Fast Islanding Detection for Distribution System including PV using Multi-Model Decision Tree Algorithm

Rasool Ebrahimi[1], Ghazanfar Shahgholian[2*], Bahador Fani[3]
1- Smart Microgrid Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
2- Department of Electronics Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
shahgholian@iaun.ac.ir (Corresponding author)
2- Department of Electronics Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran.
bahador.fani@gmail.com

Received: December 2019 Revised: April 2020 Accepted: June 2020

ABSTRACT:
Modern distribution system including Distributed Generation (DG) requires reliable and fast islanding detection algorithms in order to determine the grid status. In this paper, a new multi-model classification-based method is proposed, in order to detect islanding condition for photovoltaic units. Decision tree is chosen as the classification algorithm to classify input feature vectors. The final result is based on voting among three decision tree algorithms. First order derivatives of electrical parameters are employed to construct feature vectors. To cover intermittent nature of renewable sources, different generating states for PV unit are assumed. Probable events are simulated under different system operating states to generate classification data set. The proposed method is tested on typical distribution system including the PV unit, different loads, and synchronous generator. This study showed that this method succeeds in highly fast islanding detection. This quick response can be used in micro-grid application as well as anti-islanding strategy. The results revealed that the proposed voting-base algorithm could classify instances with very high accuracy which leads to reliable operation of distributed generation units.

KEYWORDS: Data Mining, Distributed Generation, Intelligent Classification, Micro-Grid, Passive Islanding Detection.

1. INTRODUCTION

Technological advantages, reliability issues, transmission congestion and electrical efficiency resulted in rapid growth of distributed generation units connected to the network [1-3]. On the other hand, climate change and global warming, fossil fuel sources limitations and other environmental concerns have made the renewable sources as one of the alternatives for human energy sources. Solar energy is one kind of renewable energy sources with relatively high availability and low density which can be transformed into electrical energy by means of photovoltaic (PV) units [4-8]. PV units can be installed with low rated power nearby customer site and is compatible with distributed generation concept [9-11]. However, there are several challenges related to connecting DGs into the utility network and detecting islanding situation is the most important issue regarding operating distributed generations [12-16].

IEEE standard defines islanding condition as "a condition in which a portion of an area of Electric Power System (EPS) is energized solely by one or more local EPSs through the associated points of common coupling (PCCs) while that portion of the area EPS is electrically separated from the remaining area EPS [17]". Islanding condition can create a shock danger for personnel utility. In addition, islanding operation can damage the system equipment and consumers in the event because of out-of-phase reconnection of the network by the reclosers due to phase difference between the island voltage and the network [18]. Absence of grounding, uncoordinated protection, and change in error power, frequency and voltage control and power quality destruction are the other problems related to islanding condition [19].

As for these subjects, IEEE standard recommended the distributed generations to be disconnected in the islanding condition [20]. On the other hand, islanding operation is closely related to micro grid concept and will provide numerous benefits such as reliability improvement. A fast and reliable detection is an integral part in both anti-islanding protection and islanding operation concepts.

Several references in technical literature can be found on islanding detection approaches [21-23].

The islanding detection methods can be broadly

Paper type: Research paper
DOI: https://doi.org/10.29252/mjee.14.4.29
How to cite this paper: R. Ebrahimi, Gh. Shahgholian and B. Fani, **"Fast Islanding Detection for Distribution System including PV using Multi-Model Decision Tree Algorithm"**, *Majlesi Journal of Electrical Engineering*, Vol.14, No. 4, pp. 29-38, 2020.

classified into classical and modern as shown in Fig. 1 [24], [25].

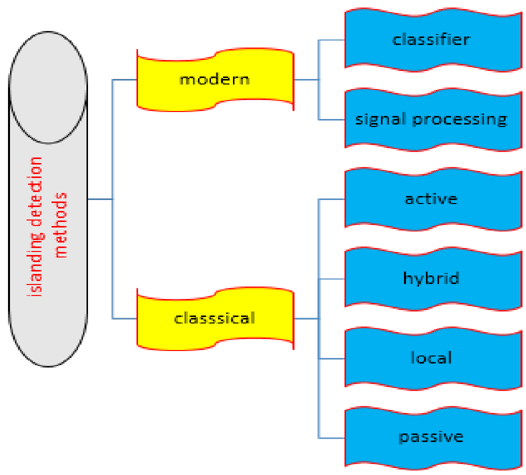

Fig. 1. Classification of the islanding detection methods.

In communication-based approaches downstream receives a continuous signal from utility where distributed generations are located and whenever this signal is not received by DG, islanding condition is identified [26]. These methods are expensive compared to other islanding detection methods at the present time [27]. The local techniques do not use any communication system to transfer data and can be grouped into active and passive islanding detection methods. Active approaches are based on intentionally injecting some sort of disorders into the grid and supervision their responses. At a time when utility is disconnected, in the other words formed an island, injected disruptions cause abnormal situation which is detectible as islanding condition [28,29]. Active methods have smaller indiscrimination zone; however, the power quality degradation is the important concern regarding these methods especially in the presence of renewable distributed generations.

Furthermore, many of these techniques do not show an acceptable performance when there are several distributed generations within an island [30]. Many active techniques have been proposed such as slip-mode frequency shift [31,32], active frequency drift [33,34], Sandia frequency shift [35,36], harmonic distortion, voltage shift and grid impedance measurement [37,38]. Passive islanding detection technique decision making is based on measuring the network parameters such as frequency, voltage amplitude and phase at DG side. These ways basically rely on identify of disorders in measured parameters when the utility is cutoff. Passive methods do not inject any disturbances into the system; thus the power quality is not degraded.

Numerous works have been done and published on the passive islanding detection methods such as frequency change rate, voltage change rate, vector surge relays, voltage unbalance variation, the total harmonic distortion, and phase angle difference change rate [39,40].

For passive islanding recognize, the data mining approach has been used [41,42]. An intelligent-based approach for detecting islanding in DG unit is introduced in [43] in order to secure the detection of islanding for any possible network topology, penetration level and operating condition of the DG. A method for determination of the threshold settings of islanding relays in DG interconnections is introduced in [44], which it uses data-mining approaches to extract the settings information of the optimal relay from a large data set of network parameters. A passive islanding detection technique for grid-connected inverter-based DG units based on statistical signal-processing algorithm is proposed in [45]. The accuracy of this method is acceptable; however, the delay of statistic processing part has reduced the speed of detection compared to other islanding detection methods. The pattern-recognition-based method for fast detection of power islands in a DG is studied in [46], which a decision-tree classifier is trained to categorize the transient generating events as “islanding” or “non-islanding". A method based on wavelet design to determine the filter coefficients applied to passive islanding detection of DG is presented in [47], which automatically the classification process, machine learning algorithms are used to develop appropriate models.

A total comparison of Strength and weakens of different islanding techniques are shown in Table 1 [48], [49].

Table 1. Comparison of Islanding Detection Techniques.

Methods / Comparable Parameter	Classical			Modern	
	Active	Passive	Hybrid	Remote	Machine learining
Non-detection zone	Limmited	Broad	Limited	None	limited
Detection time	Long	Short	Long	Very short	Variable
Cost	Averege	Low	High	High	High
Detectin reliability	High	Low	High	Very high	High
Power quality	Degradation	No effect	Degradation	No effect	No effect
Effect of multiple DGs	Synchronization issues	None	Synchronization issues	None	None

In this paper, a passive islanding detection method based on multi-model decision tree approach is presented. Each model is extracted from a specific set of feature for all training instances. The final result is based on voting between the outputs of each model. The proposed approaches can be used in micro-grid and mandatory islanding operation [50] and also protection applications in anti-islanding.

2. PATTERN RECOGNITION

Electrical parameters follow several detectible patterns after islanding at the DG bus. To recognize these patterns, we have to define appropriate features and construct data set. Subsequently, we can train a number of classifiers which are able to recognize islanding patterns.

2.1. Feature Calculation

The features map the electrical parameter values to a space in which data mining algorithms can find specific patterns. Generally, each grid event results in variation of electrical parameters such as voltage, current, and frequency. On-line local network monitoring at node end of DG reads the information needed to build the islanding detection data set. Sampling an electrical signal constructs a data string x[i]. The time interval between two samples is Δt. The first order discrete derivative of x can be defined as:

$$Dx[i] = \frac{x[i+1] - x[i]}{\Delta t} \tag{1}$$

The features which are used as data mining inputs are usually a number instead of a string; thus we have to transform them into a number. Averaging over an appropriate time interval (T) can provide us a number which represents the behavior of that signal over a specific period of time:

$$\overline{D}x(n,T) = \sum_{i=n}^{n+T} Dx[i] \tag{2}$$

2.2. Data Set Construction

Sampling three-phase current and three-phase voltage signals results in strings of data which are employed to construct the features. In other words, each feature is a function of previous samples of voltage and current signals. Each Feature Vector (FV) is a point in n-dimensional feature space and represents system behavior in previous T samples. The class of each feature vector shows islanding condition during that time interval:

$$FV^i = \left\{ f_1^i,\ f_2^i, \ldots,\ f_n^i \right\}; \quad c^i \in \{0,1\} \tag{3}$$

Where, f_n^i is n^{th} feature for i^{th} instance and c^i is class of i^{th} instance (for non-islanding 0 and for islanding condition 1). Each feature vector represents system behavior after an event under a specific operating condition. Consequently, a Feature Matrix (FM) including *m* feature vectors and the corresponding Class Vector (CV) can be defined as follows:

$$FM = \begin{bmatrix} FV^1 \\ FV^2 \\ \vdots \\ FV^i \\ \vdots \\ FV^m \end{bmatrix} = \begin{bmatrix} f_1^1 & f_2^1 & \cdots & f_j^1 & \cdots & f_n^1 \\ f_1^2 & f_2^2 & \cdots & f_j^2 & \cdots & f_n^2 \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ f_1^i & f_2^i & \cdots & f_j^i & \cdots & f_n^i \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ f_1^m & f_2^m & \cdots & f_j^m & \cdots & f_n^m \end{bmatrix} \tag{4}$$

$$CV = \begin{bmatrix} c^1 & c^2 & \cdots & c^i & \cdots & \cdots & \cdots & c^m \end{bmatrix}^T \tag{5}$$

2.3. Training and Testing

Any event in the network has a special signature on the feature vector which can be identified via a trained classifier. The main objective of data mining-based islanding detection methods is to classify feature vectors as islanding and non-islanding. The classifiers of islanding detection are trained by tagged feature vectors called training data set. Figs. 2 and 3 show the islanding detection classifier training and testing process, respectively. Training and testing feature matrix are chosen randomly from the original data set (Fig. 2). The classifiers are trained with Training Feature Matrix and corresponding Training Class Vector. The trained classifiers will be tested by Testing Feature Matrix. Ultimately, classification accuracy will be determined by comparing Result Class Vector and Testing Class Vector, which is displayed in Fig. 4.

3. DECISION TREE ALGORITHM

Decision tree algorithm is employed to classify feature vectors in this paper [51-54]. Decision tree classifiers are easier to interpret than other classification methods because decision tree is able to break down complex decision making process into multi union of simpler decisions. Generally, decision tree classifier training is based on finding the best split at each node. An index (frequently called information gain) is used as a measure for quality of splitting. It indicates that how good the node is segmented. Using a search method, the split which gives the best information gain will be determined. This split is chosen among all the possible splits over all the features. Based on this segmentation, two nodes called child nodes are created. This procedure continues until data purity of each node reaches a predefined threshold. A terminal node is one where no more splits are made and contains the purest data. Each leaf node has a label indicating the class of majority of its data. In spite of much time consumption at decision tree's training process, its classification is highly fast because it is accomplished just by several sequential comparisons. Fig. 5 shows a 2-class decision tree with 3 child and 5 leaf nodes.

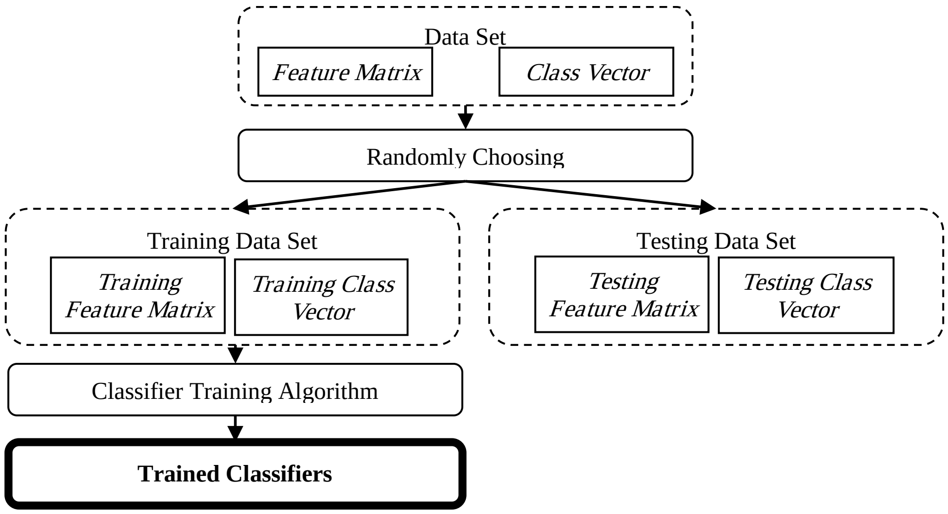

Fig. 2. Training the islanding detection classifiers.

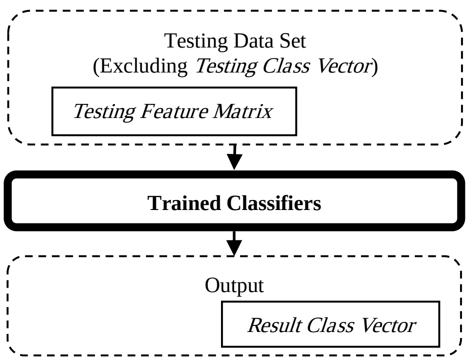

Fig. 3. Testing the islanding detection classifiers.

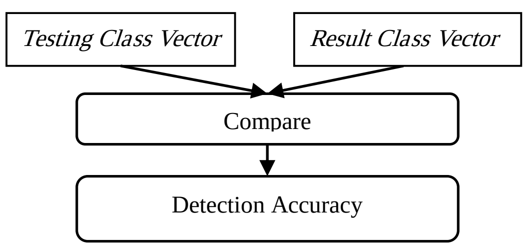

Fig. 4. Determining detection accuracy.

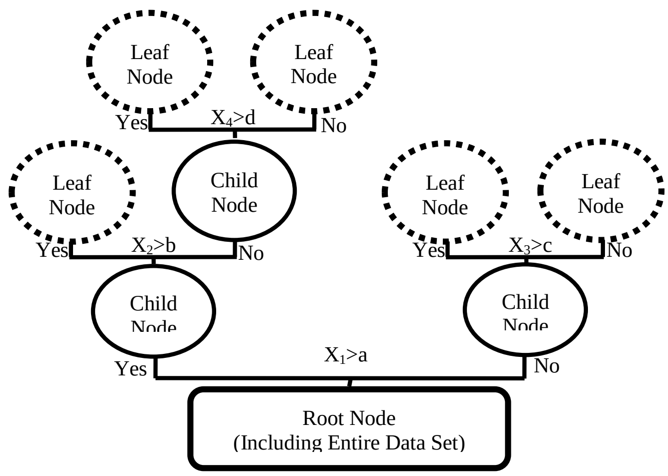

Fig. 5. Two class decision tree with 3 child nodes and 5 leaf nodes.

4. ISLANDING DETECTION USING DECISION TREE ALGORITHM

Decision tree algorithm was explained in previous section. This section describes how islanding condition can be detected by means of this algorithm. Initially, the features should be defined and then data set will be constructed. Eventually, we should train and test appropriate classifiers to detect the islanding condition.

4.1. Islanding Detection Features

Choosing appropriate features is an integral part of classification problem. Diverse electrical parameters can be chosen for island detection; however, several considerations should be taken into account such as calculation effort and the required measurement devices. Features which are selected for islanding detection in this study are given in Table 2.

4.2. Islanding Detection Data Set

Each feature vector represents the behavior of system after an event occurrence under a specific operation condition. To build a comprehensive data set for islanding detection classifier training, different system operating conditions as well as probable events should be simulated. Renewable sources power intermittency and load variation are the main factors which change the system operation condition. By dividing the range of generating/consuming power DGs/Loads into the discrete values and combining them, different operating stated of the system can be determined. Various events may occur in the grid and each one has specific signature on feature vector; thus diverse events should be simulated. Events such as switching action, fault events, load outage, DG outage and line outage should be simulated under aforementioned network operation states.

Table 2. Islanding Detection Features.

Feat.	Definition	Dimension	Parameter
f_1	D(P)	[MW/s]	DG active power
f_2	D(Q)	$[MVAr/s]$	DG reactive power
f_3	D(f)	$[Hz/s]$	Frequency
f_4	D(v)	$[p.u./s]$	Voltage phasor amplitude
f_5	D(S/V)	$[MVA/p.u.\times s]$	Apparent power over voltage
f_6	D(Cosφ)	$[MW/MVA\times s]$	DG power factor
f_7	D(θ_V)	$[rad/s]$	Voltage phase
f_8	D(φ)	$[rad/s]$	Angle between voltage and current

4.3. Decision Making Based on Multi-Model Decision Tree

A decision tree as shown in Fig. 4, classifies input feature vectors by a sequential decision making process. Each tree uses a limited number of the features and to avoid over fitting by pruning algorithms, a number of the node are eliminated. Normally in islanding detection applications, number of features which a decision tree algorithm uses to classify the data set, is less than the total number of input data features. Since heuristic search method finds the best split at each node of decision tree, some data may be lost. To overcome the addressed problem, a multi model algorithm is proposed which is capable to classify islanding cases with higher accuracy. In the first step, the features are sorted based on their importance. Next, two subsets including four members and one subset including all features are selected. Fig. 6 illustrates feature allocation to each model. In the proposed scheme, the decision making process is based on voting between three decision tree models. As shown in Fig. 6, the features should be sorted base on their importance. Different ways can be applied to sort the features at this stage. One approach can be as explained below:

Step 1: Train decision tree classifier using all features.

Step 2: Determine the first feature which is split. Place this feature at top of the list of feature which is sorted by the feature importance.

Step 3: Omit previous feature. Train decision tree classifier with the remaining features.

Step 4: Do steps 2 to 4 until all features are sorted.

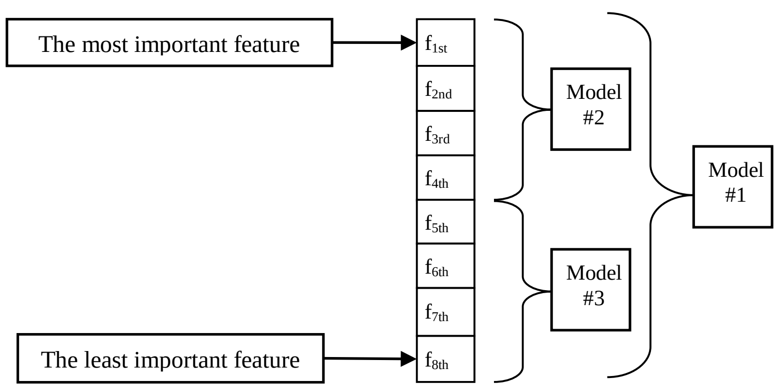

Fig. 6. Allocating feature to three decision tree models.

5. SYSTEM UNDER STUDY

A single-line diagram of a 13.8 KV distribution network is show in Fig. 7. It used to demonstrate the proposed islanding detection method. The system under study consists of two DG units: a conventional DG unit connected to bus two and a set of PV units connected to bus four. The conventional DG is a slow-response diesel generator equipped with excitation and governor controllers. The elements rated values for distribution system of Fig. 7 are given in appendix. Three scenarios for PV generation and two scenarios for system loading are assumed to construct the classification data set.

Table 3 summarizes PV generation states and system loading states, respectively. Combination of PV states and system loading result in 6 (=3×2) operating states. Eight accidents are defined to be simulated under the above operating states. Events are based on topology of system and are listed in Table 4. Short circuit event (Ev5) is cleared without any circuit breaker operation after five ms, therefore this event should not be detected as islanding event. All events are simulated under each aforementioned operating state. The combination of events and operating states result in 48 (=6×8) simulations cases.

Table 3. PV Generation and System Loading States.

	State Index	**Description**
PV Generation State	**PVH**	PV Generation 100% of its Capacity
	PVM	PV Generation 100% of its Capacity
	PVL	PV Generation 100% of its Capacity
Loading State	**Load H**	All Loads are at 100% of nominal value
	Load L	All Loads are at 25% of nominal value

Table 4. System Events.

Event Index	Event Type	Event place	Element	Islanding status
Ev1	Load Outage	Bus 4	L2	-1
Ev2	Load Outage	Bus 3	L1	-1
Ev3	Sync. Gen. Outage	Bus 2	Sync. Gen.	-1
Ev4	Line Outage	Between Bus 2&4	Line 2	-1
Ev5	Short Circuit	Bus 1	-	-1
Ev6	Circuit Breaker Trip	Bus 2	cb 3	1
Ev7	Circuit Breaker Trip	Bus 1	cb 2	1
Ev8	Circuit Breaker Trip	Bus 1	cb 1	1

6. RESULTS AND DISCUSSION

Randomly, 80% of the total features (38 features) are chosen for training and 20%remaining (10 features) for testing the proposed classification algorithm. The final results of 10 randomly chosen features for PV bus are listed in Table 5. The results reveal that for 10 test cases, decision tree model number 1, 2 and 3 have 80, 70 and 70 percent accuracy, respectively but voting based multi-model decision tree has 90 percent accuracy. Decision tree model number 1 has false result for both short circuit events (Ev5-PVM-Load Land Ev5-PVL-Load H). Decision tree model number 2 has false result for load outage nearby PV unit (Ev1- PVH-Load H), short circuit event (Ev5-PVL-Load H) and main outage (Ev7-PVL-Load H). Decision tree model number 3 has false result for load outage nearby PV unit (Ev1- PVH-Load H), short circuit event (Ev5-PVL-Load H) and main outage (Ev7-PVL-Load L). Voting based multi model decision tree has just one misclassification case where all models have false result (Ev5-PVL-Load H). Generally, cases which are related to load outage nearby PV bus (Ev1-PVM-Load L, Ev1- PVH-Load H) and short circuit events (Ev5-PVM-Load L, Ev5-PVL-Load H) have severe effect on the electrical parameters which is similar to islanding condition and consequently in these cases probability of false islanding trip increases.

On the other hand, in cases which the difference between load and generation is not much enough, the probability of not detecting islanding condition, increases. It can be perceived that the proposed method can detect islanding condition with high accuracy and can increase reliability of the system operation.

The proposed method for islanding detection has a very fast response which makes it suitable for both micro-grid operation and anti-islanding protection applications.

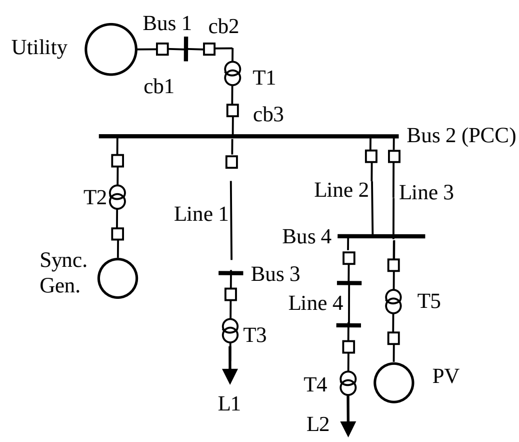

Fig. 7. Case Study Distribution System.

Table 5. Islanding Detection Results for PV unit.

No	Simulation Index	Islanding Status	Decision Tree Model Results			Voting based Multi model- Decision Tree Results
			Model #			
			1	2	3	
1	**Ev1-PVM-Load L**	-1	-1	-1	1	-1
2	**Ev1- PVH-Load H**	-1	-1	1	-1	-1
3	**Ev3-PVM-Load H**	-1	-1	-1	-1	-1
4	**Ev4-PVM-Load L**	-1	-1	-1	-1	-1
5	**Ev4-PVL-Load H**	-1	-1	-1	-1	-1
6	**Ev5-PVM-Load L**	-1	1	-1	-1	-1
7	**Ev5-PVL-Load H**	-1	1	1	1	1
8	**Ev6-PVH-Load L**	1	1	1	1	1
9	**Ev7-PVL-Load H**	1	1	-1	1	1
10	**Ev7-PVL-Load L**	1	1	1	-1	1
Correctly Classified instances			8	7	7	9
Accuracy			80%	70%	70%	90%

The classification process needs limited number of logical comparisons which can be performed within one millisecond. Feature vector extracting also does not need considerable calculation effort and can be done within three milliseconds. Maximum intrinsic time delay of this technique (as mention in previous sections) is five milliseconds. Considering the unpredictable delays related to measurement devices and other system components, the proposed method can detect islanded system within one cycle which improves control and protection systems to perform effectively in islanding conditions.

7. CONCLUSION

A passive data mining-based islanding detection method in system for PV unit's application is presented in this paper. Multi-model decision tree algorithm is used to reveal islanding condition. Intermittent behavior of renewable generation is considered in training data set generation by assuming several generation scenarios for PV unit. The data mining-based islanding detection method is capable of detecting islanding condition with high accuracy which is further increased due to voting-base decision making process. The selected features do not require any mathematical transformations; thus feature calculation time is less than transformation-base algorithms. Moreover, classification algorithm can be run just by comparison process which leads to detecting islanding condition within one cycle. The proposed fast multi-model decision tree algorithm can be utilized for both micro-grid and anti-islanding protection applications.

APPENDIX

Synchronous Generator (2.15 MW), H=2.9 s, X_d=0.97p.u., X_q=0.41p.u., X'_d=0.26p.u., X'_q=0.36p.u., X''_d=0.175p.u., X''_q=0.21p.u.,

PV (135 kW) including monocrystalline photovoltaic panels equipped with sun tracking system.

T1: rated MVA=15 MVA, rated kV= 69/13.8 kV, Dyn, Z=0.00667+j0.0533 p.u., RG=20 Ω;

T2: rated MVA=3.5 MVA, rated kV= 13.8/2.4 kV, Dyn, Z=0.021+j0.1094 p.u.;

T3: rated MVA=3.75 MVA, rated kV= 13.8/2.4 kV, Dyn, Z=0.0244+j0.148 p.u., RG=3.5Ω;

T4: rated MVA=1.25 MVA, rated kV= 13.8/0.48 kV, Dyn, Z=0.056+j0.48 p.u.;

T5: rated MVA=0.315 MVA, rated KV= 13.8/4.14 KV,Dy, Z=0.0256+j0.113p.u.;

L1: rated power =1.0 MW, rated kV=2.40 kV; L4:rated power =1.0 MW, rated kV=0.48 kV;

L2: rated power =1.0 MW, rated kV=0.48 kV; L6:rated power =1.0 MW, rated kV=0.48 kV;

Line 1: rated kV=13.8 kV, Z_S=0.06141+ j0.03066 p.u.; Line 2: rated kV=13.8 kV, Z_S=0.03564+ j0.02661 p.u.;

Line 3: rated kV=13.8 kV, Z_S=0.03564+ j0.02661 p.u.; Line 4: rated kV=13.8 kV, Z_S=0.00420+ j0.00154 p.u.;

REFERENCES

[1] H. Manafi, N. Ghadimi, M. Ojaroudi, P. Farhadi, **"Optimal placement of distributed generations in radial distribution systems using various PSO and DE algorithms"**, *Elecktronika*, Vol. 19, No. 10, pp. 53-57, 2013.

[2] S. Gorji, S. Zamanian, M. Moazzami, **"Techno-economic and environmental base approach for optimal energy management of microgrids using crow search algorithm"**, *Journal of Intelligent Procedures in Electrical Technology*, Vol. 11, No. 43, pp. 49-68, Autumn 2020.

[3] E. Aghadavoodi, G. Shahgholian, **"A new practical feed-forward cascade analyze for close loop identification of combustion control loop system through RANFIS and NARX",** *Applied Thermal Engineering*, Vol. 133, pp. 381-395, March 2018.

[4] G. Shahgholian, Z. Azimi, **"Analysis and design of a DSTATCOM based on sliding mode control strategy for improvement of voltage sag in distribution systems"**, *Electronics*, Vol. 5, No. 3, pp. 1-12, 2016.

[5] J. Faiz, G. Shahgholian, M. Ehsan, **"Stability analysis and simulation of a single-phase voltage source UPS inverter with two-stage cascade output filter",** *European Transactions on Electrical Power*, Vol. 18, No. 1, pp. 29-49, Jan. 2008.

[6] B. Fani, F. Hajimohammadi, M. Moazzami, M. J. Morshed, **"An adaptive current limiting strategy to prevent fuse-recloser miscoordination in PV-dominated distribution feeders"**, *Electric Power Systems Research*, Vol. 157, pp. 177-186, April 2018.

[7] M. Salari, F. Haghighatdar-Fesharaki, **"Optimal placement and sizing of distributed generations and capacitors for reliability improvement and power loss minimization in distribution networks",** *Journal of Intelligent Procedures in Electrical Technology*, Vol. 11, No. 43, pp. 83-94, Autumn 2020.

[8] B. Keyvani-Boroujeni, G. Shahgholian, B. Fani, **"A distributed secondary control approach for inverter-dominated microgrids with application to avoiding bifurcation-triggered instabilities",** *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 8, No. 4, pp. 3361-3371, Dec. 2020.

[9] M.A. Ozcelik, A.S. Yilmaz, S. Kucuk, M. Bayrak, **"Efficiency in centralized DC systems compared with distributed DC systems in photovoltaic energy conversion",** *Elektronika*, Vol. 21, No. 6, pp. 51-56, 2015.

[10] M. Tavoosi, B. Fani, E. Adib, **"Stability analysis and control of DFIG based wind turbine using FBC strategy",** *Journal of Intelligent Procedures in Electrical Technology*, Vol. 4, No. 15, pp. 31-42, 2013.

[11] E. Hosseini, G. Shahgholian, **"Partial- or full-power production in WECS: A survey of control and structural strategies"**, *European Power Electronics and Drives*, Vol. 27, No. 3, pp. 125-142, Dec. 2017

[12] F. Varshosaz, M. Moazzami, B. Fani and P. Siano, **"Day-ahead capacity estimation and power management of a charging station based on queuing theory"**, *IEEE Trans. on Industrial Informatics*, Vol. 15, No. 10, pp. 5561-5574, Oct. 2019

[13] G. Wang, J. Wang, Z. Zhou, Q. Wang, Q. Wu, X. Jiang, E. Santana, **"State variable technique islanding detection using time-frequency energy analysis for DFIG wind turbine in microgrid system**", ISA *Transactions*, Vol. 80, pp. 360-370, Sep. 2018.

[14] E. Abbaspour, B. Fani, E. Heydarian-Forushani, **"A bi-level multi agent based protection scheme for distribution networks with distributed generation",** *International Journal of Electrical Power and Energy Systems*, Vol. 112, pp. 209-220, Nov. 2019

[15] R. Nale, K. Venkatanagaraju, S. Biswal, M. Biswal, N. Kishor, **"Islanding detection in distributed generation system using intrinsic time decomposition",** *IET Generation, Transmission and Distribution*, Vol. 13, No. 5, pp. 626-633, March 2019.

[16] A. Shrestha, R. Kattel, M. Dachhepatic, B. Mali, R. Thapa, A. Singh, D. Bista, B. Adhikary, A. Papadakis, R. K. Maskey, **"Comparative study of different approaches for islanding detection of distributed generation systems",** *Applied System Innovation*, Vol. 25, No. 2, 2019.

[17] IEEE Standards 1547, "**Standard for interconnecting distributed resources with electric power systems",** July 2003.

[18] A.S. Aljankawey, W. G. Morsi, L. Chang, C.P. Diduch, **"Passive method-base islanding detection of renewable-based distributed generation: The Issue",** *Proceeding of the IEEE/EPEC*, pp. 1-8, Aug. 2010.

[19] A. Elmitwally, M. Elsaid, M. Elgamal, Z. Chen, **"A fuzzy-multi agent service restoration scheme for distribution system with distributed generation",** *IEEE Trans. on Sustainable Energy*, Vol. 6, No. 3, pp. 810-821, July 2015.

[20] IEEE Standards 1547.1, **"Standard conformance test procedure for equipment interconnecting distributed resources with electric power systems**, 2005.

[21] M. M. Taheri, H. Seyedi, M. Nojavan, M. Khoshbouy, B. Mohammadi-Ivatloo, **"High-speed decision tree based series-compensated transmission lines protection using differential phase angle of superimposed current",** *IEEE Trans. on Power Delivery*, Vol. 33, No. 6, pp. 3130 – 3138, Dec. 2018.

[22] H. Pourbabak, A. Kazemi, **"Islanding detection method based on a new approach to voltage phase angle of constant power inverters"**, *IET Generation, Transmission and Distribution*, Vol. 10, No. 5, pp. 1190-1198, April 2016.

[23] M. M. Taheri, H. Seyedi, B. Mohammadi-Ivatloo, **"DT-based relaying scheme for fault classification in transmission lines using MODP",** *IET Generation, Transmission and Distribution*, Vol. 11, No. 11, pp. 2796-2804, Feb. 2017.

[24] V. Menon, M.H. Nehrir, **"A hybrid islanding detection technique using voltage unbalance and frequency set point",** *IEEE Trans. on Power Systems*, Vol. 22, No. 1, pp. 442-448, Feb. 2007.

[25] S. Dutta, P. K. Sadhu, M. J. B. Reddy, D. K. Mohanta, **"Shifting of research trends in islanding detection method- A comprehensive survey",**

Protection and Control of Modern Power Systems, Vol. 3, No. 1, pp. 1-20, 2018.

[26] W. Xu, G. Zhang, C. Li, W. Wang, G. Wang, J. Kliber, **"A power line signaling technique for anti-islanding protection of distributed generators- Part I: Scheme and analysis",** *IEEE Trans. on Power Delivery*, Vol. 22, No. 3, pp. 1767-1772, July 2007.

[27] R.S. Kunte, W. Gao, **"Comparison and review of islanding detection for distributed energy resources",** *Proceedings of the North American Power Symposium*. pp. 1-8, 2008.

[28] L.A.C. Lopes, H. Sun, **"Performance assessment of active frequency drifting islanding detection methods",** *IEEE Trans. on Energy Conversion*, Vol. 21, No. 1, pp. 171-180, Feb. 2006.

[29] M.E. Ropp, M. Begovic, A. Rohatgi, **"Analysis and performance assessment of the active frequency drift method of islanding prevention",** *IEEE Trans. on Energy Conversion*, Vol. 14, No. 3, pp. 810-816, Sep. 1999.

[30] P. Mahat, Z. Chen, B. Bak-Jensen**, "Review of islanding operation of distribution system with distributed generation"**, *Proceedings of the IEEE/PES*, pp. 1-8, July 2011.

[31] F. Liu, Y. Kang, Y. Zhang, S. Duan, X. Lin**, "Improve SMS islanding detection method for grid-connected converters"**, *IET Renewable Power Generation*, Vol. 4, No. 1, pp.36-42, Jan. 2010.

[32] S. Bifaretti, A. Lidozzi, L. Solero, F. Crescimbini, **"Anti-islanding detector based on a robust PLL",** *IEEE Trans. on Industry Applications*, Vol. 51, No. 1, pp. 398-405, Jan./Feb. 2015.

[33] B. Wen, D. Boroyevich, R. Burgos, Z. Shen, P. Mattavelli, **"Impedance-based analysis of active frequency drift islanding detection for grid-tied inverter system",** *IEEE Trans. on Industry Application*, Vol. 52, No. 1, pp. 332-341, Jan./Feb 2016.

[34] A. Yafaoui, B. Wu, S. Kouro, **"Improved active frequency drift anti-islanding detection method for grid connected photovoltaic systems",** *IEEE Trans. on Power Electronics,* Vol. 27, No. 5, pp. 2367-2375, May 2012.

[35] H.H. Zeineldin, S. Kennedy, **"Sandia frequency-shift parameter selection to eliminate nondetection zones",** *IEEE Trans. on Power Delivery*, Vol. 24, No. 1, pp. 486-487, Jan. 2009.

[36] M.A. Hosani, Z. Qu, H.H. Zeineldin, **"Scheduled perturbation to reduce non detection zone for low gain sandia frequency shift method"**, *IEEE Trans. on Smart Grid*, Vol. 6, No. 6, pp. 3095-3103, Nov. 2015.

[37] S. Liu, S. Zhuang, Q. Xu, J. Xiao, **"Improved voltage shift islanding detection method for multi-inverter grid-connected photovoltaic systems",** *IET Generation, Transmission & Distribution*, Vol. 10, No. 13, pp. 3163-3169, Oct. 2016.

[38] D.D. Reigosa, F. Briz, C.B. Charro, J.M. Guerrero, **"Islanding detection in three-phase and single-phase systems using pulsating high-frequency signal injection"**, *IEEE Trans. on Power Electronics*, Vol. 30, No. 12, pp. 6672-6683, Dec. 2015.

[39] W. Freitas, W. Xu, C.M. Affonso, Z. Huang, **"Comparative analysis between ROCOF and vector surge relays for distributed generation applications",** *IEEE Trans. on Power Delivery*, Vol. 20, No. 2, pp. 1315-1324, April 2005.

[40] J. Merino, P. Mendoza-Araya, G. Venkataramanan, M. Baysal, **"Islanding detection in microgrids using harmonic signatures"**, *IEEE Trans. on Power Delivery*, Vol. 30, No. 5, pp. 2102–2109, Oct. 2015.

[41] A.G. Abd-Elkader, S.M. Saleh, M.B.M. Eiteba, **"A passive islanding detection strategy for multi-distributed generations"**, *International Journal of Electrical Power and Energy Systems*, Vol. 99, pp. 146-155, July 2018.

[42] H. Samet, F. Hashemi, T. Ghanbari, **"Islanding detection method for inverter-based distributed generation with negligible non-detection zone using energy of rate of change of voltage phase angle",** *IET Generation, Transmission and Distribution*, Vol. 9, No. 15, pp. 2337-2350, Nov. 2015.

[43] P. Mahat, Z. Chen, B.B. Jensen, **"A hybrid islanding detect technique using rate of voltage change and real power shift"**, *IEEE Trans. on Power Delivery*, Vol. 24, No. 2, pp. 764-771, April 2009.

[44] W. Freitas, Z. Huang , W. Xu, **"A practical method for assessing the effectiveness of vector surge relays for distributed generation applications"**, *IEEE Trans. on Power Delivery,* Vol. 20, No. 1, pp. 57-63, Jan. 2005.

[45] S.I. Jang, K.H. Kim, **"An islanding detection method for distributed generation using voltage unbalance and total harmonic distortion of current",** *IEEE Trans. on Power Delivery*, Vol. 19, No. 2, pp.745-752, 2004.

[46] A. Samui S.R. Samantaray, **"Assessment of ROCPAD relays for islanding detection in distributed generation",** *IEEE Trans. on Smart Grid*, Vol. 2, No. 2, pp.391-398, June 2011.

[47] N. Liu, C. Diduch, L. Chang, J. Su, **"A reference impedance- based passive islanding detection method for inverter-based distributed generation system",** *IEEE Journal of Emerging and Selected Topics in Power Electronics*, Vol. 3, No. 4, pp. 1205-1217, July 2015.

[48] G. Bayrak, E. Kabalci, **"Implementation of a new remote islanding detection method for wind–solar hybrid power plants",** *Renewable and Sustainable Energy Reviews*, Vol. 58, pp. 1-15, May 2016.

[49] A. Pigazo, M. Liserre, R. A. Mastromauro, V. M. Moreno, A. Dell'Aquila, **"Wavelet-based islanding detection in grid-connected PV systems",** *IEEE Trans. on Industrial Electronics*, Vol. 56, No. 11, pp. 4445–4455, Nov. 2009.

[50] K. El-Arroudi, G. Joós, I. Kamwa, D.T. McGillis, **"Intelligence base approach to islanding detection in distributed generation",** *IEEE Trans. on Power Delivery*, Vol. 22, No. 2, pp. 828-835, April 2007.

[51] K. El-Arroudi. G. Joós, I. Kamwa, "**Data mining approach to threshold settings of islanding relays in distributed generation",** *IEEE Trans. on Power Systems*, Vol. 22, No. 3, pp. 1112-1119, Aug. 2007.

[52] W.K.A. Najy, H.H. Zeineldin, A.H.K. Alaboudy, W.L. Woon, **"A bayesian passive islanding detection**

method for inverter-based distributed generation using ESPRIT", *IEEE Trans. on Power Delivery*, Vol. 26, No. 4, pp. 2687-2696, Oct. 2011.

[53] X. Wang, F. Liu, **"Data-driven relay selection for physical-layer security: A decision tree approach",** *IEEE Access*, Vol. 8, 12105 – 12116, 2020.

[54] M. Gohari, A. M. Eydi, **"Modelling of shaft unbalance: Modelling a multi discs rotor using k-nearest neighbor and decision tree algorithms"**, *Measurement*, Vol. 151, Article 107253, Feb. 2020.