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Detection and Classification of Faults and Disturbance in Distributed Generation System using Support Vector Machine Technique

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Abstract

DG (distributed generation) offers reliable, cost-effective, and environmentally friendly electricity to customers. DG efficiently utilizes renewable energy resources (RERS) to meet electricity demand. To ensure reliable operation of DG robust smart protection is required. One of the main issues in DG is to prevent false tripping by successfully classifying faults and disturbances. This paper presents a novel approach to classify between the single line to ground fault (SLG), line to line (L-L) fault, disturbance like inrush current of transformer and motor starting current. The proposed approach was implanted on IEEE 13 bus distribution system with integrated PV in MATLAB/Simulink. Phasor measurement units (PMU) are installed at various buses to measure voltage or current. PMUs give a symmetrical component of current, which further use to classify various nature of the fault. Zero sequence current is used for a line to ground and negative sequence is used for L-L fault. Support vector machine (SVM) learning technique is applied on the symmetrical component for classification of fault and disturbance. The results justify the effectiveness of the proposed model for classification in DG.

Keywords- IEEE 13 bus distribution system, PV, fault, and disturbance classification, SVM (support vector machine) technique.

1 INTRODUCTION

Distributed generation (DG) is playing an important role to assist the utilization of renewable energy resources (RERs). DG has many advantages over traditional grids like it is environmentally friendly, more reliable, and can smartly achieve distribution and transmission expansion[1]. RERs reduce harmful gas emissions and provide clean energy. By incorporating different RERs the DG become further complex in term of infrastructure and protection[2]. The dynamic and nonlinear behavior of DG has many challenges with the conventional protection scheme. Distribution systems face various types of faults and disturbances due to change in different parameters. Nature of fault and disturbance varies with adding group (hydro, wind, and solar) of RERs[3]. Many kinds of faults occur i.e. single line to ground (SLG), line to line(L-L), and other disturbances like inrush current and motor starting current. Mostly the faults detected by electrical features: (1). Symmetrical component of voltage and current, (2) current and voltage waveform characteristic, and (3) differential quantities[4]. This paper proposes a technique to detect various kinds of fault and disturbance in distribution system with help of PMU (phasor measurement unit) and SVM (support vector machine) algorithm. The proposed approach uses negative and zero sequence current components collected from PMUs to detect the faults and apply SVM to classify them. It is implemented on IEEE 13 bus feeder model in Simulink integrated with PV model. The retrieved data of symmetrical components (negative, zero sequence) from PMUs are passed by SVM algorithm to classify faults and disturbance. The machine learning algorithm SVM is trained on data collected from PMUs and it predicts the nature of fault and disturbance on base of trained and test data. The structure of rest of paper is systemized as follows: The details about IEEE 13 bus feeder system and PV integration is discussed in section 2. The modeling of phasor measurement unit in MATLAB/Simulink elaborate in section 3. After that, the proposed support vector algorithm is described and followed by simulation results are discussed in section 4. The last section summaries the conclusion.

2 IEEE 13 BUS SYSTEM WITH PV

The schematic diagram of the IEEE 13 bus feeder and PV system is illustrated in figure 2.1, which consists of 13 buses, three transformers, and a PV system. The main transformer which is connected between the gird and feeders is 5000kVA and 115/4.160 kV. The second transformer is connected between bus 633 and 634 which is 500 kVA, 4160/220 V of ratings. A three-phase induction motor is installed at bus 632 to study the disturbance behavior of starting current. A three-phase transformer of 250 kVA, 4160/220 rating is connected to bus 680 to analyze the inrush current of the transformer. The PV is connected to bus 675, which is terminating the bus to maintain the voltage level constant and meet the demand. PV system is connected through 250kVA, 600/4160 V transformer. The PV is connected to IEEE 13 bus distribution system is 250kW, which terminal voltage is 600V. PMUs are installed at six buses which can completely monitor the whole system based on optimal placement algorithm. The PMUs give a symmetrical component of current, angle, and frequency. The symmetrical component current data collect from PMUs and apply SVM for classification. This proposed model containing an IEEE 13 bus system, PV of 250kW, transformer, and three-phase induction motor to classify the various kinds of faults and disturbances in DG.

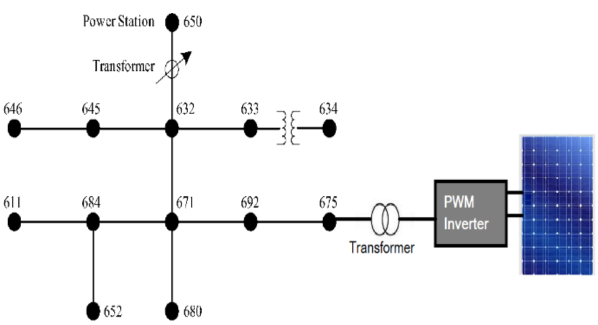

Figure 2.1 IEEE 13 bus system with PV

3 PMU MODELING

In DGs, the integration, management, and optimal usage of RERs are very important. The inconsistent nature of RERs leads to dynamic power system operation, there very fast monitoring of the power system is required. SCADA (Supervisory Control and Data Acquisition) control, supervise and manages the power system. It measures the only magnitude of a quantity and sends one sample in 2-5 seconds. It is used for local monitoring and control of the system. There is no time synchronization in data of different parts of the power system, which means it does not show the dynamic image of the power system. For the dynamic operation of DG Phasor measurement units (PMU) are used. PMU can transmit 50-60 samples per second to a local or remote receiver. PMU is used to measure phase angle, frequency, voltage, and current symmetrical components. PMU offered timely synchronized control for various parts of the power system which ensure dynamic observability. How it gives magnitude, angle and frequency are shown in a mathematical equation.

$$x(t) = Xm\cos(\omega t + \phi) \qquad (1)$$

Where Xm = magnitude of a sinusoidal waveform, ω is 2*π*f where f is instantaneous frequency, and ϕ is the angle of the waveform. The PMU package in MATLAB/Simulink is shown in figure 3.1.

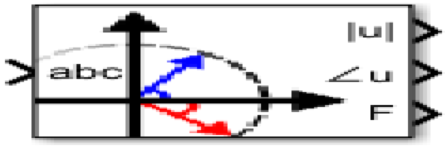

Figure 3.1 Existing PMU in Simulink

It takes a three-phase value of voltage or current, computes positive sequence component of current, angle, and frequency. Inside a PMU it has a filter circuit, sampling circuit, and processing unit. Before processing the input current or voltage to estimate its phasor value it is filtered and sampled to avoid an aliasing problem. Through DFT or FFT method is used to compute phase and magnitude. The existing package in MATLAB/Simulink gives only a positive sequence component and for a line to ground fault zero sequence component is required. This package is modified to give zero and negative sequence components of input voltage or current. The modified block is shown in figure 3.2.

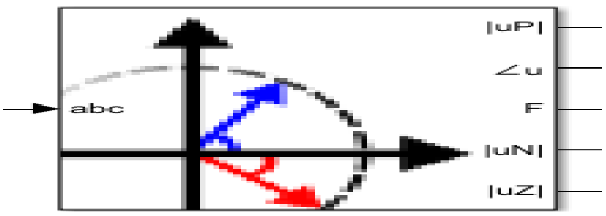

Figure 3.2 Modeled PMU

The modified block compute positive, negative and zero sequence component, angle, and frequency. It has a separate block for zero and negative sequence components shown in the figure which helps in single line to ground and double line to ground faults. The under-mask view of a modified. Negative sq and Zero sq are sequence analyzers used for computing their respective symmetrical components. The sampling rate of this package is 64 samples per second. This is a novel approach to measure zero and negative sequence component.

4 Faults and disturbance analysis

A fault in any system is an unwanted deviation from the normal operating condition. It may occur by internal or some external sources. Internal sources include insulation failure of equipment, overheating, and overloading while external causes include physical touch between two-line, falling of line on the ground, falling off a tree on lines, or contact of birds or animal. The more chance of external faults occurring are L-L fault, SLG fault, and L-L-G fault, these faults are called unsymmetrical faults.

4.1 Single line to ground fault:

In a three-phase system, we have phases R, Y, and B. Let the SLG fault occur on the R phase means phase R touch the ground shown in figure 4.1. The R phase touch the ground so, $V_R=0$, I_Y and $I_B = 0$

The symmetrical component of the SLG fault current is given below in Eq 2.

$$I_0 = 1/3(I_R+I_B+I_Y) = 1/3I_R \quad (2)$$

$$I_1 = 1/3I_R,\ I_2 = 1/3I_R \quad (3)$$

$V_R = V_0+V_1+V_2 = 0$ (4) because R phase is shorted to ground

$$V_Y = V_0+ a^2V+aV_2 \quad (5)$$

$$V_B = V_0+aV_1+a^2V_2 \quad (6)$$

When the SLG fault occurs, there is only zero sequence component exist, therefor the proposed model considers zero sequence component for detection. The proposed model takes two-cycle before the fault event, two after the fault to detect and classify the nature of the fault. Similar is done for L-L and L-L-G fault, except for L-L negative sequence component is considered.

5 Simulation results

Studied IEEE 13 bus distribution system with PV in MATLAB/Simulink under normal, faulty, and disturb conditions to validate the proposed algorithm. The data is sent to the workspace at 200 samples/cycle, thus the sample per second is 10000 for 50 Hz frequency.

DG has many loads which cause a disturbance in a system for a moment. The magnetizing current drawn by the primary of a transformer is called inrush current, which does not cause any permanent fault but causes undesired switching of a circuit breaker. Starting current or magnetizing current in a three-phase motor also causes disturbance in the system. Inrush current in DG leads to false tripping of a relay. The proposed model avoided false tripping and classify the inrush current as a disturbance in the system.

5.1 SLG fault at bus 633:

Single line to ground fault is generated at bus 633 by using three-phase fault packages from the Simscap library in Simulink. Current and voltage are measured by three phases VI measurement block. Circuit breaker close to creating fault at 0.833 sec and clear the fault at 0.866 sec shown in figure 5.1. SLG fault is generated from phase A to ground. Zero sequence component data is stored in workspace MATLAB, data is further sent to python for training the SVM algorithm.

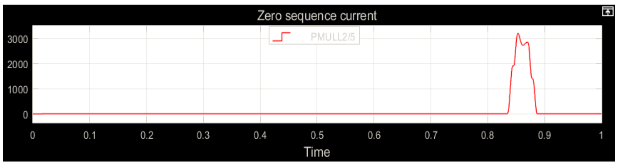

Figure 5.1 zero sequence component of line to ground fault

5.2 L-L fault at bus 633

A double line fault is created at bus 633. The simulation result is shown in figure 5.2. The fault is created at 0.833 sec and ends at 0.866, the same number of samples are taken for analysis of this fault.

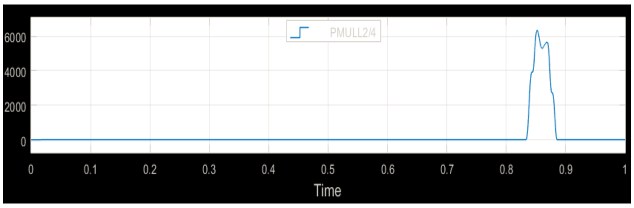

Figure 5.2 positive sequence component of L-L -G fault

5.3 Disturbance in system:

The magnetizing current of the transformer and motor are taken to study normal disturbance in DG. Transformer magnetizing and motor starting current cause disturbance in a system which sometimes leads to relay for false tripping. Inrush current data is sent to workspace MATLAB to form a data set. SVM algorithm is also trained for inrush current data, as a result, the SVM algorithm predicts disturbance for testing data.

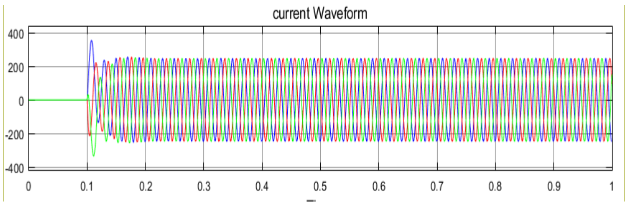

Figure 5.3 Motor starting current.

5.4 Python and Excel dataset

After getting results from Matlab/Simulink the SVM technique applied in python for this proposed method. The data are collected for twelve cycles, two cycle before the fault and ten cycle after the fault. The collected data is converted to CVS format for further process. The different labels are given to different faults and disturbance, the SVM technique applied on the collected data in python which give 66% correct classification on test data set.

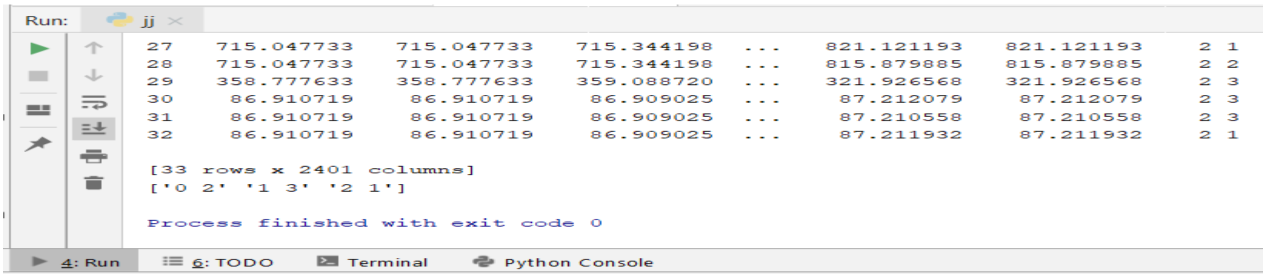

Figure 0.5 Python result of classification

6 Conclusion

The paper presents an effective way of avoiding false tripping, classification of faults, and disturbance. The PMUs have been installed at the feeder end to collects the current signal and applied the proposed machine learning technique. For SLG fault zero sequence components and for a double line to ground fault, negative sequence components are considered. Various fault current signals and disturbance current signals are taken from different feeders and passed by the SVM algorithm to train the model. The trained model is tested on current signal taken from other buses and successfully predict the nature of fault and disturbance

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