Network Reconfiguration using Fuzzy Logic for Power Flow Balancing in IEEE 30 Bus System

Fidah Hussian[1], Sam Joseph Paul[2], Govind Rai Goyal[3], Aadesh Kumar Arya[4]

[1]*College of Engineering Roorkee, Roorkee, India fidasheikh1511998@gmail.com*
[2]*College of Engineering Roorkee, Roorkee, India alexandersam288@gmail.com*
[3]*College of Engineering Roorkee, Roorkee, India er.grgoyal@gmail.com*
[4]*Roorkee College of Engineering Roorkee, India adeshkumararya1982@gmail.com*

Abstract -As the existing power systems is gradually moving from a traditional power transmission system to the more highly developed smart grid our objective in this research work is to make the power flow control more intelligent. In this paper an old problem of phase balancing for power flow control is considered and solved by network reconfiguration technique using the fuzzy logic. Network reconfiguration is required as a solution to the problems associated with power distribution system such as planning, power loss and power flow unbalancing. The proposed technique is implemented in IEEE 30 bus system to balance the power flow in under loaded or overloaded lines. The total load per phase of the lines is considered as input to the fuzzy system and load required to inter changing unbalanced lines is the output. The fuzzy logic system's suggested load values, both negative and positive, are to be considered as input to the load changing system. Load flow analysis, which can be used to compute the electric potential build and the difference in vector positions of the active values at each bus, as well as the consumption of energy expressed as curves in individual transmission circuit, is at the core of modern power systems. The objectives of this research can be used to define the system's most important lines, leading to better production scheduling and the reduction of the risk of voltage instability.

Keywords-Feeder load balancing; Fuzzy logic control; Network reconfiguration

1. INTRODUCTION

Energy efficiency has always been an issue in the electricity supply system. With the rising electricity demand, the challenge is to condense the system failure and to get better the system efficiency. However, it is also desired for the system to be able to deliver help when one or more of the system's lines fail .Numerous of the faults to facilitate arise at by chance in a transmission line can be dangerous. To resolve this concern, tolerable automation of the power distribution system is required. Distribution automation preserve be characterized as the concept of an integrated system, which involves monitoring, controlling and, sometimes, the choice to transform any type of load. The automatic distribution system provide instructions for automatic switch reclosing and remote monitor of the loads that relate to the phase balancing process. In order to diminish distribution feeder losses and get better system safety, phase balancing becomes very important .In a distribution system there are various switches that required being open or close. By adjusting the unpredictable position either open or closed connected to the switches thus connected to the feeder, with load currents there is a possibility for transmissibility of feeder connection. It can be transferred to less loaded feeders instead of connecting them to the heavily loaded. To minimize the unbalanced flowing feeder current, the connecting phases of some feeders are altered manually after thorough analysis of the situation in a simulated environment using a software. This study proposes the use of fuzzy logic based load changing system as problem solving technique to balance the feeder load. Fuzzy logic has risen in importance in this field because it is a realistic, effective, and adaptable technique. The concept of fuzzy sets provides a suitable method for converting design, operator's knowledge into dynamic control systems that is simple to fix instantaneous applications. The fundamental contribution of this study is to identify the majority fault finding transmission line in IEEE 30 bus system, its breakdown potentially cause the system to fail completely. In this paper make comments how to get better grid's procedure by making ideas operating how to improve the process of such lines. After considering the load flow analysis results, those dangerous transmission lines will be identified. Although in some cases change the current phase imbalance, this method is more timely and fallacious. In this study Newton Raphson method is used in calculation of power flow in IEEE 30 bus system.

For feeder reconfiguration, Baean and Kelly utilized the state estimate methodology[1].Various research have been conducted on loss minimization of feeder distribution [3-4].With the advancements in the fields of artificially simulated intelligent systems and high voltage electronic equipments in power systems, it has become much easier than before to analyze the phase and load balance problem. Customers will benefit from advanced automation that is also cost-effective [4]. The estimated load current that the feeder can handle could be used as a reference. The IEEE 30 bus system has been the focus many studies on a variety of topics. We present a number of similar research in this part, all of which are appropriate to our work[5].The author [5] get a load flow analysis with the goal of determining the converge bus voltages used Newton-Raphson method, as well as comparing the two statistical methods in conditions of difficulty and meeting charge. M.Sugeno, Industrial applications of fuzzy control[8]. Performance curve of Newton-Raphson method in Load Flow Analysis using MATLAB, Nivedita Nayak and Dr. A.K. Wadhwani. Review of load-flow computation methods [10], by B. Stott.Ulas Eminoglu and M. Hakan Hocaoglu for radial distribution systems, a new power flow method with voltage dependent load models has been developed [15].

2. FEEDER DESCRIPTION

Distribution feeders usually are 3 phase 4-wire star connected system with an interconnected system. It is required to understand the conductors' current capabilities while avoiding any tapping. The connection between the distribution transformer and the distribution feeder has been rearranged properly to enable for a balanced state. There are four distribution feeder systems viz. radial, parallel feeders, ring main, and mash connected system. The mash connected system method is the simplest and most economical to work with, from the point of view of construction and security. For the difficulty in this paper, we take for granted IEEE-30 bus test system. IEEE-30 bus test systems are widely used by researchers to execute new thoughts and concept .The IEEE-30 bus test system is described in detailed technical note point. It has 30 buses, 41 transmission lines plus different transformers and synchronous condensers make the IEEE-30 bus test system. The system is demonstrated in Figure 2.1 below.

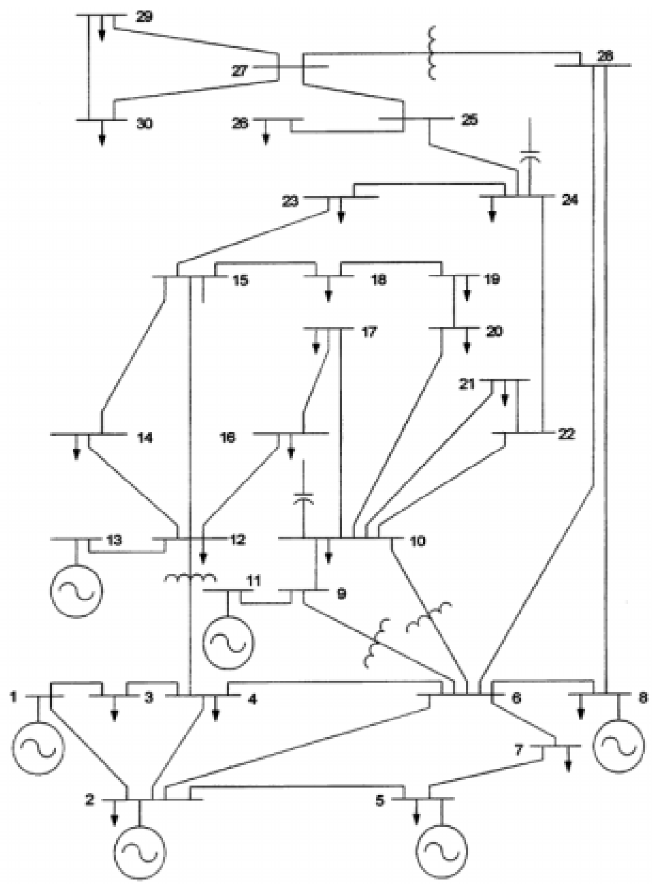


Figure 2.1 SLD of IEEE-30.

3. METHODOLOGY

The process of estimating the magnitude and phase angle of voltage at each bus in a power system under balanced 3-phase steady state conditions is known as the load flow problem. This method can be used to calculate actual and reactive power loses in the transmission system and transformers, along with equipment losses. For this research, we examined load flow analysis of the IEEE-30 bus test system utilizing the Newton Rephson Method. A load flow analysis was obtained for the proposed example, in which all of the systems transmission lines are operating. The measured load flow further disconnecting one transmission line instantaneously for a total of 41 times. The major goal of experimenting this was to calculate and identify the least performing flow values in the system in the event of a single transmission line failure. In other words, a study of the IEEE-30 bus test system susceptibility to a single transmission line failure. We may also simulate the effect of voltage collapse failure in an IEEE-30 bus test system by removing the lines that overload when a single line fails and repeating the cycle. After this, process utilizes fuzzy logic for load balancing. Load balancing (also known as phase balancing) is a useful tool for reducing distribution feeder losses, boosting system safety. Load currents can be changed from highly loaded to less loaded feeders by changing the open/close configuration of the feeder switches. In this paper will see the use of fuzzy logic for the purpose of load balancing in this application study the link joining particular distribution transformer and the feeder must be properly organize to enhance the system phase voltage and current imbalances. As a result, phase balancing can include reconsidering the network layout in order to reduce total real power losses caused by line branches. Load flow equation is taken from [3]. The process of proposed intelligent system is shown in Fig. 3.1

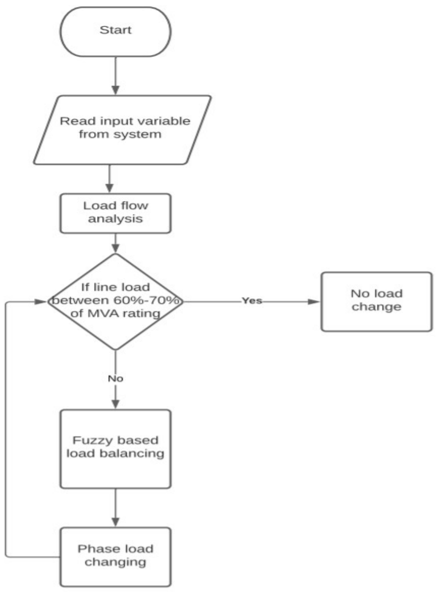


Fig. 3.1 Flowchart for load balancing

Load flow equation by Newton Repson method

$$\Delta P_i^{(r)} = P_{isp} - P_{i(\mathrm{cal})}^{(r)} \qquad i = 2,3\ldots\ldots n \qquad (3.1)$$

$$\begin{bmatrix} H & N' \\ M & L' \end{bmatrix} \qquad (3.2)$$

Obtain the value of $\Delta\delta$ and $\Delta|Vi|$ from equation shown below

$$\begin{bmatrix} \Delta & P \\ \Delta & Q \end{bmatrix} = \begin{bmatrix} H & N' \\ M & L' \end{bmatrix} \begin{bmatrix} \Delta \quad \delta \\ \dfrac{\Delta \quad V}{V} \end{bmatrix} \qquad (3.3)$$

Using the value of Δδ and Δ$|Vi|$ calculate in the above step, modify the voltage magnitude and phase angle at all load buses by the equation shown below

$$\left|v_i^{(r+1)}\right| = \left|r_i^{(r)}\right| + \Delta\left|v_i^{(r)}\right| \tag{3.4}$$

$$\delta_i^{(r+1)} = \delta_i^{(r)} + \Delta_i^{(r)} \tag{3.5}$$

$$\left|v_i^{(r+1)}\right| = \left|r_i^{(r)}\right| + \Delta\left|v_i^{(r)}\right| \tag{3.6}$$

3.1 Input and Output OF Fuzzy Controller

In this paper must first construct the input and output variables before designing the fuzzy logic controller .The output is Change, which indicates the positive or negative load change (kW) for each phase. Load is the input, which is the total phase load (kW) for each of the three phases .Table 3.1.1 displays the fuzzy categorization for the input variable, and Fig. 3.1.1 illustrates the fuzzy membership function for the input variable .Table 3.1.2 displays the fuzzy output classification, and Fig. 3.1.2 illustrates the corresponding triangular "fuzzy membership" functions for the output variable. Fuzzy nomenclature for the input and the output variables shown in table 3.1.3 The non-aligned connection between the chosen output and input variables is visualized in Fig3.1.3.

Table3.1.1. Fuzzy nomenclature for the input variable

SL. No.	Input (*Load*) Description	Fuzzy Nomenclature	Percentage range of line MVA rating
1	Very Less Loaded	VLL	45% - 50%
2	Less Loaded	LL	50% - 55%
3	Medium Less Loaded	MLL	55% - 60%
4	Perfectly Loaded	PL	60% - 70%
5	Slightly Overloaded	SOL	70% - 75%
6	Medium Overloaded	MOL	75% - 80%
7	Overloaded	OL	80% - 85%
8	Heavily Overloaded	HOL	85% - 90%

Table 3.1.2.Fuzzy nomenclature for the output variable

SL. No.	Input (*Load*) Description	Fuzzy Nomenclature	Percentage range of line MVA rating
1	Very Less Loaded	VLL	45% - 50%
2	Less Loaded	LL	50% - 55%
3	Medium Less Loaded	MLL	55% - 60%
4	Perfectly Loaded	PL	60% - 70%
5	Slightly Overloaded	SOL	70% - 75%
6	Medium Overloaded	MOL	75% - 80%
7	Overloaded	OL	80% - 85%
8	Heavily Overloaded	HOL	85% - 90%

Fig3.1.1 Fuzzy membership function for the input variable

Table.3.1.3 Fuzzy nomenclature for the input and the output variables

SL. No.	Output (*Change*) Description	Fuzzy Nomenclature	KW Range
1	High Subtraction	HS	-25% to -20%
2	Subtraction	S	-20% to -15%
3	Medium Subtraction	MS	-15% to -10%
4	Slight Subtraction	SS	-10% to -5
5	Perfect Addition	PA	0 to 10%
6	Medium Addition	MA	+5% to +10%
7	Large Addition	LA	+10% to 15%
8	Very Large Addition	VLA	+15% to +20%

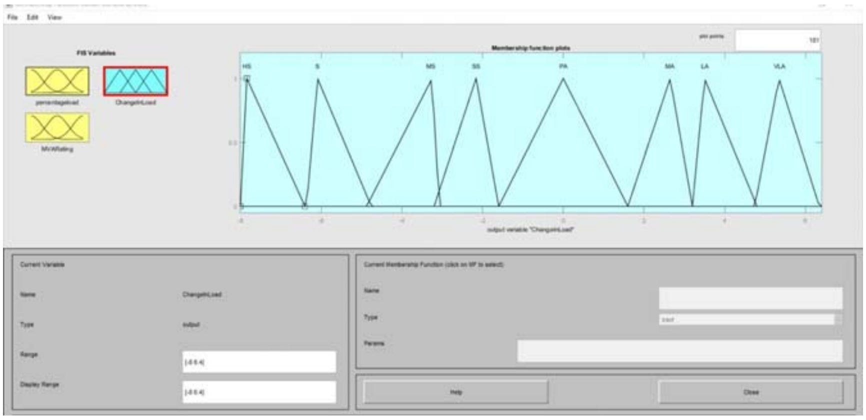


Fig3.1.2 Fuzzy membership function for output variable

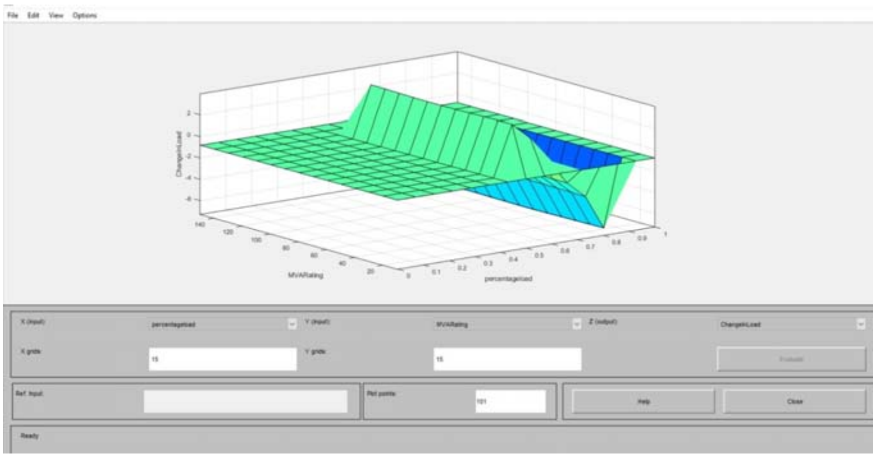
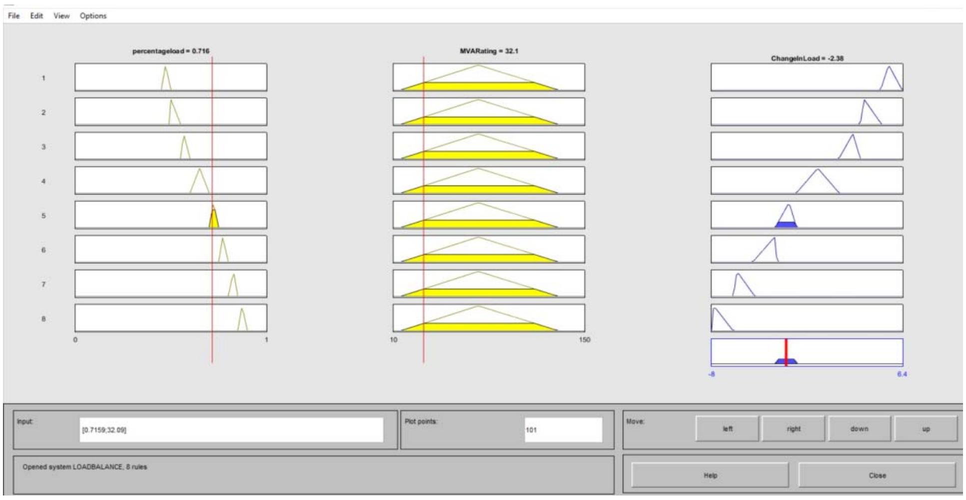


Fig3.1.2 .Non aligned relationship between the input and the output variables

4. Application Result

In this section shows the application result outcomes using the fuzzy logic load balancing technique. For the simulation, Matlab fuzzy toolbox [6] is implemented .The Mamdani [7] fuzzy assumption technique is used. Then use of 32-MVA line as an example input load configuration for one phase .Using the fuzzy controller mentioned earlier, we attempt to balance it. The eight fuzzy rules were used to create a graphical representation of (output load change) for the 3 phases that correspond this input load are shown in Fig. 4.1.The Mamdani approach [7] is used in the defuzzification process. A change in phase line 42 whose MVA rating is 32 of the output load is determined.



Output load changes Fig. 4.1

According to the output of lines is mostly very low loaded, but some lines are highly overloaded and slightly overloaded, according to the fuzzy logic rule. In this research, using of fuzzy logic and a combinatorial optimization-based implementation technique, investigate the phase balancing problem in the field of power system. As a result, the approaches and application provided in this study are based on the following assumptions. In this paper line 41 whose MVA rating is 32 is perfectly loaded is resulted by fuzzy shown in table 4.2

Line No.	MVA Rating	before fuzzy system			after fuzzy system		
		P flow (MW)	Q flow (MVAr)	S flow (MVA)	P flow (MW)	Q flow (MVAr)	S flow (MVA)
1	130	147.00464	-14.779	147.746	18.94193	120.2866	121.7688
2	130	64.15866	4.253	64.299	25.22224	62.10914	67.03512
3	65	31.89110	2.606	31.997	19.65685	31.76457	37.35478
4	130	60.08551	0.462	60.089	18.24865	59.89339	62.61176
5	130	72.45313	2.642	72.501	36.40318	33.45417	49.4406
6	65	46.24380	0.332	46.425	25.13013	40.30862	47.50061
7	90	62.34209	-10.144	63.162	25.41322	44.0644	50.8675
8	70	-18.03501	9.962	20.604	-3.7674	9.738385	10.44172

9	130	41.48121	-0.998	41.493	20.72668	6.076963	21.59919
10	32	28.01775	6.548	28.173	7.499785	17.12618	18.69633
11	65	15.64737	-7.277	17.257	12.73784	27.2345	30.0661
12	32	8.94964	0.407	8.959	11.67912	12.42233	17.0504
13	65	0.00000	-14.168	4.631	-19.9995	9.999891	22.36019
14	65	15.64737	7.138	16.874	32.74595	14.0673	35.63967
15	65	21.03856	13.629	16.197	23.08951	32.98348	40.26209
16	65	-10.00000	-6.203	11.768	-19.9994	14.99983	24.99943
17	32	5.54120	2.040	5.905	5.416038	4.432526	6.998626
18	32	14.97793	6.164	16.197	11.71724	10.51301	15.74221
19	16	9.31938	2.784	9.726	4.934937	3.827369	6.245187
20	16	2.30320	0.361	2.331	0.494732	0.769686	0.914973
21	16	5.74203	0.187	5.789	3.114955	0.500675	3.154936
22	16	6.75696	1.381	6.896	4.258271	2.767308	5.078471
23	16	3.51021	0.386	3.531	2.036365	0.77651	2.179392
24	16	-1.99721	-3.029	3.628	-4.2015	-5.79478	7.157662
25	32	4.22897	3.799	5.685	6.106298	7.128666	9.386413
26	32	0.29252	5.061	5.070	2.956522	7.281496	7.85883
27	32	9.68892	9.706	13.714	9.224285	13.71755	16.53054
28	32	4.58661	4.470	6.405	4.411683	6.418773	7.788683
29	32	-1.87073	-1.622	6.766	-0.80448	-2.12996	2.276821
30	16	6.15969	2.331	6.586	3.04751	2.925743	4.224605
31	16	2.8805	2.790	3.874	2.861699	4.268992	5.139418
32	16	2.92005	0.651	2.992	1.120424	0.359848	1.176792
33	16	0.88106	0.994	1.328	0.568758	-4.26356	4.301328

34	16	3.54393	2.366	4.261	1.353565	3.206076	3.480095
35	16	-2.6660	-1.377	3.001	-1.39373	-8.00394	8.12438
36	65	10.77672	4.891	11.835	19.0542	10.96653	21.98471
37	16	4.06548	1.519	4.340	4.14314	3.750763	5.588724
38	16	4.03588	1.472	4.296	4.842887	3.920929	6.231151
39	26	1.62654	0.564	1.716	2.64185	1.949938	3.283539
40	32	-2.07919	-4.138	4.631	1.958523	1.358664	2.383648
41	32	28.01775	6.548	28.173	11.9861	16.57891	20.45793

Fuzzy result Table 4.2

5 .Conclusion

Phase balancing is a critical and realistic procedure for reducing distribution feeder losses and improving safety. In this research, we propose a load balancing system based on fuzzy logic, as well as load change implementation system based on optimization algorithms. Total (kw) load per phase of the feeders is supplied into the fuzzy stage. The load transform values are the fuzzy step's output, with a negative value designed for load leaving a ‘positive value’ for load, receiving. The entire load remains constant throughout phase balancing because the sum of the negative and positive numbers is zero. The input of the load-changing system will be read by the fuzzy line .The implementation system divides the alter (kw) values by the number of load points, then chooses the appropriate load locations using combinatorial optimization approaches. It also ensures that load points are properly interchanged between the releasing and receiving phase’s unbalanced 3-phase, 4-wire feeders are being used to test the load balancing system. A specific design example that uses Matlab for simulations illustrates the proposed system's application. Additional implementation results for different feeder loading configurations show that imbalance conditions have improved. The planned fuzzy logic phase balancing method and implementation systems are both practical and effective in minimizing feeder disturbance. The phase balancing technique and system described in this paper might be applied to different distribution system and feeders load configuration.

5 .References

[1] M.E. Baran, W. Kelly, State estimation for real time monitoring of distribution systems, IEEE Transactions on Power Systems 9 (3) (1994) 1601-1609.

[2] A. Ukil, M. Siti, J. Jordaan, Matlab® based fast balancing of distribution system using heuristic method, SAIEE Transactions (under review).

[3] C. C. Liu, S. J. Lee, K. Vu, Loss minimization of distribution feeders: Optimality and algorithms, IEEE Transactions

[4] T. P. Wagner, A. Y. Chikani, R. Hackman, Feeder reconfiguration for loss reduction: An application of distribution automation, IEEE Transactions on Power Delivery 6 (1991) 1922– 1933 on Power Delivery 4 (1989)1281–1289

[5] Dharamiit and D.K.Tanti. "Load Flow Analysis of ieee 30 bus System" . International .Journal of Scientific and Research Publications, Vol 2, No 11, ISSN 2250-3153, 2012.

[6] MATLAB ® Documentation – Fuzzy Logic Toolbox, Version 6.5.0.180913a Release 13, TheMathworks Inc., Natick, MA.

[7]E. H. Mamdani, Applications of fuzzy logic to approximate reasoning using linguistic synthesis, IEEE Transactions on Computers, 26 (12) (1977) 1182-1191.

[8] M. Sugeno, Industrial applications of fuzzy control, Elsevier Science Pub. Co., 1985.

[9]B. Kosko, Fuzzy Engineering, Prentice Hall, 1999

[10] B. Stott, “Review of load-flow calculation methods,” in Proc. of IEEE, Vol. 62, p p. 916-929, 2005.

[11] H. Saadat, “Power System Analysis,” McGraw-Hill, New York, 1999.

[12] C. L. Wadhwa, “Electrical Power Systems”, New Age, New Delhi, 6th edition, 1983.

[13] W. F. Tinney and C. E Hart, “Power flow solution by Newton’s method,” IEEE Transactions on Power Systems PAS- 86, pp.1449-1456, 1967.

[14] Nivedita Nayak, Dr. A.K. Wadhwani, “Performance of Newton-Raphson Techniques in Load Flow Analysis using MATLAB,” National Conference on Synergetic Trends in engineering and Technology, pp. 177-180, 2014.

[15] Ulas Eminoglu and M. Hakan Hocaoglu,“A new power flow method for radial distribution systems including voltage dependent load models,” Electric Power Systems Research, pp. 106-114, 2005.

[16] F. Hussian, G. R. Goyal, A. K. Arya and B. P. Soni, "Contingency Ranking for Voltage Stability in Power System," 2021 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), 2021, pp. 1-4, doi: 10.1109/CONECCT52877.2021.9622724.