines CBs status. The advantage of the proposed system has proved that there is no need the information about the lines phase angles which remove the drawback of complexity. Also, the proposed fuzzy system can be extended for wide grids to detect more line outage contingencies by definition additional fuzzy rules and can be used as a simple comprehensive GUIfor simple and fast decision making. The identification of multi-line outage scenarios in the power system are useful for control and protection purposes. The proposed method is applied to IEEE 5-bus system and the results show its efficiency in detection of line outage scenarios.

References

[1] J. Sahebkar Farkhani, M. Zareein, A. Najafi, R. Melicio, and E. M. G. Rodrigues, "The Power System and Microgrid Protection—A Review," *Appl. Sci.*, vol. 10, no. 22, p. 8271, Nov. 2020, doi: 10.3390/app10228271.

[2] A. Shahzad, "Towards Shrewd Object Visualization Mechanism," *Trends Comput. Sci. Inf. Technol.*, pp. 097–102, Nov. 2020, doi: 10.17352/tcsit.000030.

[3] S. Ashraf *et al.*, "Bodacious-Instance Coverage Mechanism for Wireless Sensor Network," *Wirel. Commun. Mob. Comput.*, vol. 2020, pp. 1–11, Nov. 2020, doi: 10.1155/2020/8833767.

[4] S. Ashraf, T. Ahmed, and S. Saleem, "NRSM: node redeployment shrewd mechanism for wireless sensor network," *Iran J. Comput. Sci.*, Oct. 2020, doi: 10.1007/s42044-020-00075-x.

[5] S. Nie, L. Ding, and W. Li, "Multiple Line-Outage Detection in Power System With Load Stochastic Perturbations," *IEEE Trans. Circuits Syst. II Express Briefs*, vol. 67, no. 10, pp. 1994–1998, Oct. 2020, doi: 10.1109/TCSII.2019.2940095.

[6] M. Ghofrani, S. Talaei, P. Nguyen, A. Suherli, and A. Arabali, "A novel AC model for multiple-line outage detection," in *2017 IEEE Power and Energy Conference at Illinois (PECI)*, Feb. 2017, pp. 1–6, doi: 10.1109/PECI.2017.7935770.

[7] S. Ashraf, S. Saleem, T. Ahmed, Z. Aslam, and M. Shuaeeb, "Iris and Foot based Sustainable Biometric Identification Approach," in *2020 International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Split, Hvar, Croatia, Sep. 2020, pp. 1–6, doi: 10.23919/SoftCOM50211.2020.9238333.

[8] "Protection and Control of Modern Power Systems," *Protection and Control of Modern Power Systems*. https://pcmp.springeropen.com/ (accessed May 16, 2021).

[9] M. A. M. Shaheen, H. M. Hasanien, and A. Al-Durra, "Solving of Optimal Power Flow Problem Including Renewable Energy Resources Using HEAP Optimization Algorithm," *IEEE Access*, vol. 9, pp. 35846–35863, 2021, doi: 10.1109/ACCESS.2021.3059665.

[10] S. Ashraf, S. Saleem, and S. Afnan, "FTMCP: Fuzzy based Test Metrics for Cosmetology Paradigm," *Adv. Comput. Intell. Int. J. ACII*, vol. 4, no. 7, pp. 1–13, 2020, doi: 10.5121/acii.2020.7401.

[11] S. Ashraf, M. Gao, Z. Chen, H. Naeem, A. Ahmad, and T. Ahmed, "Underwater Pragmatic Routing Approach Through Packet Reverberation Mechanism," *IEEE Access*, vol. 8, pp. 163091–163114, 2020, doi: 10.1109/ACCESS.2020.3022565.

[12] S. Ashraf, Z. Aslam, S. Saleem, S. Afnan, and M. Aamer, "Multi-biometric Sustainable Approach for Human Appellative," *CRPASE Trans. Electr. Electron. Comput. Eng.*, vol. 06, no. 3, pp. 146–152, 2020.

[13] S. Ashraf, S. Saleem, T. Ahmed, Z. Aslam, and D. Muhammad, "Conversion of adverse data corpus to shrewd output using sampling metrics," *Vis. Comput. Ind. Biomed. Art*, vol. 3, no. 1, p. 19, Dec. 2020, doi: 10.1186/s42492-020-00055-9.

[14] S. Ashraf, S. Saleem, and T. Ahmed, "Sagacious Communication Link Selection Mechanism for Underwater Wireless Sensors Network," *Int. J. Wirel. Microw. Technol.*, vol. 10, no. 4, pp. 22–33, Aug. 2020, doi: 10.5815/ijwmt.2020.04.03.

[15] S. Ashraf, D. Muhammad, M. Shuaeeb, and Z. Aslam, "Development of Shrewd Cosmetology Model Through Fuzzy Logic," *J. Res. Eng. Appl. Sci.*, vol. 5, no. 3, pp. 93–99, Jul. 2020, doi: 10.46565/jreas.2020.v05i03.003.

[16] S. Ashraf, D. Muhammad, and Z. Aslam, "Analyzing challenging aspects of IPv6 over IPv4," *J. Ilm. Tek. Elektro Komput. Dan Inform.*, vol. 6, no. 1, p. 54, Jul. 2020, doi: 10.26555/jiteki.v16i1.17105.

[17] S. Ashraf, D. Muhammad, M. A. Khan, and T. Ahmed, "Fuzzy based efficient Cosmetology Paradigm," vol. 8, pp. 513–520, doi: 10.14741/ijmcr/v.8.4.3.

[18] A. Shahzad and A. Tauqeer, "Dual-nature biometric recognition epitome," *Trends Comput. Sci. Inf. Technol.*, vol. 5, no. 1, pp. 008–014, Jun. 2020, doi: 10.17352/tcsit.000012.