International Journal of Engineering & Technology, 7 (1) (2018) 228-231

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i1.9559
Research paper

SVM based pattern recognised islanding detection approach in a multiple distributed generation system

Gundala Srinivasa Rao [1] *, Dr. G. Kesava Rao [2]

[1] Research Scholar, [2] Professor in Department of EEE
Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India – 522502
**Corresponding author E-mail: gundala247@gmail.com*

Abstract

The penetration of Distributed generation (DG) ensures the increase of demand for consistent, reasonable and spotless electricity facing with some design and operational challenges such as islanding. Several active and passive methods have been suggested in the past to detect islanding. Since they suffer from the large non detection zone and a high cost. In order to defeat such issues we propose a SVM based pattern recognising approach for islanding detection in a multiple DG system. The results show that our proposed method detects islanding with high accuracy.

Keywords: *Islanding; Support Vector Machine (SVM); Pattern Recognising Approach.*

1. Introduction

The increased power demand in present days has lead to depend mostly on Distributed generation (DG) system which promises the more reliable power supply utilizing the generation resources like wind, photovoltaic, fuel cells etc. that are sited at the load terminals[1]. But it introduces the power quality problems like Frequency deviation, voltage fluctuation in grid and Harmonics in load current when the DG systems are operated in parallel with utility power systems, especially with reverse power flow [2]. The frequent problems that encounters in interconnection of DGs can be solved by the concept of microgrid which is well defined as small-scale power system and it constitutes generation, consumption and storage [3-4]. However, numerous issues still need to be seriously considered when DGs are connected to the utility grid or micro grid [5]. One of the most important consideration is "Islanding Detection". Islanding is the condition when utility system disconnected from microgrid that contains both load and distributed generation [6]. Islanding creates many problems, such as difficulty in orderly power restoration, fluctuation in grid side voltage and load current, and endangering the lives of utility employees [7].

Methods that are used to find Islanding are generally be classified as remote methods which are associated with islanding on the utility side and local methods which are associated with islanding on the DG side. The local methods are based up on the measurement of voltage, current and frequency at the terminals of distributed generator (inverter) which are classified as passive and active techniques. In passive schemes the local measurements of transient voltage and current signals are used. Active schemes are accomplished by injecting the disturbances locally into the system and their responses are used to detect islanding conditions [8-9]. Examples of active methods include active frequency drift with voltage and frequency shift methods and DG voltage variation are explained in [10]. Passive schemes use the under/over voltage and under/over frequency relays as given in [11-13]. The main problem with the passive schemes is related to their large Non Detection Zone (NDZ), they fails to detect the islanding under the perfectly matched load condition of a DG and active methods suffers from their negative impact on power quality [14-15].

In order to overcome the above stated problems in detecting islanding here we have proposed a SVM pattern recognition approach. Our foremost contribution in this paper is to accurately detect and classify the islanding condition by SVM.

2. Islanding detection in microgrid

Islanding is caused in DG when it is suddenly disconnected from the main power grid which is difficult to sense. As large numbers of DG are continuously accumulated to the power network, there is increased risk in the safety of the personnel and harm to the power system. Therefore, detecting islanding in time is an idea to optimize control in microgrid [16]. In order to achieve that we propose a SVM based pattern recognising approach for islanding detection in microgrids in this paper. Figure 1 shows the block diagram of the proposed system.

From figure1 it is visible that from various locations of microgrids the current and voltage is measured to ensure that the gird was working in a protective condition. The number of available features is extracted from the decomposed voltage and current signals by Wavelet transform which makes the computation of feature extraction process less complex with reduced computation time. The features that can be extracted from the features are like voltage unbalance, frequency deviation, voltage and current harmonic distortion, power factor etc. Based on these extracted features the trained SVM classifier detects the islanding and non-islanding conditions in the microgrid. To prove the importance of our proposed method a system model has to be considered which is explained in the following section.

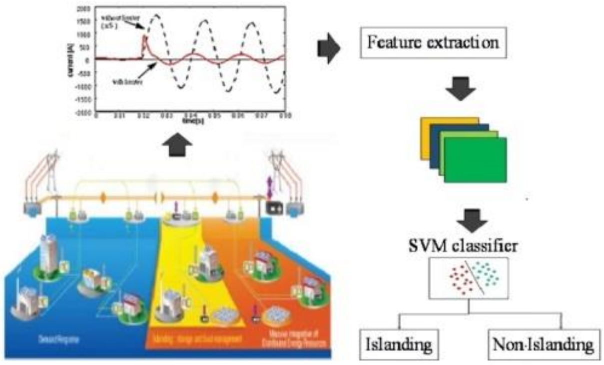

Fig. 1: Block Diagram of the Proposed System.

a) Signal decomposition and Feature extraction

Feature extraction is a process to get the information with adequate exactness. The basic feature extraction procedure consists of Decomposing the signal using DWT and Extracting the features from the DWT coefficients. The features extracted from the Discrete wavelet transform (DWT) coefficients of the test signals are used as input into classifiers due to their effectual time–frequency representation of nonstationarity signals. In this work we put forward DWT based on Mallats' pyramid algorithm to decompose the signals before extraction of features which is explained below.

i) Discrete Wavelet Transform

Discrete wavelet transform is used to extract features from a signal on various dimension arranged by following high pass and low pass filtering. The DWT analyses a signal by decomposing the signal into a course approximation and detail information. The course approximation is decomposed again to obtain the details of the next level and so on [17].

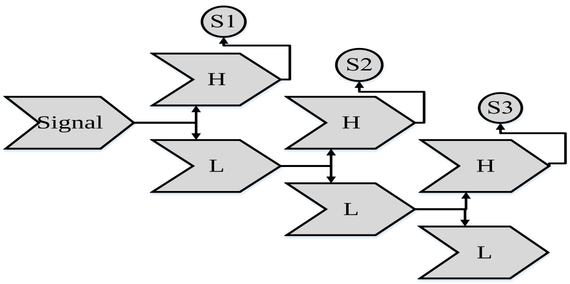

Fig. 2: Decomposition of Signals.

Figure 2 shows the three level decomposition of the input signals which results the wavelet coefficient of the input signal at each level. In figure 3 the S1, S2 and S3 represents the signal coefficients resulting at each level. As the signal x (n) passes through the low pass and high pass filter the signal decomposes into coefficients. The scaling and wavelet coefficients at different levels which are resulting from DWT is expressed by the following equation respectively.

$$S_m(n) = \sum_n l(2n-k)S_{m-1}(k)$$
$$W_m(n) = \sum_n h(2n-k)S_{m-1}(k) \qquad (1)$$

At level m, both $S_m(n)$ and $W_m(n)$ are composed of 2^-m coefficients and the resulting decomposed signals are represented as $[w_1, w_2, ..., w_J, S_J]$ which is the DWT of signal x (n).

ii) Feature extraction

From the decomposed signal $[w_1, w_2, ..., w_J, S_J]$ the available features like Rate of change of voltage, Rate of change of frequency, Magnitude of -ve and +ve sequence, Rate of change of power, Current THD, Voltage THD, Voltage Unbalance, Power factor and Rate of change of VU which shows rapid change in them when DG disconnected from utility are extracted which supports to test the classifier to detect islanding The transient current and voltage signals are used extract the required feature vectors for classification. The features extracted from the decomposed signal is of the from {f1, f2, f3…fn}, where n is the total number of features extracted. And such features are utilized for further to detect islanding by SVM.

b) Pattern recognising approach

In SVM classifier has been performed in two phases Training phase and testing phase. Figure 3 shows the classification process performed in our proposed SVM.

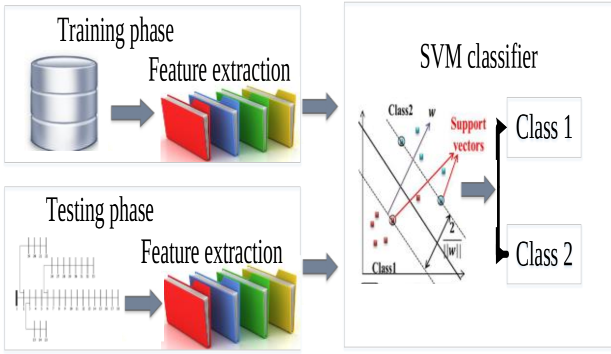

Fig. 3: SVM Classification Process.

Initially The SVM classifier is trained offline with the features associated with different islanding and non-islanding events. In the training phase a training set $P = \{(p_1, q_1), (p_2, q_2), ...(p_n, q_n)\}$ is considered. The SVM classifier separates the classes by formulating a hyper plane boundary between the two classes based on the extracted features. The hyper plane is expressed on the basis of orthogonal weight vector φ and bias b as follows

$$h(p) = w^T p + b \qquad (2)$$

The decision is taken by means of the function sgn(h(p)) which indicates the class of input. If the training sets are linearly non separable, then soft margin SVM are required in which the weight vector w and bias b is determined by solving the below expressions

$$\min_{\varphi, \vartheta} 0.5\|w\|^2 + K\sum_{i=1}^{N}\vartheta_i \qquad (3)$$

Bounded to $\begin{array}{ll} q_i(w^T p_i + b) \geq 1 - \vartheta_i & for\ i = 1,2,...N \\ \vartheta_i \geq 0 & for\ i = 1,2,...N \end{array}$

The distance between the boundary and the training samples deposited on the inappropriate side of the boundary is calculated by the slack variable ϑ_i . The trade off between the maximization of the boundary and the minimization of classification error is determined by a regularization parameter K.

In order to solve the above equations effectively the Lagrange multipliers are introduced $\mu_i \geq 0 and\ \sigma_i \geq 0$ and the function is expressed as

$$L(w, b, \vartheta, \mu, \sigma) =$$
$$0.5\|w\|^2 + K\sum_{i=1}^{N}\vartheta_i - \sum_{i=1}^{N}\mu_i\{q_i(w^T p_i) - 1 + \vartheta_i\} - \sum_{i=1}^{N}\vartheta_i\sigma_i \qquad (4)$$

A dual formulation of the problem is introduced to solve the above equation as

$$\max_{\mu}\left\{\sum_{i=1}^{N}\mu_i - 0.5\sum_{i=1}^{N}\sum_{j=1}^{N}\mu_i\mu_j q_i q_j p_i^T p_j\right\} \qquad (5)$$

Bounded to $\sum_{i=1}^{N}\mu_i q_i = 0 and\ K \geq \mu_i \geq 0\ for\ i = 1,2,...N$ (6)

From the above equations the calculation of weight vector w can be rearranged in to

$$w = \sum_{i=1}^{N} \mu_i q_i p_i \tag{7}$$

The w has the spreading out in terms of a subset of the training data where the Lagrange multipliers $\mu_i \neq 0$. The training data has to satisfy the following condition given by

$$\mu_i \{q_i (w^T p_i + b) - 1 + \vartheta_i\} = 0 \; for \; i = 1, 2, ...N \tag{8}$$

The training vectors that produces the non-zero Lagrange multipliers are essential to depict the hyper plane and these are specified as support vectors. Hence the decision boundary h (p) is determined by the expression follows

$$h(p) = \sum_{\mu_i > 0} \mu_i q_i p_i^T p + b \tag{9}$$

Where p is the input test vector $p_i^T p$ is the inner product. For a linearly non-separable class the original input space is mapped in to a high dimensional dot product space known as feature space. Substituting for the inner product $p_i^T p$ by a kernel function C $(p_i, ...p_j)$ a similar type of dual formulation problem can be obtained [18]. So that the decision function will be expressed as

$$h(p) = \sum_{\mu_i > 0} \mu_i q_i \mathrm{C}\,(\mathrm{p_i}, ...p) + b \tag{10}$$

Thus the hyper plane separates the two classes of microgrid as islanding or non-islanding.

3. Results and discussion

a) Simulation results

The voltage signal and current signal measured from the particular location of the bus system is shown in figure 6. The measured voltage and current signals are decomposed into wavelet co-efficient by means of discrete wavelet transform (DWT). This results in reduction of computational complexity for further processing. The decomposed voltage and current signal resulted from DWT is shown in figure 4.

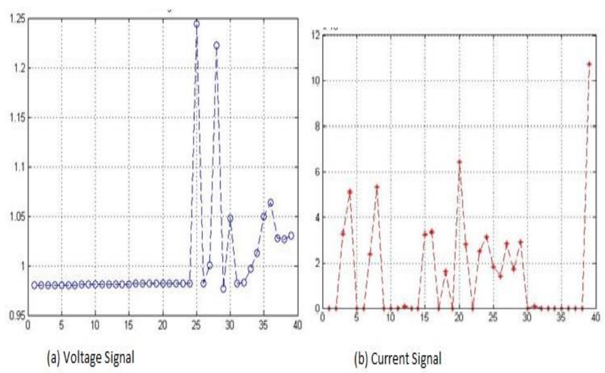

Fig. 4: Voltage Signal & Current Signal.

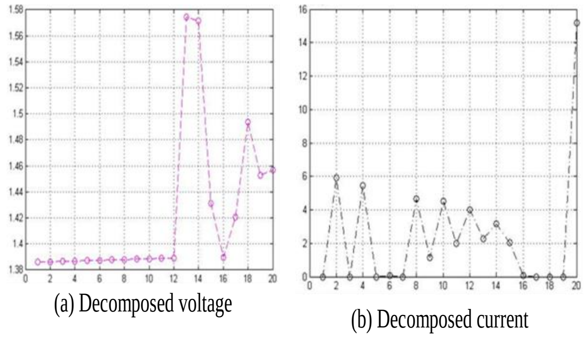

Fig. 5: Decomposed Signal.

The features are extracted from the above decomposed signal and given as input to the trained classifier. The SVM classifier classifies the location of the bus by the two classes such as islanding or non-islanding as output. The classification result of the test bus system is shown in table 3.

Table 3: Classification Results

Cases	Results
No. of Buses Islanding	10
No. of Buses Non-islanding	29

b) Parameter Evaluation

Our proposed method performance have been is evaluated using several parameters like accuracy, sensitivity, specificity, Positive predictive value, Negative predictive value etc. Table 4 shows the contingency table for the classification.

Table 4: Contingency Table

Classes	Predicted value	
	Islanding	Non-Islanding
Islanding	TP (9)	FP (1)
Non-Islanding	FN (0)	TN (29)

Where TP = No. of true positive pixels,
FP = No. of false positive pixels,
FN = No. of false negative pixels
TN = No. of true negative pixels.
The parameter values of our proposed SVM classifier based on the above Contingency table is given in table 5.

Table 5: Parameter Values of SVM Classifier

Sensitivity (%)	100	FPR	0.033
Specificity (%)	96.67	FNR	0
Accuracy (%)	97.43	FDR	0.1
PPV (%)	90	NPV (%)	100

c) Comparisons and Discussion

In our test system model there are 9 islanding and 30 non-islanding locations. The TP, TN, FN and FP values are calculated based on the output of the classifier. Table6 shows the comparison of our proposed SVM classifier with KNN, ANN classifiers. By this we come to know that our proposed classifier is better than the existing classifiers with high accuracy and precision. Also the classification in SVM is done within simple computational steps. So we prefer SVM classifier to detect islanding in microgrids with less effort and high exactness.

Table 6: Comparison of SVM, KNN, and ANN Classifier for Islanding Detection

	KNN	ANN	SVM
Sensitivity (%)	95	90	100
Specificity (%)	80	90	96.67
Accuracy (%)	85	90	97.43
PPV (%)	65	85	90
FPR	0.1723	0.1453	0.033
FNR	0	2.15	0
FDR	0.4	0.3	0.1
NPV (%)	100	90	100

4. Conclusion

The main issue in the microgrid namely islanding is concentrated in this paper and also a new effective method is proposed to detect and reduce such issue. The islanding in a multiple DG system is detected by means of a pattern recognising approach with the knowledge of the features extracted from the various locations of the microgrid. The simulation results show that our proposed method proficiently detects and classifies the islanding condition presents in a multiple DG system with high accuracy.

References

[1] Ray, Prakash K., Soumya R. Mohanty, and Nand Kishor. "Disturbance detection in grid-connected distributed generation system using wavelet and S-transform." Electric Power Systems Research, Vol.81, No.3, pp. 805-819, 2011. https://doi.org/10.1016/j.epsr.2010.11.011.

[2] Hashemi, Farid, Noradin Ghadimi, and Behrooz Sobhani. "Islanding detection for inverter-based DG coupled with using an adaptive neuro-fuzzy inference system." International Journal of Electrical Power & Energy Systems, Vol.45, No.1, pp.443-455, 2013 https://doi.org/10.1016/j.ijepes.2012.09.008.

[3] Nasirian, Vahidreza, et al. "Distributed cooperative control of dc microgrids." IEEE Transactions on Power Electronics, Vol.30, No.4, pp. 2288-2303, 2015. https://doi.org/10.1109/TPEL.2014.2324579.

[4] Guerrero, Josep M., et al. "Advanced control architectures for intelligent microgrids—Part II: Power quality, energy storage, and AC/DC microgrids." IEEE Transactions on Industrial Electronics, Vol.60, No.4, pp. 1263-1270, 2013. https://doi.org/10.1109/TIE.2012.2196889.

[5] Miller, Laurie E., et al. "Smart grid opportunities in islanding detection." 2013 IEEE Power & Energy Society General Meeting. IEEE, 2013.

[6] Ahmad, Ku Nurul Edhura Ku, Jeyraj Selvaraj, and Nasrudin Abd Rahim. "A review of the islanding detection methods in grid-connected PV inverters." Renewable and Sustainable Energy Reviews, Vol.21, pp. 756-766, 2013. https://doi.org/10.1016/j.rser.2013.01.018.

[7] Dong, Dong, et al. "Analysis of phase-locked loop low-frequency stability in three-phase grid-connected power converters considering impedance interactions." IEEE Transactions on Industrial Electronics, Vol.62, No.1, pp. 310-321, 2015. https://doi.org/10.1109/TIE.2014.2334665.

[8] Trujillo, C. L., et al. "Analysis of active islanding detection methods for grid-connected microinverters for renewable energy processing." Applied Energy, Vol.87, No.11, pp. 3591-3605, 2010. https://doi.org/10.1016/j.apenergy.2010.05.014.

[9] Khamis, Aziah, et al. "A review of islanding detection techniques for renewable distributed generation systems." Renewable and sustainable energy reviews, Vol.28, pp. 483-493, 2013. https://doi.org/10.1016/j.rser.2013.08.025.

[10] Alshareef, Sami, Saurabh Talwar, and Walid G. Morsi. "A new approach based on wavelet design and machine learning for islanding detection of distributed generation." IEEE Transactions on Smart Grid, Vol. 5, No.4, pp. 1575-1583, 2014. https://doi.org/10.1109/TSG.2013.2296598.

[11] Karegar, H. Kazemi, and B. Sobhani. "Wavelet transform method for islanding detection of wind turbines." Renewable Energy, Vol.38, No.1, pp. 94-106, 2012. https://doi.org/10.1016/j.renene.2011.07.002.

[12] ElNozahy, M. S., R. A. EL-Shatshat, and M. M. A. Salama. "Single-phasing detection and classification in distribution systems with a high penetration of distributed generation." Electric Power Systems Research, Vol.131, pp. 41-48, 2016. https://doi.org/10.1016/j.epsr.2015.10.008.

[13] Merlin, V.L., R.C. Santos, A.P. Grilo, J.C.M. Vieira, D.V. Coury, and M. Oleskovicz. "A new artificial neural network based method for islanding detection of distributed generators", International Journal of Electrical Power & Energy Systems, 2016. https://doi.org/10.1016/j.ijepes.2015.08.016.

[14] Samet, Haidar, Farid Hashemi, and Teymoor Ghanbari. "Minimum non detection zone for islanding detection using an optimal Artificial Neural Network algorithm based on PSO." Renewable and Sustainable Energy Reviews, Vol.52, pp. 1-18, 2015. https://doi.org/10.1016/j.rser.2015.07.080.

[15] Raza, Safdar, et al. "A Sensitivity Analysis of Different Power System Parameters on Islanding Detection." IEEE Transactions on Sustainable Energy, Vol.7, No.2, pp. 461-470, 2016. https://doi.org/10.1109/TSTE.2015.2499781.

[16] Li, Canbing, Chi Cao, Yijia Cao, Yonghong Kuang, Long Zeng, and Baling Fang. "A review of islanding detection methods for microgrid", Renewable and Sustainable Energy Reviews, 2014. https://doi.org/10.1016/j.rser.2014.04.026.

[17] Sharma, Rashmi, and Pratibha Singh. "Islanding detection and control in grid based system using wavelet transform", 2012 IEEE. Fifth Power India Conference, 2012. https://doi.org/10.1109/PowerI.2012.6479557.

[18] Alam, M. R., K. M. Mut t aqi, and A. Bouzerdoum. "A Multi feature-Based Approach f or Islanding Detection of DG in the Subcritical Region of Vect or Surge Relays", IEEE Transact ions on Power Delivery, 2014. https://doi.org/10.1109/TPWRD.2014.2315839.