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# Application of Fuzzy Logic Based Analytical Hierarchy Process to Choose Weighting Factors for Contingency Ranking in Electric Power Systems

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**Abstract** – *Contingency screening and ranking is one of the most important issues for security assessment in the field of power system operation. The objective of contingency ranking is to quickly and accurately select a short list of critical contingencies from a large list of potential contingencies and rank them according to their severity. Then suitable preventive actions can be implemented considering these contingencies that are likely to affect the power system performance. In this paper a novel approach is presented for contingency ranking based on static security assessment (SSA). This method employs weighted performance index with the application of Fuzzy Logic based Analytical Hierarchy Process (FLAHP) in order to select appropriate weighting factors to be imposed. The proposed method is applied to IEEE 30 bus system and the results are presented.* 

***Keywords**: Contingency Ranking, Static Security Assessment (SSA), Performance index (PI), Weighting Factor, Fuzzy Logic, Analytical Hierarchy Process (AHP)*

## Nomenclature

| | |
|---|---|
| $V_i, w_i$ | Voltage amplitude and associated weighting factor for $i_{th}$ bus respectively |
| $S_j, w_j$ | Apparent power and associated weighting factor for $j_{th}$ line or transformer respectively |
| $V_{ref,i}$ | Nominal voltage magnitude which is assumed to be $1pu$ for all load buses (i.e. PQ buses) and to be equal to specified value for generation buses (i.e. PV buses) |
| $S_{j,max}$ | Apparent power nominal rate of $j_{th}$ line or transformer |

## I. Introduction

The advancement of computer technology has made almost all major aspects in human activities run smoothly, however, several events caused by natural disasters are sometimes unpredictable and beyond our control. In power system operation, unpredictable events are termed "contingency". It may be caused mainly by transmission line or transformer outages which could lead to entire power system instability. The rapid demand for electric energy has made the task of power engineers become more challenging, since they have to think and decide how to ensure an efficient and secure power dispatch to the consumer. With the existing infrastructure and no extensive development of power stations, it is believed that most of existing power systems could not cope with the increase in demand. Therefore contingency analysis is one of the major issues for security assessment in any power system. Contingency analysis should be performed to ensure power system security when unexpected and sever events or disturbances may occur.

The result of contingency analysis can be used to save the power system by preventing other cascade accidents. Contingency analysis leads to assess the two aspects of power system security [1]:

a) Static Security Assessment (SSA) which is mainly based on voltage security (i.e. voltage stability) and transmission line or transformer power flow security (i.e. overloads).
b) Dynamic Security Assessment (DSA) which considers those criteria in SSA accompanied with dynamic and transient stability.

A group of probable line outages composes a contingency set. Some critical cases in contingency set may violate the well established static and dynamic security margins during power system operation. Such critical contingencies should be quickly identified for further evaluations or, where possible, corrective actions.

The simple procedure of identifying the critical contingencies is based on advanced full ac load flow method (e.g. Fast Decoupled Newton Raphson Method). As power systems are now large, complex and extensively interconnected, this approach is no longer suitable for identifying the most critical contingencies

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due to extensive computation time. The approach to reduce computation burden of identifying the most sever contingencies is termed contingency ranking, which categorizes the possible contingency events in two different classes [1]:

a) Definitely harmless events with no further evaluation required.
b) Potentially harmful events with further evaluation required.

Several contingency ranking method have been reported [2]-[15]. These papers have employed analytical approaches based on specific Performance Index (PI) and different algorithms or intelligent techniques such as artificial neural networks for simulation purposes [10]-[15]. In present paper, an attempt has been made to introduce a novel approach for contingency ranking in electric power networks appropriate for SSA studies due to line or transformer outage. The new proposed method is based on weighted performance index (PI) accompanied by novel application of Fuzzy Logic based Analytical Hierarchy Process (FLAHP) [16,17]. The proposed method is tested on IEEE 30 bus system in order to demonstrate its efficiency for contingency ranking.

### *I.1. Performance Index for Contingency Ranking*

In present paper the performance index (PI) used for contingency ranking is:

$$PI = \sum_{i=1}^{Bus\ number} w_i \left|V_i - V_{ref,i}\right|^n + \sum_{j=1}^{line\ number} w_j \left|\frac{S_j}{S_{j,max}}\right|^n \quad (1)$$

Although the above performance index is reported in [18], however this index is not yet used for contingency ranking extensively. This index is used in [18] for optimal allocation of FACTS devices to enhance power system security. In addition, there is no clear and explicit indication of how to select weighting factors and all the weighting factors are mostly assumed to be equal. In this paper exponent $n$ is assumed to be $2$ in order to give more importance to high level of voltage variations and overloads. In presented paper we use the above performance index extensively in the field of contingency ranking to be suitable for SSA studies. We believe that this index is much simpler to perform contingency ranking, compared to previous methods. We also apply a novel approach called Fuzzy Logic based Analytical Hierarchy Process (FLAHP) for the first time to adjust the appropriate and unequal values for weighting factors in above index, in order to provide more accurate and realistic contingency ranking. In fact this approach is the main goal of the present paper, which is not seen previously and leads us eventually to:

$$\sum_i w_i = \sum_j w_j = 1 .$$

TABLE I
THE PREFERENCE VALUES

| Preference | Numerical Values |
|---|---|
| Extremely Preferred | 9 |
| Very Strongly Preferred | 7 |
| Strongly Preferred | 5 |
| Moderately Preferred | 3 |
| Equally Preferred | 1 |
| Preference between the steps | 2,4,6,8 |

## II. Analytical Hierarchy Process

It is more convenient for human to express his idea in linguistic forms, rather than numerical figures. It is also more common for human to compare two items rather than several issues.

In electric power systems the assignment of weighting factors to each bus and transmission line depends on importance of the specific bus and transmission line during power system operation. Thus the opinion of experts involved in power system operation has remarkable influence on appropriate weighting factor selection to be imposed on Performance index. The application of AHP for weighting factor selection is based on questions asked from experts. The questions can be simply classified as:

a) How is the importance of $i_{th}$ bus respect to $j_{th}$ bus?
b) How is the importance of $i_{th}$ line respect to $j_{th}$ line?

Based on above two questions, the specific preference value given in Table I should be selected by each expert. As seen in Table I a numerical figure is assigned to each answer. Then according to integer of average value for each answer provided by experts, weighting factors could be calculated by AHP which is based on preference matrix (PM) [16]-[17].

Consider a three bus power system shown in Fig. 1. Suppose the preference matrix based on experts' opinion related to voltage security (i.e. $\left|V_i - V_{ref,i}\right|$) in all bus bars for this simple system is:

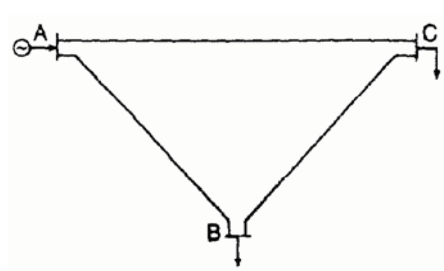


Fig. 1. Three Bus Power System

$$W_{PM}=\begin{array}{c} \\ Bus1 \\ Bus2 \\ Bus2 \end{array}\begin{array}{c} \begin{array}{ccc} Bus1 & Bus2 & Bus2 \end{array} \\ \begin{bmatrix} 1 & 2 & 8 \\ \frac{1}{2} & 1 & 6 \\ \frac{1}{8} & \frac{1}{6} & 1 \end{bmatrix} \end{array} \tag{2}$$

In $W_{PM}$ it is clear that due to experts' verdict the importance of voltage security in Bus1 is twice respect to related parameter in Bus2. In another word the importance (preference) of voltage security in Bus2 is half of the importance of voltage security in Bus1. Also it is obvious that the diagonal elements of preference matrix ($W_{PM}$) is always equal to unity. Now for preceding the AHP method, we must follow three steps:

**Step 1**: add the columns of $W_{PM}$, thus:

$$W_1=\begin{array}{c} \\ Bus1 \\ Bus2 \\ Bus3 \\ Sum \end{array}\begin{array}{c} \begin{array}{ccc} Bus1 & Bus2 & Bus2 \end{array} \\ \begin{bmatrix} 1 & 2 & 8 \\ \frac{1}{2} & 1 & 6 \\ \frac{1}{8} & \frac{1}{6} & 1 \\ \frac{13}{8} & \frac{19}{6} & 15 \end{bmatrix} \end{array} \tag{3}$$

**Step 2**: Divide each element of preference matrix ($W_{PM}$) in specific column to sum of its own column given in $W_1$, thus:

$$W_1=\begin{array}{c} \\ Bus1 \\ Bus2 \\ Bus3 \\ Sum \end{array}\begin{array}{c} \begin{array}{ccc} Bus1 & Bus2 & Bus2 \end{array} \\ \begin{bmatrix} 1 & 2 & 8 \\ \frac{1}{2} & 1 & 6 \\ \frac{1}{8} & \frac{1}{6} & 1 \\ \frac{13}{8} & \frac{19}{6} & 15 \end{bmatrix} \end{array} \tag{4}$$

**Step 3**: Calculate the mean value for each row in $W_2$. Thus (5):

$$W_3=\begin{array}{c} \\ Bus\ 1 \\ Bus\ 2 \\ Bus\ 3 \\ Sum \end{array}\begin{array}{c} \begin{array}{cccc} Bus1 & Bus2 & Bus3 & Mean \end{array} \\ \begin{bmatrix} 0.615 & 0.631 & 0.533 & 0.533 \\ 0.308 & 0.316 & 0.4 & 0.341 \\ 0.077 & 0.0533 & 0.067 & 0.066 \\ 1 & 1 & 1 & 1 \end{bmatrix} \end{array}$$

The values of the fourth column in $W_3$ provide appropriate and different weighting factors based on AHP due to hypothesis experts' opinion on voltage security importance in power system shown in Fig. 1. Therefore the calculated weighting factors for the given power system is:

$$w_1=0.593 \quad w_2=0.341 \quad w_3=0.066$$

These results indicate that Bus1 is the most important bus from experts' point of view on the subject of voltage security in three bus sample system.

It is obvious that the same procedure could be implemented in order to calculate weighting factors for power flow security (i.e. $\frac{S_j}{S_{j,max}}$).

## III. Fuzzy Logic Based Analytical Hierarchy Process

Fuzzy set theory is designed to extract the possible outcome from a great variety of information expressed in vague and imprecise terms [19].

Fuzzy set theory treats to express vague data in terms of membership functions.

Membership function is certain distribution which could be effectively implemented for logical reasoning. In this paper each linguistic variable provided by experts shown in preference section of Table I is defined by triangular fuzzy number (i.e. triangular membership function), because triangular fuzzy numbers are easy to use and interpret.

In a universe $X$, a fuzzy subset $A$ of $X$ is expressed by a membership function $\mu_A(x)$, which maps each element $x$ of $X$ to a real number in the interval [0,1].

The value of membership function $\mu_A(x)$ represents membership degree of $x$ in $A$.

Membership function of a triangular fuzzy number $\mu_A(x):\Re\rightarrow[0,1]$ is defined as:

$$\mu_A(X)=\begin{cases}\dfrac{x-c}{a-c} & c\le x\le a\\[2ex] \dfrac{x-b}{a-b} & a\le x\le b\\[2ex] 0 & otherwise\end{cases} \tag{6}$$

With $-\infty < c \le b < \infty$. This triangular fuzzy number can be denoted by triplet $(c,a,b)$ shown in Fig. 2. Maximal grade of $\mu_A(x)$ is given by the parameter $a$ (i.e. $\mu_A(a)=1$) This is the most probable value of the evaluation data. Moreover, $c$ and $b$ are lower and upper bound of available area for evaluation data. Narrower interval $[c,b]$ express the lower fuzziness of the evaluation data.

Operational laws of the triangular fuzzy numbers $\tilde{A}$ and $\tilde{B}$ parameterized by the triplets $(a_1,a_2,a_3)$ and $(b_1,b_2,b_3)$ are defined as:

$$\tilde{A}(+)\tilde{B}=(a_1+b_1,a_2+b_2,a_3+b_3) \tag{7}$$

$$\tilde{A}(-)\tilde{B}=(a_1-b_1,a_2-b_2,a_3-b_3) \tag{8}$$

$$\tilde{A}(\times)\tilde{B}=(a_1b_1,a_2b_2,a_3b_3) \tag{9}$$

$$\tilde{A}(\div)\tilde{B}=\left(\frac{a_1}{b_3},\frac{a_2}{b_2},\frac{a_3}{b_3}\right) \tag{10}$$

$$k\tilde{A}=(ka_1,ka_2,ka_3) \tag{11}$$

$$\tilde{A}^{-1}=\left(\frac{1}{a_3},\frac{1}{a_2},\frac{1}{a_1}\right) \tag{12}$$

Using graded mean integration method, triangular fuzzy number $\tilde{A}=(a_1,a_2,a_3)$ can be defuzzified as:

$$P(\tilde{A})=\frac{a_3+4a_2+a_1}{6} \tag{13}$$

In this paper graded mean integration method is applied to defuzzify triangular fuzzy numbers.

In proposed algorithm, each element of preference matrix $W_{PM}$ is a linguistic variable obtained by experts' opinion. So, main linguistic variables are selected and defined as [20]:

$EP=(0,0,3)$ (Equally Preferred)

$MP=(0,3,5)$ (Moderately Preferred)

$SP=(2,5,8)$ (Strongly Preferred)

$VSP=(5,7,10)$ (Very Strongly Preferred)

$ExP=(7,10,10)$ (Extremely Preferred)

These fuzzy numbers are shown in Fig. 3.

After completing preference matrix in fuzzy environment, each element is divided to sum of its column by above arithmetic fuzzy procedure. Weighting factors are also obtained by defuzzification of the mean of each row similar to previous section.

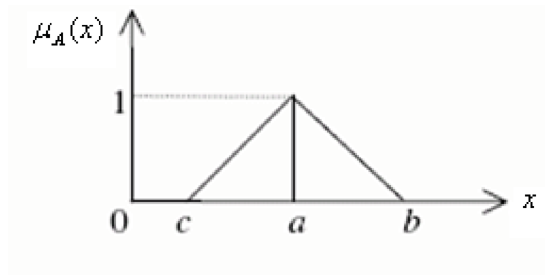


Fig. 2. Membership function of a triangular fuzzy number A = (c, a, b).

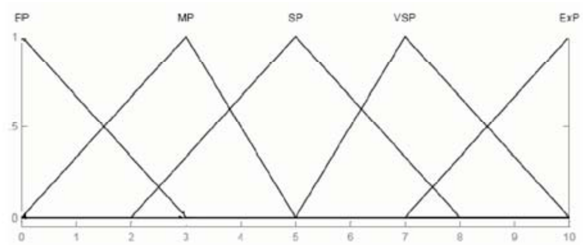


Fig. 3. Membership function of linguistic variables

## IV. Simulation Results

In this section, three simulation studies are presented for contingency ranking in IEEE 30 bus power system due to line outage using previous performance index associated by AHP and FLAHP, suitable for SSA studies. Before demonstrating simulation results, we present the weighting factors for different bus bars ($w_i$) and lines or transformers ($w_j$) shown in Tables II to V. The results appeared in these tables are obtained by hypothesis experts' opinion and preference matrix ($W_{PM}$) related to AHP and FLAHP for IEEE 30 bus benchmark shown in Fig. 4.

*Case1: Contingency Ranking with Unequal Weighting Factors obtained by AHP*

In this case the performance index given in Eq. (1) is used. The weighting factors which are given in Table II and III are also employed for contingency ranking in IEEE 30 bus power system due to line or transformer outages. The appropriate flow chart for simulation program in this case is shown in Fig. 5. In fact for each line or transformer outage the value of $PI$ should be calculated by advanced full ac load flow program and must be arranged in descending order for complete contingency ranking, Table IV present the contingency ranking for this case.

TABLE II
WEIGHTING FACTORS FOR LINES ( $w_j$ ) OBTAINED BY AHP

| Line Number | Bus to Bus | Weighting Factor | Line Number | Bus to Bus | Weighting Factor |
|---|---|---|---|---|---|
| L1 | 1-2 | 0.029774 | L22 | 15-18 | 0.025309 |
| L2 | 1-3 | 0.022966 | L23 | 18-19 | 0.024873 |
| L3 | 2-4 | 0.017672 | L24 | 19-20 | 0.026181 |
| L4 | 3-4 | 0.021241 | L25 | 10-20 | 0.027742 |
| L5 | 2-5 | 0.027053 | L26 | 10-17 | 0.02552 |
| L6 | 2-6 | 0.027513 | L27 | 10-21 | 0.026649 |
| L7 | 4-6 | 0.026822 | L28 | 10-22 | 0.025275 |
| L8 | 5-7 | 0.019763 | L29 | 21-22 | 0.024786 |
| L9 | 6-7 | 0.023354 | L30 | 15-23 | 0.02612 |
| L10 | 6-8 | 0.020729 | L31 | 22-24 | 0.027216 |
| L11 | 6-9 | 0.025185 | L32 | 23-24 | 0.025077 |
| L12 | 6-10 | 0.023173 | L33 | 24-25 | 0.026423 |
| L13 | 9-11 | 0.001922 | L34 | 25-26 | 0.001244 |
| L14 | 9-10 | 0.026527 | L35 | 25-27 | 0.025405 |
| L15 | 4-12 | 0.025133 | L36 | 28-27 | 0.056676 |
| L16 | 12-13 | 0.001871 | L37 | 27-29 | 0.028424 |
| L17 | 12-14 | 0.025414 | L38 | 27-30 | 0.02837 |
| L18 | 12-15 | 0.027778 | L39 | 29-30 | 0.025321 |
| L19 | 12-16 | 0.02522 | L40 | 8-28 | 0.024943 |
| L20 | 14-15 | 0.024902 | L41 | 6-28 | 0.029519 |
| L21 | 16-17 | 0.024918 | | | |

TABLE III
WEIGHTING FACTORS FOR BUSES ( $w_i$ ) OBTAINED BY AHP

| Bus | Weighting Factor | Bus | Weighting Factor |
|---|---|---|---|
| 1 | 0.2676 | 16 | 0.013 |
| 2 | 0.0184 | 17 | 0.0145 |
| 3 | 0.0095 | 18 | 0.0095 |
| 4 | 0.0095 | 19 | 0.0117 |
| 5 | 0.0272 | 20 | 0.0095 |
| 6 | 0.2386 | 21 | 0.0184 |
| 7 | 0.0184 | 22 | 0.0095 |
| 8 | 0.0184 | 23 | 0.0095 |
| 9 | 0.013 | 24 | 0.0095 |
| 10 | 0.0991 | 25 | 0.0117 |
| 11 | 0.0184 | 26 | 0.0095 |
| 12 | 0.0145 | 27 | 0.0145 |
| 13 | 0.0184 | 28 | 0.0557 |
| 14 | 0.0095 | 29 | 0.0095 |
| 15 | 0.0095 | 30 | 0.0095 |

*Case2: Contingency Ranking with Unequal Weighting Factors obtained by FLAHP*

In this case the performance index given in Eq. 1 is used. The weighting factors which are given in Table IV and V are also employed for contingency ranking in IEEE 30 bus power system due to line or transformer outages. The appropriate flow chart for simulation program in this case is also similar to Fig. 5. In fact for each line or transformer outage the value of $PI$ should be calculated by advanced full ac load flow program and must be arranged in descending order for complete contingency ranking, Table VII present the contingency ranking for this case.

TABLE IV
WEIGHTING FACTORS FOR LINES ( $w_j$ ) OBTAINED BY FLAHP

| Line Number | Bus to Bus | Weighting Factor | Line Number | Bus to Bus | Weighting Factor |
|---|---|---|---|---|---|
| L1 | 1-2 | 0.02835 | L22 | 15-18 | 0.024222 |
| L2 | 1-3 | 0.021912 | L23 | 18-19 | 0.023804 |
| L3 | 2-4 | 0.0151 | L24 | 19-20 | 0.025051 |
| L4 | 3-4 | 0.02026 | L25 | 10-20 | 0.026546 |
| L5 | 2-5 | 0.025848 | L26 | 10-17 | 0.024423 |
| L6 | 2-6 | 0.026308 | L27 | 10-21 | 0.025509 |
| L7 | 4-6 | 0.025652 | L28 | 10-22 | 0.02419 |
| L8 | 5-7 | 0.018897 | L29 | 21-22 | 0.02372 |
| L9 | 6-7 | 0.022349 | L30 | 15-23 | 0.025002 |
| L10 | 6-8 | 0.019799 | L31 | 22-24 | 0.02606 |
| L11 | 6-9 | 0.024101 | L32 | 23-24 | 0.024001 |
| L12 | 6-10 | 0.0184 | L33 | 24-25 | 0.025292 |
| L13 | 9-11 | 0.002284 | L34 | 25-26 | 0.023097 |
| L14 | 9-10 | 0.025392 | L35 | 25-27 | 0.024304 |
| L15 | 4-12 | 0.024017 | L36 | 28-27 | 0.0453 |
| L16 | 12-13 | 0.022863 | L37 | 27-29 | 0.027219 |
| L17 | 12-14 | 0.02432 | L38 | 27-30 | 0.027163 |
| L18 | 12-15 | 0.02659 | L39 | 29-30 | 0.024236 |
| L19 | 12-16 | 0.024136 | L40 | 8-28 | 0.023872 |
| L20 | 14-15 | 0.023832 | L41 | 6-28 | 0.0245 |
| L21 | 16-17 | 0.023846 | | | |

TABLE V
WEIGHTING FACTORS FOR BUSES ( $w_i$ ) OBTAINED BY FLAHP

| Bus | Weighting Factor | Bus | Weighting Factor |
|---|---|---|---|
| 1 | 0.04565 | 16 | 0.032254 |
| 2 | 0.032538 | 17 | 0.032333 |
| 3 | 0.03207 | 18 | 0.03207 |
| 4 | 0.03207 | 19 | 0.032185 |
| 5 | 0.033001 | 20 | 0.03207 |
| 6 | 0.044124 | 21 | 0.032538 |
| 7 | 0.032538 | 22 | 0.03207 |
| 8 | 0.032538 | 23 | 0.03207 |
| 9 | 0.032254 | 24 | 0.03207 |
| 10 | 0.036784 | 25 | 0.032185 |
| 11 | 0.032538 | 26 | 0.03207 |
| 12 | 0.032333 | 27 | 0.032333 |
| 13 | 0.032538 | 28 | 0.034501 |
| 14 | 0.03207 | 29 | 0.03207 |
| 15 | 0.03207 | 30 | 0.03207 |

*Case 3: Contingency Ranking with Equal or Unity Weighting Factors*

In this case the performance index given in Eq. (1) is used with equal or unity weighting factors in order to have comparative views with previous cases. The flow chart for this case is similar to Fig. 5 unless the weighting factors are assumed to be unity. Table VIII present the contingency ranking for this case.

TABLE VI
Contingency Ranking With Unequal Weightng Factors Obtained By Ahp

| Line Outage | $PI \times 1000$ | Line Outage | $PI \times 1000$ |
|---|---|---|---|
| L36 | 2.3323 | L28 | 1.0401 |
| L1 | 1.2252 | L19 | 1.0378 |
| L41 | 1.2147 | L11 | 1.0364 |
| L37 | 1.1697 | L15 | 1.0343 |
| L38 | 1.1675 | L32 | 1.032 |
| L18 | 1.1431 | L40 | 1.0265 |
| L25 | 1.1416 | L21 | 1.0254 |
| L6 | 1.1322 | L20 | 1.0248 |
| L31 | 1.12 | L23 | 1.0235 |
| L5 | 1.1133 | L29 | 1.02 |
| L7 | 1.1038 | L9 | 0.96104 |
| L27 | 1.0966 | L12 | 0.95361 |
| L14 | 1.0916 | L2 | 0.94507 |
| L33 | 1.0873 | L4 | 0.87408 |
| L24 | 1.0774 | L10 | 0.85305 |
| L30 | 1.0749 | L8 | 0.81327 |
| L26 | 1.0502 | L3 | 0.72722 |
| L17 | 1.0458 | L13 | 0.079 |
| L35 | 1.0455 | L16 | 0.0781 |
| L39 | 1.042 | L34 | 0.0512 |
| L22 | 1.0415 | | |

TABLE VII
CONTINGENCY RANKING WITH UNEQUAL WEIGHTNG FACTORS OBTAINED BY FLAHP

| Line Outage | $PI \times 1000$ | Line Outage | $PI \times 1000$ |
|---|---|---|---|
| L36 | 2.51 | L17 | 1.455 |
| L1 | 1.62 | L20 | 1.448 |
| L37 | 1.582 | L19 | 1.44 |
| L38 | 1.57 | L28 | 1.44 |
| L31 | 1.57 | L35 | 1.43 |
| L33 | 1.56 | L39 | 1.43 |
| L14 | 1.56 | L29 | 1.41 |
| L25 | 1.559 | L2 | 1.4 |
| L5 | 1.522 | L9 | 1.4 |
| L6 | 1.522 | L23 | 1.4 |
| L41 | 1.52 | L40 | 1.4 |
| L18 | 1.51 | L15 | 1.38 |
| L11 | 1.51 | L4 | 1.26 |
| L7 | 1.5 | L10 | 1.24 |
| L24 | 1.493 | L8 | 1.19 |
| L27 | 1.49 | L12 | 1.15 |
| L30 | 1.49 | L3 | 0.91 |
| L26 | 1.478 | L13 | 0.097 |
| L21 | 1.47 | L16 | 0.078 |
| L22 | 1.47 | L34 | 0.054 |
| L32 | 1.455 | | |

TABLE VIII
CONTINGENCY RANKING WITH UNITY WEIGHTING FACTORS

| Line Outage | $PI \times 1000$ | Line Outage | $PI \times 1000$ |
|---|---|---|---|
| L36 | 161.9777 | L26 | 41.4185 |
| L41 | 55.0195 | L19 | 41.0677 |
| L38 | 54.483 | L32 | 40.8743 |
| L25 | 50.8848 | L6 | 40.7363 |
| L18 | 50.5765 | L5 | 40.4339 |
| L41 | 49.7693 | L20 | 40.3348 |
| L1 | 48.7684 | L40 | 40.2867 |
| L31 | 48.4768 | L21 | 40.2744 |
| L27 | 45.8769 | L23 | 40.1766 |
| L33 | 45.4728 | L29 | 39.8948 |
| L14 | 45.4301 | L15 | 39.430 |
| L24 | 44.7375 | L7 | 38.5458 |
| L30 | 44.6709 | L11 | 37.0016 |
| L35 | 42.6301 | L2 | 36.0731 |
| L17 | 42.2035 | L12 | 35.4504 |
| L39 | 41.9912 | L4 | 34.8507 |
| L22 | 41.7688 | L10 | 33.9673 |
| L9 | 41.6888 | L8 | 31.5433 |
| L28 | 41.5353 | L3 | 27.8856 |

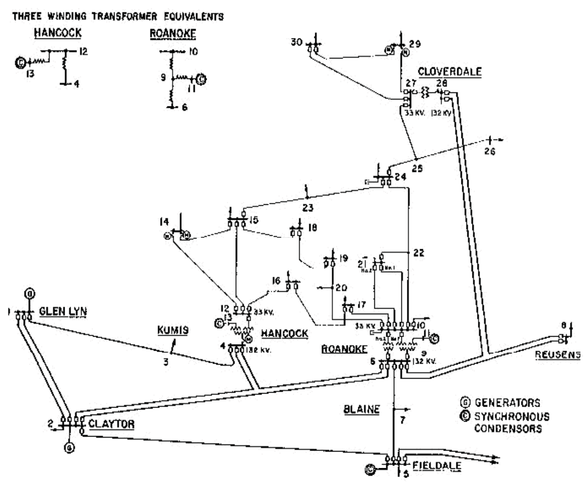


Fig. 4. IEEE 30 Bus Power System

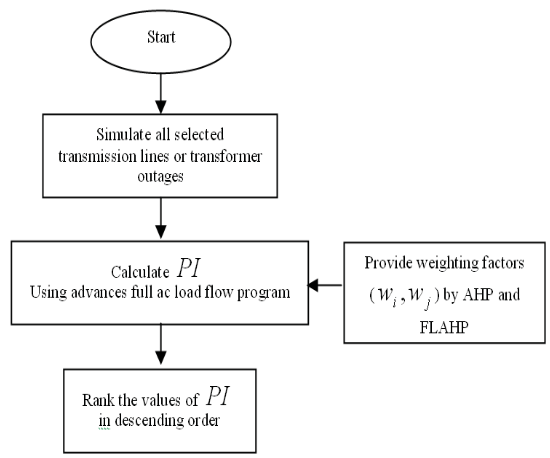


Fig. 5. Flow Chart of Proposed Algorithm

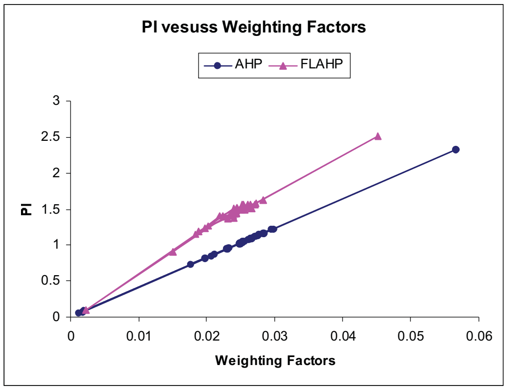


Fig. 6. $PI$ versus $w_j$ for unequal weighting factors

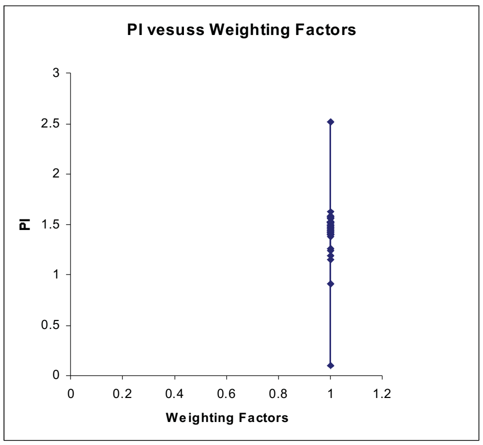


Fig. 7. $PI$ versus $w_j$ for equal weighting

## V. Discussion

Due to results presented in Tables VI to VIII the plots related to variation of performance index versus transmission line weighting factors ( $w_j$ ) are given in Figs. 6 and 7. It is clear in unequal weighting factors; the PI value is linearly dependent to weighting factors. In case of equal weighting factors it is clear that $PI$ versus $w_j$ is a straight vertical line

## VI. Conclusion

Fig. 5 Flow Chart of Proposed Algorithmnatural behavior of existing power systems. .

## References


[1] V.Brandwajn, A.B.R.Kumar, A.Ipakci, A.Bose and S.D.Kuo, Severity Indices for Contingency Screening in Dynamic Security Assessment, *IEEE Trans.on power systems, Vol 12, Issue 3*, Aug. 1997, pp.1136 – 1142.

[2] Zhihong Jia and B.Jeyasurya, Contingency Ranking for On-line Voltage Stability Assessment, *IEEE Trans.on power systems, Volume"IEEE Trans.on power systems, Vol. 15, No. 3*, Aug 2000, pp.1093-1097.

[3] E.Vaahedi, C.Fuchs, W.Xu, Mansour, H.Hamadanizade and G.K.Morison, Voltage Stability Contingency Screening and Ranking, *IEEE Trans. on Power Systems, Vol. 14,No.1*, Feb. 1999, pp.256-265.

[4] N. Amjadi and M.Esmaili, Application of a New Sensitivity Analysis Framework for Voltage Contingency Ranking, *IEEE Tran. on Power Systems, Vol 20, No. 2*, May 2005, pp.973-983.

[5] S.Greene, I.Dobson, F.L.Alvardo, Contingency Ranking for Voltage Collapse via Sensitive from a Single Nose Curve, *IEEE Power Engineering Society, Summer Meeting*, July 1997, Berlin, Germany, paper # SM97-707.

[6] I.Musirin and Ti Titik Kawa Abdul Rahman, Simulation Technique for Voltage Collapse Prediction and Contingency Ranking in Power Systems, *Proceeding of IEEE Syudent Conference on Research and Development*, 2002, Shah Alam, Malaysia, pp. 188-191.

[7] I.Musirin and Ti Titik Kawa Abdul Rahman, Fast Automatic Contingency Analysis and Ranking Technique for Power System Security Assessment. *Proceeding of IEEE Student Coference on Research and Development*, Shah 2002, Alam, Malaysia, pp.231-236.

[8] M.Moghavemi and F.M.Omar, Technique for Contingency Monitoring and Voltage Collapse Prediction, *IEE Proc. On Gener, Transm, Distrib, Vol. 145, No. 6*, Nov 1998, pp.634-640.

[9] M.Moghavemi and O.Faruque, Real-time Contingency Evaluation and Ranking Technique, *IEE Proc. on Gener, Transm, Distrib, Vol. 145, No. 5*, Sep 1998, pp.517-524.

[10] Y. Mansour, A.Y.Cahng, Jeyant Tamby, E. Vaahedi, B.R.Corns and El-Sharkawi, Larg Scal Dynamic Security Screening and Ranking using Neural Networks. *IEEE Trans.on power systems, Vol 12,No. 2*, May 1997, pp.954-960.

[11] Y.Mansour, E.Vaahedi and M.A.El-Sharkawi, Dynamic Security Contingency Screening and Ranking Using Neural Networks, *IEEE Tran on Power Systems, Vol. 8, No. 4*, July 1997,pp.954-960.

[12] L.Srivastava, S.N.Singh and J.Sharma, Knowledge Based Neural Network for Voltage Contingency Selection and Ranking, *IEEE Proc. On Gener,TRansm, Distrib, Vol.146, No.6*, Nov 1999, pp.649-656.

[13] K.L.Lo, L.J.Peng, J.F.Macqeen, A.O.Ekwue and D.T.Y.Cheng, Fast Real Power Contingency Ranking Using Counter Propagation Neural Network, *IEEE Trans. on Power Systems, Vol.13, No.4*, pp. 1259-1264.

[14] I. Musirin and Titik Kawa Abdul Rahman, Hybrid Neural Network Topology for Line Outage Contingency Ranking, *Proceeding of IEEE National Power and Energy Conference (PECon)*, 2003, Bangi, Malasia, pp.220-240.

[15] T. Jain, L.Srivastava and S.N. Singh, Fast Voltage Contingency Screening Using Radial Basis Function Neural Network, *IEEE Trans. on Power Systems, Vol. 18, No.4*, Nov 2003, pp. 1359-1366.

[16] T.L.Saaty, *The Analytical Hierarchy Process*, *Planning, Priority, Resource Allocation*, (RWS Publication, USA, 1980).

[17] E.H.Forman and M.A.Sally, *Decision by Objectives*, (World Scientific Pub, USA, 2002).

[18] S. Gerbex, R. Cherkaoui and A.J.Germond, Optimal Loacation of FACTS Devices to Enhance Power System Security, *IEEE, PowerTech Confrence*, June2003, Bologna, Italy.

[19] V. Belton, T.J. Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach*, (Kluwer Academic Publisher, USA, 2002).

[20] T.L. Saaty, *The Analytic Hierarchy Process*, (McGraw-Hill, New York, 1980).


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