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Application of Fuzzy Logic Approach for Obtaining Composite Criteria based Network Contingency Ranking for Practical Power System Networks

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ABSTRACT

In the present day power system planning and operation, considerable interest is being shown in contingency analysis. Contingency screening and ranking is one of the important components of on-line system security assessment which is done with the help of various computer softwares which employ iterative methods like Newton Raphson and Fast Decouple Load Flow Methods for obtaining the magnitudes of various parameters. The objective of contingency screening and 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. Suitable preventive control actions can be implemented considering contingencies that are likely to affect the power system performance. Network contingencies often contribute to overloading of network branches, unsatisfactory voltages and also leading to voltage collapse. To maintain security against voltage collapse, it is desirable to estimate the effect of contingencies on the voltage stability. This research paper presents a new approach using fuzzy logic to evaluate the degree of severity of the considered contingency and to eliminate masking effect in the technique.

Keywords: Voltages, Real Power, Reactive Power, Power System.

1. INTRODUCTION

The effect of the line outage when the rest of the system is stable is called contingency study. The study of contingency is an essential activity in planning operation and control of power systems. The outage or change in the independent parameters of the power systems gives rises to transient phenomena in the electrical and electromechanical states of those power systems[1]. The main thrust of contingency studies carried out in power system control centers is to determine the steady state effects of outages[2]. Large power systems require the analysis of all the credible contingence within a very short time so as to exercise the control in the short time available for corrective action[3].

The following algorithm gives the ranking of lines using conventional Newton Raphson load flow and Fast decoupled load flow methods:

1. Read input N, I, J.R, X, Y_1, T, P_G, Q_G, P_L, Q_L, V_1, S;
2. Form nodal admittance matrix, Y, Susceptance matrix B;
3. Perform "Newton raphson" load flow or Fast decoupled load flow for base case voltage (V^0) and angle (δ) for all buses (assume all buses as load bus except slack bus);
4. Calculate power flows for base case;
5. Remove line no (1);
6. Modify the admittance matrix Y, Susceptance matrix B for line outage;
7. Perform Newton raphson load flow or Fast decoupled load flow for outage case and find V and δ for all buses;
8. Calculate power flows for this contingency;
9. Calculate the performance index of this line by real power flows.

$$PI(P) = \sum_{i=1}^{nL} \frac{w_i}{2n} \left[\frac{p_{i\,new}}{p_{i\,\lim it}} \right]^{2n} \quad (1)$$

10. Calculate voltage index by

$$PI(V) = \sum_{i=1}^{nB} \frac{w_i}{2n} \left[\frac{V_{i\,new} - V_{i\,Base}}{0.05} \right]^{2n} \quad (2)$$

11. Calculate the reactive power index by

$$PI(V) = \sum_{i=1}^{nL} \frac{w_i}{2n} \left[\frac{q_{i\,new}}{q_{i\,\lim it}} \right]^{2n} \quad (3)$$

Where nL = No. of lines

w_i = weightage factor

12. If another contingency has to be studied repeat step(6) to step(12);
13. Based on PI(P), PI(Q), PI(V) Ranking is given to the lines.

2. FUZZY REPRESENTATION OF POST CONTINGENT QUANTITIES

The post-contingent quantities must first be expressed in fuzzy set notation before they can be processed by the fuzzy reasoning rules.

2.1. Line Loadings

Each post-contingent percentage line loading is divided into four categories using Fuzzy set notation: Lightly loaded, 0-50% (LL), Normally loaded, 50-80% (NL), Fully loaded 85-100% (FL), Overloaded, above 100% (OL).

The output membership functions to evaluate the severity of a post-contingent quality are also divided into four categories using Fuzzy set notation: Less severe (LS), Below severe (BS), Above severe (AS) and More severe (MS).

The Fuzzy rules, which are used for evaluation of severity indices of post-contingent quantities of line loadings are

If line loading is LL then severity is LS

If line loading is NL then severity is BS

If line loading is FL then severity is AS

If line loading is OL then severity is MS

After obtaining the severity indices of all the lines the overall severity index (OSILL) of the line loading for a particular line outage is obtained using the following expression.

$$OSILL = \sum w\,SI, \qquad (4)$$

Where w = Weighting coefficient for a severity index.

SI = Severity Index of a post-contingent quantity.

The weighting coefficient used for the severity indices are

w = 0.25 for LS

= 0.50 for BS

= 0.75 for AS

= 1.00 for MS

The effect of these weighting coefficients is that all overall severity index is first dominated by fourth category of severity index (MS) next by third, second and first category of severity index respectively. Thus the overall severity index reflects the actual severity of the system for a contingency.

2.2. Bus Voltage Profiles

In this case each post-contingent bus voltage profiles is divided into three categories using Fuzzy set notations: Low voltage, below 0.9pu (LV), Normal voltage, 0.9-1.02pu (NV) and over voltage, above 1.02pu (OV).

The output membership functions used to evaluate the severity of a post-contingent quantity are also divid ed into three categories using Fuzzy set notations: Below severe (BS), above sever (AS) and More severe (MS)

Fuzzy rules, which are used for evaluation of severity indices of post-contingent quantities of voltage profiles are

If voltage profile is NL then severity is BS

If voltage profile is OV then severity is AS

If voltage profile is LV then severity is MS

After obtaining the severity indices of all the voltage profiles the overall severity index (OSIVP) of the bus voltage profile for a particular line outage is obtained using the following expressions.

$$OSIVP = \sum w\,SI, \qquad (5)$$

The weighting coefficient used for the severity indices are

w = 0.30 for BS

= 0.60 for MS

= 1.00 for MS

2.3. Reactive Power Loading

In this case each post-contingent reactive power loading are divided into the four categories using fuzzy set notations: Lightly loaded reactive power, 0-50% (LL), Normally loaded reactive power, 50-80% (NL), Fully loaded reactive power 85-100% (FL), Overloaded reactive power, above 100% (OL). This shows the correspondence between reactive power loading and the four linguistic variables, which shows the ranges of loading, as ratio of actual flow to its rated MVA loading, covered by linguistic variables.

The output membership functions to evaluate the severity of a post-contingent quantity are also divided into four categories using fuzzy set notation: Less severe (LS), Below sever (BS), Above severe (AS) and More severe (MS).

The fuzzy rules, which are used for evaluation of severity indices of, post contingent quantities of reactive power loading are.

If reactive power loading is LL then severity is LS
If reactive power loading is NL then severity is BS
If reactive power loading is FL then severity is AS
If reactive power loading is OL then severity is MS

After obtaining the severity indices of all the reactive power the overall severity index (OSI_{QL}) of the reactive power loading for a particular line outage is obtained using the following expressions.

$$OSIQL = \sum w\,SI \tag{6}$$

The weighting coefficient used for the severity indices are

w = 0.25 for LS
= 0.50 for BS
= 0.75 for AS
= 1.00 for MS

The effect of these weighting coefficients is that the overall severity index is first dominated by fourth category of severity index (MS) next by third, second and first category of severity index respectively. Thus the overall severity index reflects the actual severity of the system for a contingency.

3. PROPOSED FUZZY LOGIC APPROACH FOR CONTINGENCY RANKING

The membership function for each post contingent quantity of line flows, bus voltages and reactive power index is established and with these membership functions at hand, the overall severity index for the contingency is computed as follows.

Each post contingent quantity is described by a linguistic variable and the associated membership function.

Now, to reach a possible overall severity index for line loading, voltage profiles and reactive power index the fuzzy inference system is as shown (Fig.1.).

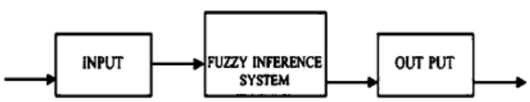

Fig 1: Fuzzy Inference System (FIS)

The inputs are line loading, voltage profiles and reactive power indices and the outputs are severity indices, which are evaluated using the fuzzy rules. The approach for evaluating the overall severity index for line loading is as follows. If the percentage line loading of a line is 75 then the severity index, which is evaluated using the above fuzzy rules, is 4.630. similarly the severity indices for all other line loadings are obtained. The overall severity index (OSI_{LL}) of the line loadings for a particular line outage is obtained using the following expression.

$$OSILL = \sum w\,SI \tag{7}$$

Similarly the severity indices and overall severity index for the bus voltages and reactive power indices are obtained by using the respective fuzzy rules. The network composite overall severity index (NCOSI) is obtained by adding the three overall severity indices.

When the overall severity index for each contingency in the contingency list has been figured out, the overall severity indices for those contingency cases with a severity index exceeding a pre-specified value are listed out and ranked according to the network composite overall severity index.

$$NCOSI = OSI_{LL} + OSI_{VP} + OSI_{Q}, \tag{8}$$

4. CONCLUSION

The proposed approach can provide the user with those outages that may cause immediate loss of load or islanding at a certain bus. This is a kind of information in which is very helpful to system operators. An overall severity index is given for which outage case. These severity indices can be used as a guideline for deciding whether corrective control actions should be taken.

In performance index method with high exponent, the resultant performance index value will depend heavily on loading of the particular line which is loaded closest to its limit, i.e. 90% to 95% of the rated capacity, other lines which are less heavily loaded i.e. 80% to 85% of the rated capacity though of large in number, will have relatively small weightage on the performance index value. In fuzzy set method the contribution of these lines, which are less heavily loaded, to the severity index are taken in to account by using membership functions for the linguistic variables. In precise, descriptions of operators experience with the system can thus be incorporated in to the overall severity index. Therefore an outage event with two lines loaded to 80% of rated capacity will not necessarily be ranked as less severe than the event with only one line loaded to 90% of its rated capacity which results in the increase in the reliability of the powersystem network Contingency Ranking where the contingency ranking analysis is compulsorily employed in almost every power system of the world.

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