SVM based Power System Security Assessment Using Composite Criteria

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Abstract**—** Power System Security is an important electrical issue. Disturbance may cause the system to an undesirable state and results in loss of synchronism. Security Analysis is the process of testing power system safety limits, to determine up to what extent the system is safe. The contingencies contribute to overloading of network branches and unsatisfactory voltages, which may lead to problems of stability/voltage collapse. Pattern classification is a promising tool for security evaluation. This paper proposes support vector machine (SVM) classifier for security assessment and classification. Power system security is divided into three classes' viz.; secure, critically secure and insecure. Here we have three number of classes so multilevel SVM technique is been used. The proposed SVM based pattern classification approach is implemented on IEEE 30 bus system. The simulation results of SVM classifier is compared with other artificial intelligence tools.

Keywords**—**System Security, Pattern Classification, Support Vector Machine, Contingencies.

I. Introduction

For General operation of power system, security analysis plays an important role. Because of rapid growth in power system, no of interconnections and sizes is also been increasing which results in increasing the complexity. Power system security generally refers to ability of system to withstand contingencies. For considering power system security, contingency analysis plays an increasingly important role. For large systems, the number of probable contingencies is also large. Contingency selection consists of computing near practical post-contingency operating conditions for a list of pre-determined contingency operating conditions and ranking them according to some criterion.

By using Fuzzy Logic Composite Criteria, we can identify the critical contingencies from a large list of credible contingencies and rank them according to their severity. In this thesis a fuzzy logic approach has been developed for network contingency ranking. The fuzzy approach is based on composite criteria, which use voltage stability indices at the load bus as post contingent quantity in addition to line loading, bus voltage profiles and generator reactive powers. Based on value of FLCC the classification will be developed

For Power System Security. Here multilevel SVM technique will be applied for the security assessment.

Patterns are generated for IEEE 30 bus systems. To generate these patterns, it is necessary to run load flow of each system. Load flow analysis (also known as power flow analysis) may be solved by three methods which are the Newton-Raphson method, Fast-Decoupled method and Gauss-Seidel method. The most common power flow method is the Newton-Raphson due to the fact that it can converge very quickly as the iteration begins near the desired root. After running load flow, the maximum and minimum voltage limits of each bus, and the maximum MVA limits of each line of each system are calculated. Maximum MVA limit will be the maximum value of the thermal limit which the line could withstand. The conventional method involves solving full ac load flow and rotor dynamics for each disturbance. This process is highly time consuming. Therefore recently, Artificial intelligence techniques such as Artificial Neural Network, Fuzzy logic and SVM techniques have been proposed for security assessment problem.

II. Need of Security Assessment

The term security defines ability of an electrical system to withstand sudden disturbances. The aim of security analysis is to increase the power system performance to run safely and operate within acceptable limits. Contingency may occur because of line overloading, reactive power variation at generation bus, and voltage variations at load bus. Due to contingency disturbance may occur in power system which results in loss of synchronism? As all the grids are interconnected loss in synchronism may cause grid failure. This may cause interruption in the system and great economical loss to the power companies. So there is need of assessing security analysis of the power system.

III. Power System Security Assessment

The security evaluation process include set of contingencies namely generator/line outage, system phase faults, sudden changes in the load etc. The line outage, voltage fluctuation and variation of reactive power are taken in this paper for testing system security.
Based on security index power system security is divided into three classes 'viz., Secure, critically secure and insecure.
Security level is defined based on the computation of a term called Fuzzy logic composite criteria (FLCC). The system is said to be secure if the power generation and bus voltages are within their limits.

IV. Fuzzy Logic Composite Criteria

Fuzzy logic is a kind of logic using graded or quantified statements rather than ones that are strictly true or false. The fuzzy sets representing linguistic variables allow objects to have grade of membership from 0 to 1. The pre/post-contingent quantities are first expressed in fuzzy set notation before they can be processed by the fuzzy reasoning rules. Composite criteria are calculated by using overall security index of line loadings, voltage profile, voltage stability index and reactive power generation. For effective determination of these indices, fuzzy logic technique is used. This is shown in following figure.

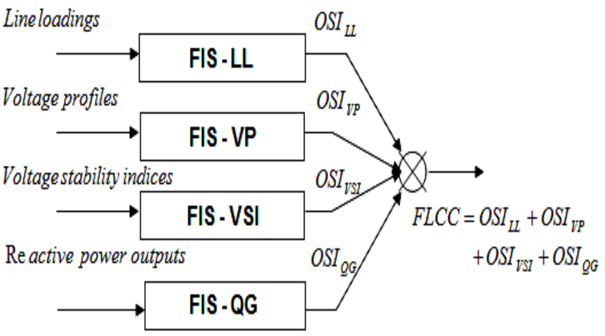

Fig.1 Parallel operated fuzzy inference system

A. Line Loadings

Each pre/post-contingent percentage line loading is divided into four categories using fuzzy set notations:

Lightly Loaded (LL)	0-50%
Normally Loaded (NL)	50-85%
fully loaded (FL)	85-100%
Over Loaded (OL)	above 100%

The output membership functions to evaluate the severity of a pre/post -contingent quantity are also divided into four categories using fuzzy set notations: Less Severe (LS), Below Severe (BS), Above Severe (AS) and More Severe (MS). After obtaining the severity indices of all the lines the Overall Severity Index (OSI_{LL}) of the line loadings for a particular line outage is obtained using the wing expression.

$$OSI_{LL} = \sum W_{LL} SI_{LL} \qquad (1)$$

Where

w_{LL} = Weighting coefficient for a severity index.

SI_{LL} = Severity Index of a pre/post-contingent quantity.

The weighting coefficients used for the severity indices are

w = 0.25 for LS, 0.50 for BS, 0.75 for AS and 1.00 for MS.

B. Bus voltage profiles

In this case each pre/post-contingent bus voltage profile is divided into three categories using fuzzy set notations:

Low Voltage (LV),	below 0.9pu
Normal Voltage (NV),	0.9-1.02pu
Over Voltage (OV),	above 1.02pu

The output membership functions used to evaluate the severity of a post -contingent quantity are also divided into three categories using fuzzy set notations: Below Severe (BS), Above Severe (AS) and MS (More Severe). After obtaining the severity indices of all the lines the Overall Severity Index ($OSIvp$) of bus voltage profile for a particular line outage is obtained using the wing expression.

$$OSI_{VP} = \sum W_{VP} SI_{VP} \qquad (2)$$

The weighting coefficients used for the severity indices are

w_{VP} = 0.30 for BS, 0.60 for AS and 1.00 for MS.

C. Voltage stability indices

Each pre/post-contingent voltage stability index is divided into five categories using fuzzy set notations:

Very Low Index (VLI)	0-0.2
Low Index (LI)	0.2-0.4
Medium Index (MI)	0.4-0.6
High Index (HI)	0.6-0.8
Very High Index (VHI)	0.8 above

The output membership functions to evaluate the severity of a pre /post -contingent quantity are also divided into five categories using fuzzy set notations: Very Less Severe (VLS), Less Severe (LS), Below Severe (BS), Above Severe (AS) and More Severe (MS). After obtaining the severity indices of all the lines the Overall Severity Index ($OSIvsi$) of the bus voltage stability index for a particular line outage is obtained using the wing expression.

$$OSI_{vsi} = \sum W_{vsi} SI_{vsi} \qquad (3)$$

The weighting coefficients used for the severity indices are

w_{VSI} = 0.20 for VLS, 0.40 for LS, 0.60 for BS, 0.80 for AS and 1.00 for MS.

Where w_{VSI} = Weighting coefficient for a severity index,

SI_{VSI} = Severity Index of a pre/post -contingent quantity.

D. Generator reactive power outputs

In this case each pre/post-contingent generator reactive power output is divided into three categories using fuzzy set notations:

Low Output (LO)	above -1p.u
Normal Output (NO)	between -1and 1p.u
Over Output (OO)	above 1p.u

The output membership functions used to evaluate the severity of a post -contingent quantity are also divided into three categories using fuzzy set notations: Below Severe (BS), Above Severe (AS) and MS (More Severe). After obtaining the severity indices of all the voltage profiles the Overall Severity index voltage profiles for a particular line outage is obtained using the expression.

$$OSI_{qg} = \sum W_{qg} SI_{qg} \qquad (4)$$

The weighting coefficients used for the severity indices are

w_{VP} = 0.30 for BS, 0.60 for AS and 1.00 for MS.

V. CLASSIFICATION OF POWER SYSTEM SECURITY

The severity of each system is tested under normal conditions by creating a line outage. The line that is mostly affected by line outage can be identified by creating this contingency. Patterns are generated by creating different line outages for an IEEE 30 bus system and they are tabulated below. These patterns are generated by executing Mat lab programs for FLCC.

TYPE OF CLASS	OSI_{LL}	OSI_{VP}	OSI_{VSI}	OSI_{QG}	FLCC
Class A	343.75	216	96.0019	54	709.75
Class A	325	216	96.0019	54	691.001
Class A	343.75	216	96.0019	54	709.751
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Class A	343.75	216	96.0019	54	709.751
Class A	325	216	96.0019	54	691.001
Class B	362.5	216	96.0019	144.999	819.501
Class B	412.5	216	96.0019	54	778.501
Class B	431.25	216	96.0019	54	797.251
Class B	456.25	216	96.0019	54	822.251
Class B	400	216	96.0019	54	766.001
Class B	437.49	216	96.0019	54	759.751
Class C	362.5	306.99	96.0019	144.99	910.501
Class C	375	301.96	120.001	54	850.971
Class C	393.75	306.99	108.001	54	862.751
Class C	368.75	216	96.001	235.99	916.751
Class C	543.74	216	132.001	54	945.751
Class C	406.25	306.99	96.0019	54	863.251
Class C	437.5	306.99	96.0019	54	894.501
Class C	387.5	336.43	120.001	54	897.933

TABLE 1 PATTERN FOR IEEE 30-BUS SYSTEM

Based on FLCC values obtained, system security is ranked and classes are specified. System security is divided into three classes:-

Class Category/Label	FLCC
Class A	650 to 750
Class B	750 to 850
Class C	Above 850

After specifying classes Artificial Intelligence tools is applied to separate different classes.

A. *Support vector machine*

Support vector machine (SVM) is one such tool, which is used for pattern classification. It is developed by Vladimir Vapnik in 1992. Pattern classification is procuring more significance in solving multiple power system troubles. The classification function is designed depending on the training set. This helps to know the security level of the power system in a short period of time. SVM performs re-substitution process which means minimization of error function by an iterative training algorithm to construct an optimal hyper plane. Here we are using SVM for multi-classification in security assessment model. Although SVM is basically intended for binary classification, the concept of multi-class SVM also exists.

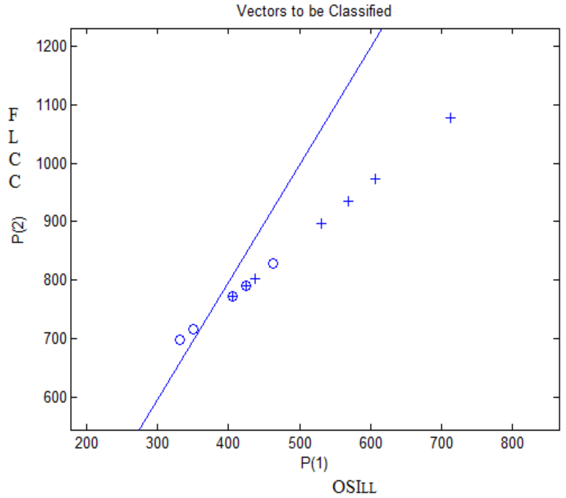

Fig. 2 Classification of system security using ANN

The simulation results obtained by artificial intelligence tools are shown in Figs. 2-5. Results achieved in Figs. 2-5 demonstrate the pattern classification. Fig. 2 shows that the error in classification. By using artificial neural network pattern are not classified successfully. So here we use support vector machine for pattern classification. For identifying the support vectors we use fast iterative algorithm for given set of points. Our algorithm works by maintaining a candidate support vector set. This algorithm makes repeated passes over the data to satisfy Karush-Kuhn-Tucker (KKT) constraints.

VI. PROPOSED ALGORITHM

Simple SVM
Candidate SV = {closest pair from opposite classes}
While there are violating points **do**
Find a violator
Candidate SV = candidate SV U violator
If any $\alpha_p < 0$ due to addition of c to S **then**
Candidate SV = candidate SV \ p
Repeat till all such points are pruned
End if
End while

For better classification we use Support vector machine (SVM) which uses iterative algorithm as mentioned above. Pattern classification by using support vector machine (SVM) is shown below.

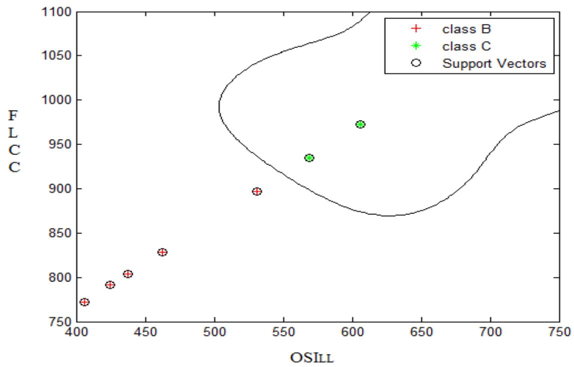

Fig.3 Classification of system security using SVM for class B & C

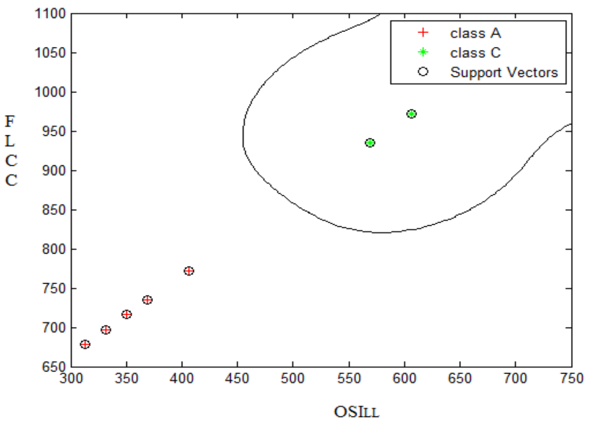

Fig.4 Classification of system security using SVM for class A & C

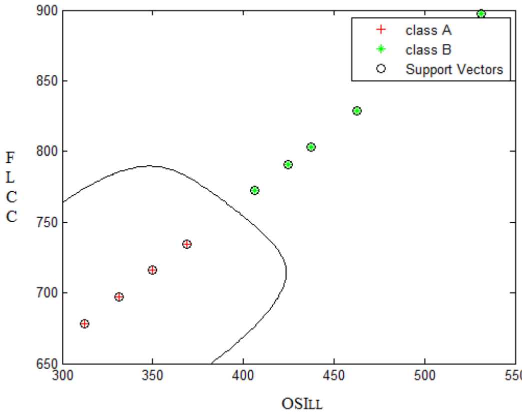

Fig.5 Classification of system security using SVM for class A & B

CONCLUSIONS

The generated patterns are classified by using SVM classifier. The SVM classifier classifies two classes at a time. The decision surface or hyper plane is obtained by using SVM algorithm. The software used for this algorithm is MATLAB R2010 in Windows XP operating system.

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