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Design of fuzzy logic controller for voltage stability condition in ieee-14 bus system.

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Abstract:
This paper work aims the predication of steady state voltage stability conditions in transmission network .the voltage stability is checked by formulating an (L) index and the corresponding uncertainties input parameters are efficiently modeled in terms of fuzzy sets by using triangular membership function. The proposed technique will be highly useful to ensure voltage security of power system by predicting the nearness of voltage collapse with respect to the existing load condition. This will in turn help us in determining the maximum load ability of the given system without causing voltage instability. The validity of the technique is tested on as ample 5-bus system and IEEE 14-bus system using software simulation. The results are provided for the feasibility of the technique includes fuzzy load flow solution for base and critical cases. This method can be applied both for off-line as well as on-line applications.

Key Terms:- Fuzzy logic, Power system enhancement, Stability index, Voltage Stability.

I. INTRODUCTION

One of the important operating requirements of a reliable power system is to maintain the voltage within the permissible ranges to ensure a high quality of customer service. In modern bulk power system, voltage instability would lead to blackout which is of major concern in planning and operation of power system. Voltage instability[1] is characterized by variation in voltage magnitude which gradually decreases to a sharp value accompanies with simultaneous decrease in power transfer to load end from the source. Prior to voltage instability , bus angle an frequency remain constant but after the occurrence of voltage instability the reactive power absorbed by the Transmission line increases to such an extent that becomes difficult to maintain the voltage magnitude Within the limit .

Hence it may be rightly said that voltage instability occur due to the inability of the system to supply reactive power to the load. It may also occur due to the network disturbance such as loss of an important transmission line, transformer or generator may also occur due to the line fault or bus fault, heavy HVDC power flow without adequate shunt capacitance and inverters [2]. In practice to over come the above problems, usually controlling devices such as tap changing transformers are employed. However they fail to get activated quickly enough to prevent voltage collapse. Most of the indices developed are system-based or based on bus orientation. There has not been much research in voltage stability assessment via line based voltage stability index. The existing technique is based on a line based voltage stability index which detects the critical lines for a specific load scenario for monitoring the system prior to experiencing line outage. The limitation of the above method is that it does not reach unity under various power factor operations of a transmission lines. Particularly, their index show very less value (much less than 1) for high power factor operation of a transmission line. A bacterium foraging technique has been implemented for minimizing loss, taking voltage stability into account [3]. An analysis of MW and MVAR management for the improvement of economical dispatch by using participation factors has been derived from the critical eigenvectors of the Jacobean matrix [4]. A new model for optimal reactive power flow has been designed by the predictor corrector primal dual interior point method [5]. A recent work on the stability index has been carried out by the use of tellegen"s theorem [7]. Other works on the stability index have included preventive control of voltage stability using a new voltage stability index [8]. Many novel methods have been employed for this voltage stability control such as the effect of load tap changers in emergency and preventive voltage stability control [9]. Nonlinear optimization techniques have been used for voltage stability analysis by fast computation of voltage stability security margins [10]. Other applications of the nonlinear programming have included congestion management problem ensuring voltage stability [11]. The voltage collapse prediction [12] methodology has been presented based on line voltage stability index [13]. It is predicted by estimating the load flow solution and then calculating the line voltage stability index. Hence, the lines which are in stressed conditions can be easily identified. This information can be used as a basic tool for security monitoring [14] of the system. Most of the indices developed are system-based or based on bus orientation. There has not been much research in case of static voltage stability [15] [16] assessment via line based voltage stability index. In the existing model, a voltage stability criterion is formulated based on power transmission concept in a single line. An interconnected system is reduced to a single line network and then applied to assess the overall system stability. Utilizing Fuzzy Logic based Stability Index Power System Voltage Stability Enhancement the same concept but using it for each line of the network, a stability criterion is developed which is used to assess the system security.

In this paper, voltage stability assessment via line-based stability index is analyzed using fuzzy based controller and an effective procedure for voltage stability assessment (nearness of the operating point to voltage collapse point)using the exact line voltage stability index is developed. The developed index incorporates correctly the effect of real and reactive power increase scenario in any direction as against the existing line voltage stability index. Here the uncertainties in the input parameters would be dealt with the fuzzy sets. Fuzzy based voltage stability index is calculated in each step after performing Newton-Rap son load flow study. The fuzzy voltage stability index clearly indicates the location and status of critical bus bar. Therefore, a new method of achieving a reasonable voltage profile for economic and stable operation of a power system is the need of the hour. The software based results are provided for the proposed algorithm to validate its feasibility of operation.

II. MATHEMATICAL MODELLING OF LINE VOLTAGE STABILITY INDEX

The proposed line voltage stability index, is capable yielding accurate, consistent and reliable results as demonstrated in the case studies carried out under this paper.

$$L_i = \frac{2\frac{B}{A}\sqrt{(P_m{}^2 + Q_m{}^2}}{\frac{V_K{}^2}{A^2} - 2\frac{B}{A}P_m\cos(\beta-\alpha) - 2\frac{B}{A}Q_m\sin(\beta-\alpha)} \leq 1 \qquad (1)$$

Where,
Pm – Receiving end real power in p.u
Qm – Receiving end reactive power in p.u
Vk – Sending magnitude voltage in p.u

As long as above index is less than unity, the system is stable. Li is termed as voltage stability index of the line. At collapse point, the value of Li will be unity. Based on voltage stability indices, voltage collapse can be accurately be predicted. The lines having high value of the index can be predicted as the critical lines, which contribute to voltage collapse. At or near the collapse point, voltage stability index of one or more line approach to unity. This method is used to assess the voltage stability.

III. FUZZY BASED LOAD FLOW ANALYSIS

In Newton-Rap son load flow method the repetitive solution is obtained by the equations (1). By using these equations 'δ' and 'V' is updated in each iterations. In fuzzy load flow problem „Fuzzy Logic" is used to update 'δ' and 'V'.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \qquad (2)$$

A. MAIN IDEA OF FUZZY LOAD FLOW(FLF)ALGORITHM

The Equation (2) given by Newton-Rap son can be expressed as for the proposed Fuzzy index by the equation (3)

$$\Delta F = [J].\Delta X$$

The above equation denotes that the correction of state vector ΔX at each node of the system is directly proportional to vector ΔF. The proposed fuzzy load flow algorithm is based on the previous Newton – Rap son load flow equation but the repeated update of the state vector of the system will be performed via expressed by,

$$\Delta X = \text{fuzzy}(\Delta F)$$

B.FUZZY LOGIC LOAD FLOW ALGORITHM

In Figure 1 the power parameters such as real power (ΔFp) and reactive power (ΔFq) are calculated and

Introduced to the p- and q-v fuzzy logic controller (FLC) respectively. The FLCs algorithm executes the state vector ΔX namely, the correction of voltage magnitude Δδ for the p-δ cycle and the voltage magnitude for the q-v cycle.

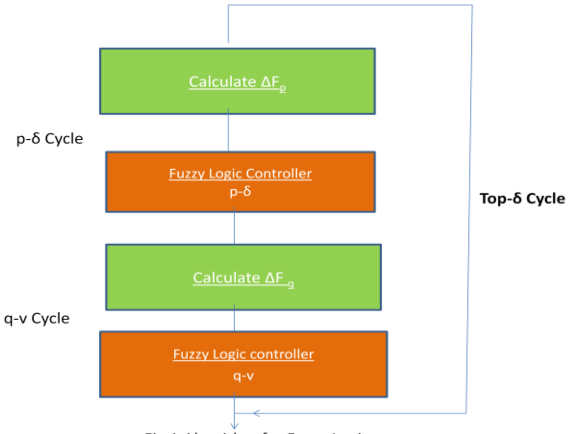


Fig 1.Algorithm for Fuzzy Logic

C. STRUCTURE OF FUZZY LOGIC LOAD FLOW CONTROLLER (FLFC)

The main structure of the proposed FLFC is shown in the Figure 2. It comprises of four principle components

- Fuzzifications interface
- Rule Base
- Process logic
- De-fuzzification

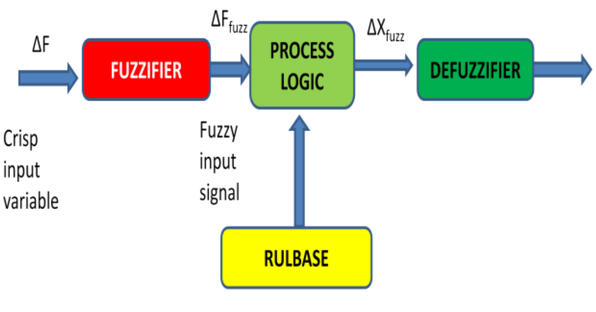


Fig 2. Structure of Fuzzy Load Flow Controller

The FLFC involves the following functions during iteration.

- Calculate and per-unite the power parameters ΔFp and ΔFq at each node of the system.
- The above parameters are elected as crisp input signals. The maximum(or worst) power parameter(ΔFpmax(or) ΔFqmax) determines the range of scale mapping that transfer the input signals into corresponding universe of discourse at every iteration.

The input signals are fuzzified into corresponding fuzzy signals (ΔFpfuz or ΔFqfuz) with seven linguistic variables

- Large negative (LN)
- Medium negative(MN)
- Small negative(SN)
- Zero(ZR)
- Small positive(SP)
- Medium positive(MP)
- Large positive(LP)

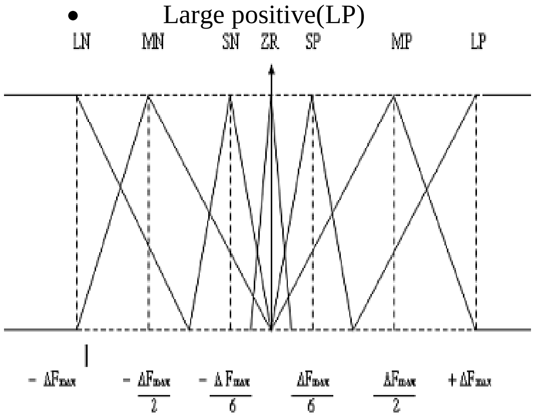


Figure 3. Triangular Membership Function

D. Fuzzification

They are represented in triangular membership function sketches of these membership functions are shown in the figure 3. Each three points designed as

$$LN : \left[-\infty, -\Delta F_{max}, -\Delta F_{max}/3 \right]$$

$$MN : \left[-\Delta F_{max}, -\Delta F_{max}/2, 0 \right]$$

$$SN : \left[-\Delta F_{max}/3, -\Delta F_{max}/6, 0 \right]$$

$$ZR : \left[-\Delta F_{max}/12, 0, -\Delta F_{max}/12 \right]$$

$$SP : \left[0, -\Delta F_{max}/6, 0, \Delta F_{max}/3 \right]$$

$$MP : \left[0, \Delta F_{max}/2, \Delta F_{max} \right]$$

$$LP : \left[\Delta F_{max}/3, \Delta F_{max}, \infty \right]$$

Similarly the output signals represented in triangular membership function, sketches of these membership functions are shown in the figure 3. Therefore, each three points of the triangular membership function of ΔXfuz are designed as,

$$\mathrm{LN}:\left[-\infty,-\Delta F_{max},-\Delta F_{max}/3\right]$$

$$\mathrm{MN}:\left[-\Delta F_{max},-\Delta F_{max}/2,0\right]$$

$$\mathrm{SN}:\left[-\Delta F_{max}/3,-\Delta F_{max}/6,0\right]$$

$$\mathrm{ZR}:\left[-\Delta F_{max}/12,0,-\Delta F_{max}/12\right]$$

$$\mathrm{SP}:\left[0,-\Delta F_{max}/6,0,\Delta F_{max}/3\right]$$

$$\mathrm{MP}:\left[0,\Delta F_{max}/2,\Delta F_{max}\right]$$

$$\mathrm{LP}:\left[\Delta F_{max}/3,\Delta F_{max},\infty\right]$$

The rule base involves seven rules with seven linguistic variables.

Rule 1 : if ΔF fuz is LN then ΔXfuz is LN
Rule 2 : if ΔFfuz is MN then ΔXfuz is MN
Rule 3 : if ΔFfuz is SN then ΔXfuz is SN
Rule 4 : if ΔFfuz is ZR then ΔXfuz is ZR
Rule 5 : if ΔFfuz is SP then ΔXfuz is SP
Rule 6 : if ΔFfuz is MP then ΔXfuz is MP
Rule 7 : if ΔFfuz is LP then ΔXfuz is LP

These fuzzy rules are consistent with the observation that corrective action to state vector ΔX is directly proportional to power vector ΔF at every iteration.

E. Process Logic

The fuzzy signals ΔFfuz are sent to the process logic which generates the fuzzy output signals ΔXfuz based on the Previous rule base which are represented by seven linguistic variables similar to input fuzzy signals. The output fuzzy signal ΔX_{fuz} are then sent to the de-fuzzification interface.

F. Defuzzification

The maximum corrective action ΔX_{max} of state variables determines the range of scale mapping that transfers the output signal into the corresponding universe of discourse at every iteration . The maximum correction of these values can be calculated by,

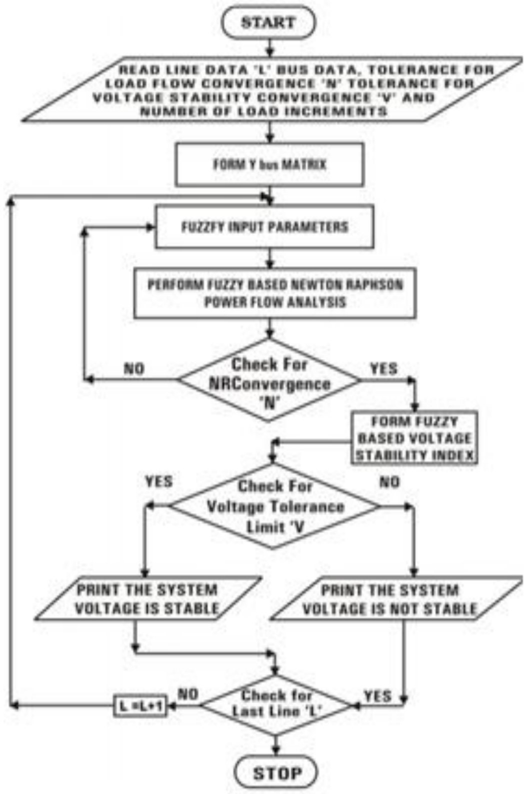
$$\frac{\Delta F_{max1}}{\Delta X_{max}}=\frac{dF_1}{dX_1} \quad (3)$$

$$\Delta X_{max}=\left[\frac{dF_1}{dX_1}\right]^{-1}\Delta F_{max1} \quad (4)$$

Where,
F1 - Real or Reactive power balance equation at node with maximum real or reactive power mismatch of the system. X1 - voltage angle or magnitude at node 1. Finally the defuzzifier will transform fuzzy output signals ΔXfuz into crisp values ΔX for every node of the network. The centroid-of-area (COA) defuzzification strategy is adapted and the state vector is updated using equation (4),

$$X^{i+1}=X^{i}+\Delta X \quad (5)$$

where, i' indicates the number of iterations. The proposed algorithm is illustrated in the form of flow chart shown in the Figure 4.



IV. SIMULATION PARAMETERS

The proposed fuzzy index algorithm for voltage stability is developed in the Matlab/Simulink software environment to analysis with IEEE-14 bus. The algorithm is verified for various load power factor and load conditions by line compensation for the accuracy of the proposed fuzzy index technique. The simulation results also provided for Newton-Rap son method for comparison with the proposed algorithm for its feasibility.

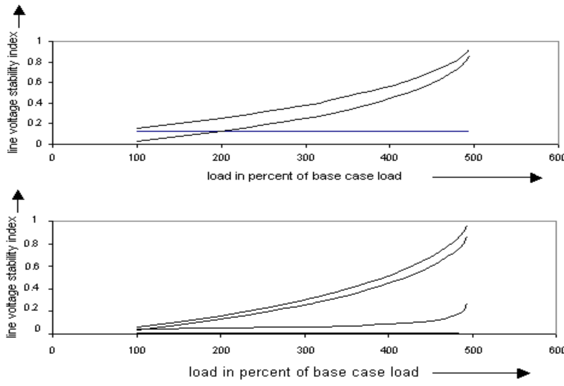
TABLE I.Variation Of Line Voltage Stability Using Fuzzy Index With Load Increments For Sample 5 Bus System.

Bus No.	Voltage Magnitude			
	Base Case Load		Critical case load	
	Conventional	Fuzzified	Conventio	Fuzzified
1	1.0600	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0450	1.0450
3	1.0100	1.0100	1.0100	1.0100
4	1.0700	1.0700	1.0700	1.0700
5	1.0900	1.0900	1.0900	1.0900
6	1.3140	1.0273	0.7278	0.7279
7	1.0364	1.0549	0.7175	0.7178
8	1.0669	1.0337	0.8207	0.8204
9	1.0635	1.0485	0.7412	0.7415
10	1.0635	1.4510	0.7613	0.7618
11	1.0675	1.0539	0.8995	0.8998
12	1.0622	1.0546	0.9854	0.9855
13	1.0589	1.4940	0.9398	0.9398
14	1.0502	1.3100	0.7207	0.7207

Figure 5. Variation of bus voltage stability using fuzzy index with load increments of line on IEEE 14 bus system

Line Details			Load in Percent of Base Case							
No.	Starting Bus	Ending Bus	100 %	200	300 %	400 %	440 %	460 %	480 %	490 %	Max. Load 493.35 %
1	1	2	0.1233	0.1	0.12	0.12	0.12	0.12	0.12	0.12	0.1233
2	1	3	0.1579	0.2	0.37	0.56	0.67	0.73	0.81	0.87	0.9251
3	2	3	0.0318	0.1	0.24	0.44	0..55	0.62	0.72	0.80	0.8622
4	2	4	0.0378	0.	0.25	0.44	0.56	0.63	0.73	0.80	0.8696
5	2	5	0.0596	0.1	0.30	0.51	0.64	0.72	0.83	0.91	0.9720
6	3	4	0.0065	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.0132
7	4	5	0.0422	0.0	0.06	0.08	0.11	0.12	164	0.20	0.2766

TABLE II. Comparison of conventional and fuzzy load flow in voltage magnitude for ieee 14 bus system



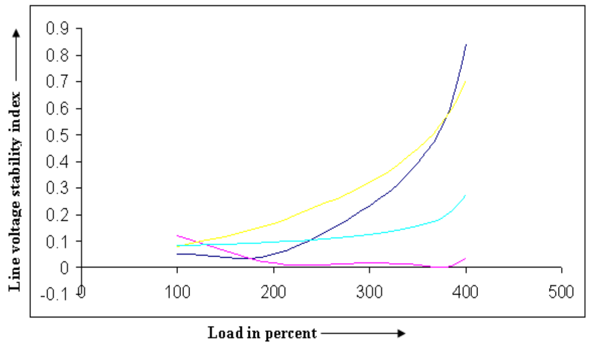


Figure 6. Variation of bus voltage stability using fuzzy index with load increments of line on IEEE 14 bus system

V. CONCLUSION

This work presents the successful analysis on voltage stability using Fuzzy Based Index and performs satisfactorily on power systems under all possible conditions such as increased load and line compensation with series and shunt capacitances for both in off-line and on- line simulation applications. The shortcomings of previous methods are overcome and consistent results are obtained. Though the number of iterations is more in fuzzy logic load flow method, the proposed algorithm does not require the factorization, refactorization and computation of jacobian matrix at each iteration which shows the validity of the proposed algorithm. This technique will be highly useful to ensure voltage security of power system by predicting the nearness of voltage collapse with respect to the existing load condition and help us in determining the maximum load ability of the given system without causing voltage instability. For the feasibility of the analysis the comparison of Newton-Raphson method and proposed technique as given in Table I & Table II.

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