Indonesian Journal of Electrical Engineering and Informatics (IJEEI)
Vol. 10, No. 3, September 2022, pp. 725~733
ISSN: 2089-3272, DOI: 10.52549/ijeei.v10i3.3928

Dynamic Security Assessment For Power System Using Attribute Selection Technique

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Article Info

Article history:

Received Jun 13, 2022
Revised Sep 6, 2022
Accepted Sep 26, 2022

Keyword:

Dynamic Security Assessment
Attribute Selection
IEEE-30Bus
Random Forest
Decision Tree

ABSTRACT

The evaluation of the dynamic security of the electrical power system after the occurrence of disturbances in the network is one of the most important tools that the control center uses to maintain the system in a safe operating mode, as well as prevent cases of system out of control and cases of complete shutdown. With the annual increase in the size of the electrical system and its distribution over a very wide geographical area, this led to a new challenge to assess dynamic security assessment (DSA), which is dealing with a huge and varied amount of data that requires processing in a very short time. To address these challenges, this study presented a new technique of artificial intelligence, which is the attribute selection technique, to reduce the size of this data and thus improve the accuracy and speed of results. This method relied on the combination of decision tree (DT) algorithms and a technique attribute selection in the data obtained from the test system IEEE-30Bus Model. The results of this method showed a significant reduction in the number of data used, which amounted to 77.27% of the total data, which led to an improvement in the classification accuracy, as the classification accuracy reached 97.39%. This reduction is very important when dealing in the online operating environment, as it saves the time necessary to reach the most accurate evaluation decision and thus issue gives a greater opportunity to take the appropriate decision in the event of disturbances and keep the power system in a secure case.

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1. INTRODUCTION

Dynamic security is one of the important problems in the operation of the power system [1]. Control center aims to evaluate the dynamic security behavior after each power grid disturbance via the DSA tool [2]. The goal is to keep the power system in a secure case after disturbances and prevent system collapse and power outages [3]. DSA has always been an important topic in power system operation to classify system operation into stable case or an unstable case. DSA is an assessment of the power system's ability to withstand sudden disturbances and maintain a secure case in the event of a sudden failure in the electrical power system.

Recently, power system has undergone drastic changes related to privatization and installation of new devices and technologies such as renewable generation sources [4, 5]. The privatization process pushed electric power networks to work near their limits, especially with the demand for continuous loads [5, 6]. In addition, the digital revolution in the fields of communications, software, computer systems and artificial intelligence systems provided advanced technologies that developed the infrastructure for various different industrial sectors, including the electric power sector. However, at the same time, it created new challenges due to the large number of data sent and received, and this matter brought challenges to the power system from unsecure cases. Traditionally, DSA relies on many differential algebraic equations that require a long time to solve, so it was usually used within the working environment offline. In addition, this method is very complex and inaccurate in the DSA [13].

Dynamic security assessment has led researchers to interest in evaluating the performance of electrical power systems effectively, reducing errors, and providing an important tool for its operators. artificial intelligence used as a means to solve dynamic security problems in the electric power system, where researchers used a variety of techniques such as Support Vector Machine (SVM) [7, 15], Adaptive Artificial Neural Network (AANN) [8], decision tree [9], Fuzzy Logic (FL) [19] and Extreme Learning Machine (ELM) [20], used different power system model like IEEE-9Bus, IEEE-14Bus or other models by applying several faults to electrical power systems and collecting the measurements that are considered as inputs and the cases of the DSA as outputs. The techniques used by the researchers showed different results depending on the algorithms used that differ in their structures. As well as the accuracy of classification based on the error rate [12]. Given the expansion of electrical power systems around the world and the large number of transmitted and received data that represent the attributes of power system like voltage, current, frequency, phase angle and others, it has become necessary to reduce this data by using modern artificial intelligence techniques in order to DSA with high accuracy in the least possible time [16, 10].

In this paper, the dynamic security assessment of electric power system IEEE-30Bus Model after several stages of fault scenarios is classifiy and create a database that includes measurements rotor angle of synchronous machines, voltage and frequency of buses for electric power system its inclusion in an artificial intelligence program used several algorithms, and selection the best algorithm to give cases the highest accuracy where the attribute selection technique gave that the number of attributes were reduced from 66 to 30 with accuracy of 96.20% through the random tree algorithm, the number of attributes reached 15 with an accuracy of 97.39% through the random forest algorithm.

2. RESEARCH METHODOLOGY

Five steps will be followed to evaluate the dynamic security by collecting the measurements of the rotor angle, voltage for buses and frequency for buses after applying several faults on the IEEE-30Bus Model, using an artificial intelligence program, finally classifying the cases and calculation of classification accuracy, shown in Fig. 1.

The first stage is to build an IEEE-30Bus computer Model using the power world program. Second stage is the application of perturbation scenarios to test the model to know the case of the system when the load is 100%, 110%, 125% of normal load. Third stage is to collect the rotor angle measurements for the synchronous machines, the voltage and the frequency for the buses, after making the perturbations on the model, where the measurements include all the parts of the model. Fourth stage is the evaluation of the dynamic security of the model through the measurements were taken from the third stage and classifiy the cases are secure or unsecure, and the last stage, feeding the data collected by the fourth stage into the weka program using attribute selection technique to reduce the number of attributes needed for classification by removing irrelevant attribute model data.

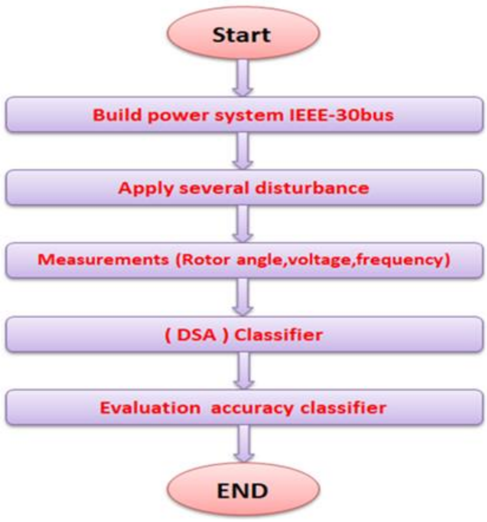

Figure 1. The flow diagram

The faults were implemented at load 100% of normal load are, single line to ground fault, line to line fault, double line to ground fault, three phases fault, loss of one transmission line both ends, loss of two transmission line both ends and loss of one synchronous machine. The faults at load 110% and 125% of normal load are, three phase fault, loss of one transmission line both ends, loss of two transmission line both ends and loss one synchronous machine. In fact these faults occur as a result of lightning, opening a transmission line, falling trees on the transmission line, or maintenance operations.

Readings are represent the rotor angle, voltage and frequency of buses are taken during the transient state of the entire model starting from bus No. 1 to bus No. 30 using the time domain, where the fault was executed at the time of 1 second and removed at the time of 1.1 second and the readings were taken at the time of 2.3 second for all readings [11].

The removal of the malfunction was determined according to the time period of the circuit breaker, which takes 5 cycles to remove the fault and return the line to work again. The time can be calculated as follows, since the frequency of the system is 50 Hz.

$$\text{Time one cycle} = \frac{1}{F} \tag{1}$$

$$\text{Time one cycle} = \frac{1}{50} = 0.02 \text{ sec.}$$

$$\text{Total time} = \text{time one cycle} \times \text{NO.of cycle} \tag{2}$$

$$\text{Total time} = 0.02 \times 5 = 0.1 \text{ sec.}$$

Rotor angle measurements, voltages, and frequency measurements are recorded on each bus for all faults. Depending on the determinants of the secure case as follows :

1- The system is considered secure if the angle is between any two generators (or group of generators) following a disturbance is $R \leq 180$ degrees. Otherwise, the system is unsecure [13].

2- The system is considered secure if the voltage magnitude at each bus is within $0.9 \leq V \leq 1.1$ per unit. Otherwise, the system is unsecure [12].

3- The system is considered secure if the frequency at each bus fluctuates within $49.5 \leq F \leq 50.5$ Hz. Otherwise, the system is unsecure [10].

Where R is rotor angle, V is voltage, F is frequency.

After implementing several fault scenarios on the IEEE-30Bus Model at transient case and determining the secure and unsecure cases and creating a database depend on the rotor angle determinants for the synchronous machines, the voltage and the frequency of the buses, they fed into the artificial intelligence program (WEKA) is an abbreviation for the phrase (Waikato Environment For Knowledge Analysis), where this program specializes in analyzing data with various artificial intelligence techniques through several specialized algorithms for the purposes of classification, prediction, description and for various scientific and research applications. This program has been used in this research to Classify accuracy of IEEE-30Bus Model for secure and unsecure cases.

The attribute selection technique is used on the data set and searching the data on the related sub-groups through several searches in the data and extracting the attributes that are not related or duplicated. This technique aims to preserve a large amount of basic data during the minizing and attribute extraction process without destroying the original data structure. This technique results in the extraction of more important attributes from the original attributes in the database. Attribute selection used to determine the accuracy of classification using decision tree algorithms, where four algorithms were used in this paper, namely: naive bayes, hoeffding tree, random forest and random tree. These algorithms with attribute selection technique gave different classification accuracy after reducing the numbers of attributes and the results will be displayed later [17].

3. IEEE-30Bus Model

The IEEE-30Bus Model used, where the model built using the power world simulator 17 program. The program contains a graphical interface that allows linking the various parts of the electrical power system from generators, transmission lines and buses. In addition, the program allows entering the real data of the electrical power system, studying the transient and stable condition of the system, and calculating the load flow for power system easily.

Newton Raphson and Gauss Seidel algorithms are used in this program in order to get best results for the system. It is capable of analyzing large systems consisting of 250,000 buses with high efficiency [11]. IEEE-30Bus Model consists of six synchronous machines: the first is 270 MW, the second is 40 MW, the third and fourth are 37 MVAR, the fifth is 16 MVAR and the sixth is 11 MVAR. The model contains 30 buses, 37 transmission lines. The total load is 283.4 MW and 126.2 MVAR [18], in addition to four transformers between buses and shunt switched 20.6 MVAR at bus 10, 4.3 MVAR at bus 24. The system shown in Fig. 2.

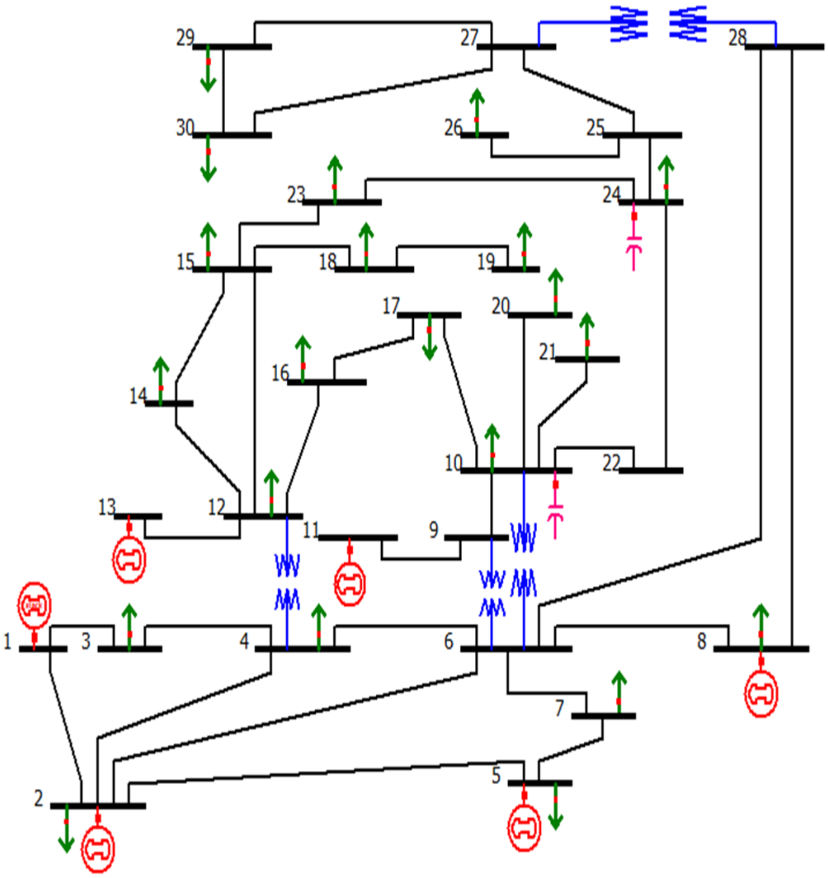

Figure 2. IEEE-30Bus Model

4. RESULTS AND DISCUSSION

Modeling of the electrical power system model was carried out in this chapter and the study cases for loads100%, 110% and 125% were simulated using the program power world simulator program. Several disturbance scenarios were implemented on the IEEE-30Bus Model at transient state, where the number of applied cases amounted 844 cases, which recorded 55704 readings of the rotor angle for synchronous machines, voltage and frequency for buses, and classify the cases of the system secure or unsecure. Where the faults were applied at a time of 1 second, the fault was removed after 0.1 second, and all readings were taken at 2.3 second. In this paper taking two cases at load 110% and 125% of normal load.

First case: losing two transmission lines. First transmission line between the bus No. 1 and bus No. 2, second transmission line between bus No. 2 and bus No. 4, at time 1.1 at (110%) load, reading measurments at 2.3 sec. where the Fig. 3 represents the rotor angle more than 180 degrees this is considered the system is unsecure case, the Fig. 4 represents the bus voltages at the same time and shows the fluctuation of voltages for the buses, because of the loss of two transmission lines from the system is considered unsecure condition due to voltages out of the normal range 0.9<V<1.1. Fig. 5 represents the bus frequency and the frequency exceeds the normal range 49.5<F<50.5, which represents the unsecure condition. All security limits violated, the system is considered unsecure case. In this case the system will deteriorate and lead to a power outage for consumers unless the necessary protection devices are activated and the appropriate decision is taken by the control center as soon as possible, this reflects the importance of the DSA in the electrical power system.

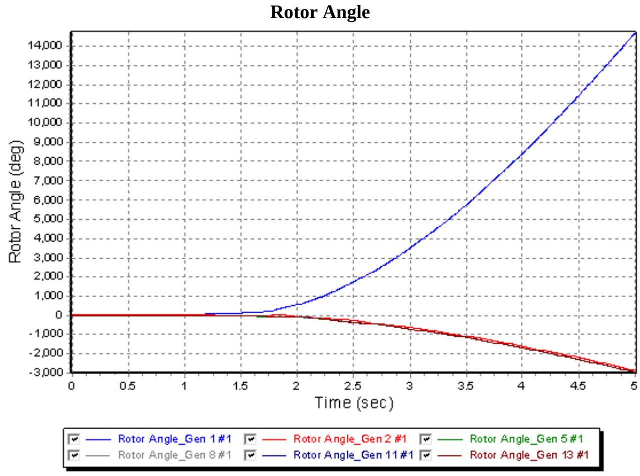

Figure 3. Show rotor angle at loss two transmission lines both ends

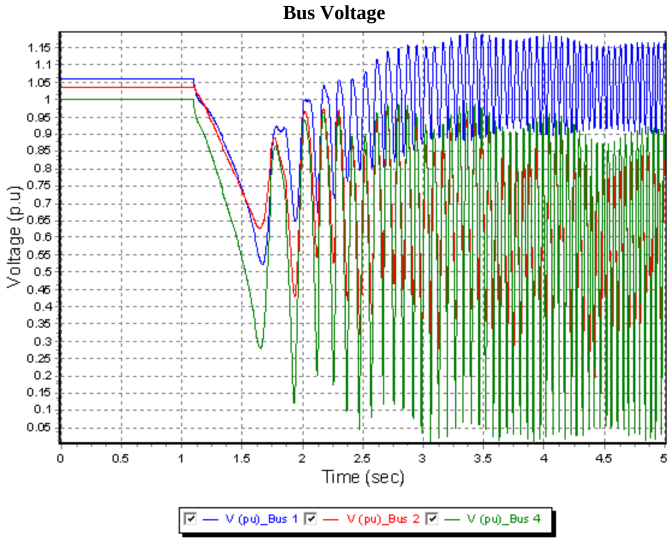

Figure 4. Bus-voltage at loss two transmission lines both end

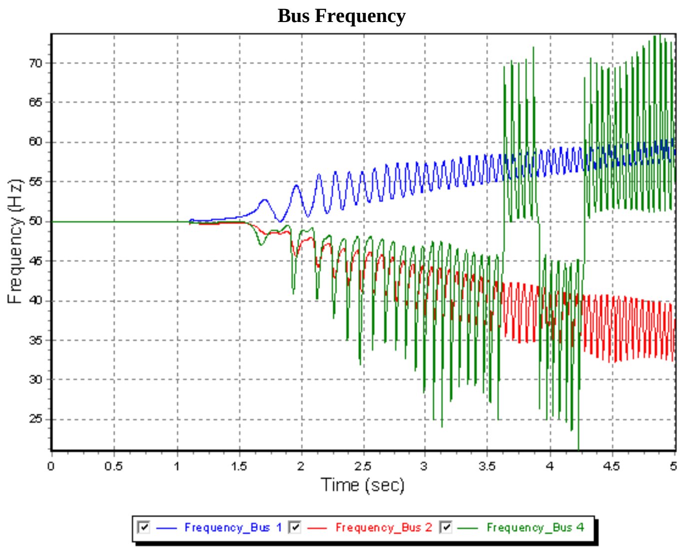

Figure 5. Bus-frequency at loss two transmission line both ends

The second case: the figures 6, 7, 8 represent the rotor angle for synchronous machines, bus voltages and bus frequency after applied a three-phase fault on the transformer between bus No. 12 and bus No. 4, where the fault was implemented at a time of 1 second and removed at 1.1 seconds at a load of 125%, reading measurments at 2.3 sec. where the figures show the secure case of the system for not exceeding the value of the rotor angle for synchronous machines show Fig. 6, the voltage and frequency of the buses determinants of security. In this case, we notice a drop in buses voltages during fault when there is a fault show Fig. 7, after the fault is removed the voltages return to the normal level and the system remains in a secure case, we also note in Fig. 8 the frequency fluctuation at the same time that the rotor angle and voltage measurements were taken, but within the normal limits and the stability of the system after removing the fault and working normally.

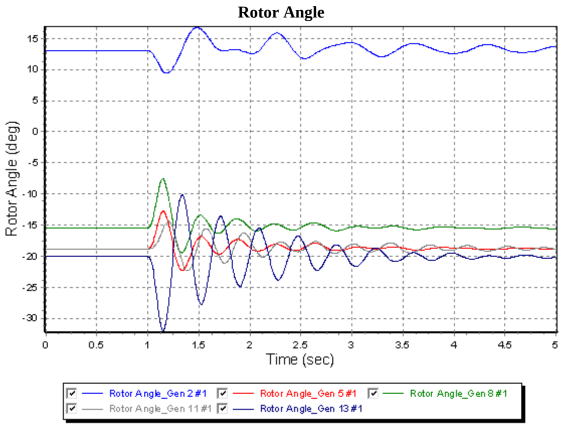

Figure 6. Rotor angle at three phase fault

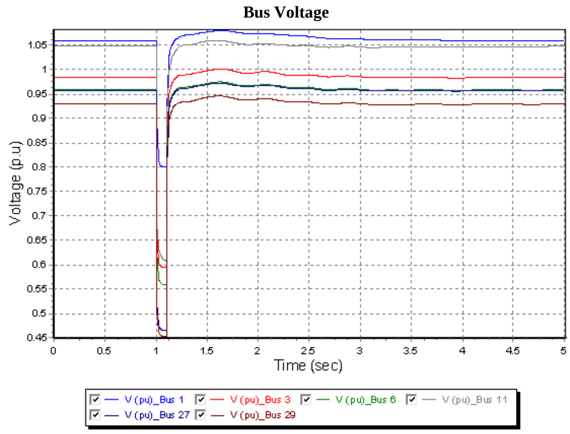

Figure 7. Bus-voltage at three phase fault

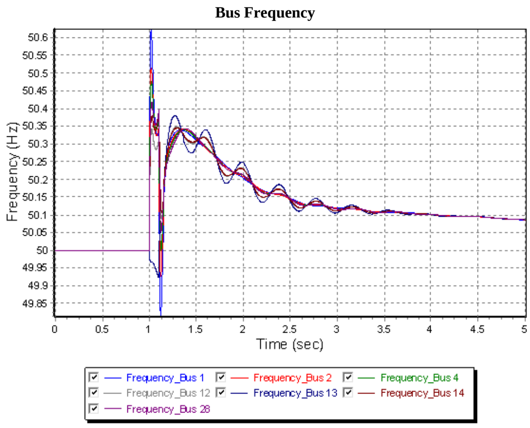

Figure 8. Bus-frequency at three phase fault

After classification the secure and unsecure system cases, and creating a database consisting of an matrix [844, 66], where the matrix row expresses 844 cases which are implemented on the model, that include emergency cases and malfunctions, the matrix column represents the number of attributes 66, which include measurements of the rotor angle for 6 synchronous machines, bus-voltage for 30 buses and bus- frequency for 30 buses. Cases represent matrix of secure cases [698, 66] which represents 82.70%, and unsecure cases [146, 66] which represents 17.29%. The database was entered into the WEKA program to find out the accuracy of classification of the secure and unsecure cases of the IEEE-30Bus Model using the attribute selection technique with decision tree algorithms, as it gave the results shown in Table 1.

Table 1. WEKA program results

Algorithm name	NO. basic Attributes	NO.Attributes using Attribute selection	Accuracy % Without Attribute selection	Accuracy % with Attribute selection
Naïve Bayes	66	6	90.28	92.65
Random Tree	66	30	94.19	96.20
Random Forest	66	15	96.44	97.39
Hoeffding Tree	66	7	89.92	93.01

Table (1) shows that results before and after using attribute selection technique. The number of attributes and accuracy, where each of these algorithms works on a specific mathematical model that works to discover the relationship between the attributes and the goal, the random forest algorithm show the highest accuracy reached 97.39% and reduced the number of attributes to 15 attribute, where attributes have been reduced to 77.27%. This algorithm works through the data, a number of decision trees are randomly built, then divided into sub-trees in the form of groups, and then new data points are predicted that give the highest vote and give the final decision. While the random tree algorithm gave accuracy 96.20%, but reduced number of attributes to 30 attribute was the reduction rate 54.54%. In this algorithm the decision tree is based on the attributes randomly at each node of the tree and then the related attributes are predicted and according to the mathematical equations of the algorithm the attributes are extracted without data trim. When using the hoeffding tree algorithm, it gives the accuracy of 93.01% and reduces the number of attributes to 7 attribute was reduction rate 89.39%, this algorithm is a big decision tree that needs big data, it assumes that the distributed data does not change over time and that it grows gradually based on hoeffding theorems that exploit it to get the ideal attribures. So we notice that the attributes are reduced by a small percentage due to the structure of this algorithm. However, when using the naive bayes algorithm the accuracy of 92.65% was given and reduce the number of attributes to 6 attribute was reducetion rate 90.90%, this algorithm relies on the absolute independence of traits through data mining, as it assumes the presence or absence of a specific attribute in a particular class that has no relation to another class. From the foregoing, we note that using the attribute selection technique with decision tree algorithms gave a reduction in the number of attributes and accuracy differently according to the structure of each algorithm, where the algorithms random forest and random tree outperformed the other algorithms.

Compared with the results of a previous study, we find the previous study used the attribute selection technique with random forest algorithm when applied to the IEEE-9Bus Model, the percentage of attribute reduction was 62.06% and accuracy reached 91.42%, and when applying the same algorithm and technique on the IEEE-14Bus Model, it gave attribute reduction rate of 68.88% and accuracy reached 97.77 [12]. By comparing the results of this paper with the results of the previous study, we note that the percentage of attribute reduction was better than IEEE-9Bus Model and IEEE-14Bus Model reached to 77.27%, as well as the accuracy was better than IEEE-9Bus Model and close to IEEE-14Bus Model, although this paper used a larger model and more faults than the previous study.

This paper used technology worked on minzing the basic data and accessing the relevant sub-data, which led to the extraction of attributes are less than the original attributes of importance, gave the highest accuracy in classification without damaging the basic data structure, so we note that the attribute selection technique has given a remarkable advantage through the use of decision tree algorithms and giving a high classification accuracy that can be used in control center to avoid emergency situations affecting the electrical power system.

5. CONCLUSIONS

The dynamic security of the electrical power system IEEE-30Bus Model was evaluated using the power world program, a number of fault scenarios were applied to the model to classify secure and unsecure cases through five steps, and a database was created to feed the artificial intelligence WEKA program to obtain classification accuracy using attribute selection technique with decision tree algorithms, where the results showed a significant reduction in the number of traits through the use of technique, which leads to speed in data analysis in the least possible time and through the use of four different algorithms, the random forest algorithm showed its superiority over other algorithms as it gave classification accuracy high reached 97.39%. This paper presents a very useful method for the control center especially when it is applied in internet environments and in general power systems, where it takes a long time to deal with large metering data. Therefore, reducing the number of attributes in the data set can improve accuracy and save more critical time for obtaining the final DSA result. This approach will help the control center to take correct and quick protection measures to protect the power grid from unsecure cases.

ACKNOWLEDGMENTS

The authors would like to thank the University of Mosul, College of Engineering, Electrical Department, for the support given during this work.

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