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Techniques for On-Line and Off-Line Fault Detection in Inverter-Based Islanded Microgrid

[1]K.Rekha,[2]K.Kusumitha,[3]M.Venkateswarlu,[4]SK.Jameerbasha,[5]G.Bhargavi
[1,2,3,4,5]Electrical and Electronics Engineering,
[1,2,3,4,5]Gokula Krishna College of Engineering, Sullurupet, India

ABSTRACT: It is critical to understand how microgrids behave under physical disturbances and the related power quality events in order to design a stable and reliable control that overcomes the difficulties presented by inverter-based microgrids. Major power quality events are caused by microgrid faults, and analysing these faults might assist develop more effective control strategies. This article describes an online and offline method for analysing fault transients in load using Park's Vector Trajectory (PVT) and the Hilbert-Huang Transform (HHT), respectively current in the event that a failure arises at the common coupling point (PCC). The analysis shows that PVT is helpful in the real-time detection of transients in load current, and that instantaneous frequency obtained from the Hilbert-Spectrum of load current can be used for fault time detection and harmonic component analysis.

I. INTRODUCTION:

Growing grid integration of Distributed Energy Resources (DERs), Renewable Energy dynamics sources (RES) and the steadily rising demand for electricity exposed fresh problems with power quality and stability. The Microgrid concept is presented as a solution to these problems. A system with DERs and related loads is a better way to define a microgrid (MG).

MGs can be thought of as a grid subsystem that can function in both islanded and grid linked modes. Identification and categorization of defects in the MGs at an early stage and resolving these problems will improve the system's operating performance and dependability. However, it is crucial to investigate the transients in MG when they are disturbed in order to address these problems. Such disruptions as transmission line faults have a significant negative influence on the overall system reliability and can lead to major stability and power quality problems.

The necessity for a greater awareness of the system's response to disturbance in order to develop control strategies highlights the importance of fault transient analysis.MG operation plan that is sturdy, dependable, and solid. Fast Fourier Transform (FFT) is the most widely utilized signal processing method for fault transient investigation. Underwater or false inter-harmonic and harmonics are the result of reduced inter-harmonic and harmonic width of the load current signal and potential leakage in the FFT method. Wavelet transform is another frequently used tool for fault signal analysis (WT). In [6], a survey of WT applications in power systems is given. Although high resolution decomposition can be accomplished by WT, a predefined basis function determines its best performance. Wavelet volatility is utilised in feature extraction to identify errors in fuzzy logic-based flaws and the presentation of wavelet multi resolution analysis coefficients for detection is made. Park's vector transform, which was first used to analyse AC machines is the idea underlying PVT.WT, a predefined basis function determines its best performance. Wavelet volatility is utilised in feature extraction to identify errors in fuzzy logic-based flaws and the presentation of wavelet multi resolution analysis coefficients for detection is made. Park's vector transform, which was first used to analyse AC machines is the idea underlying PVT. Park's vector is frequently utilised in three-phase induction motor windings to detect faults and airgap eccentricity power electronic converters, etc., for AC machines' variable speed drives. In, the Hilbert-Huang Transform (HHT) is used to locate a fault in the electrical grid. HHT applications for locating the disturbance generating voltage sags and improved HHT for power quality event analysis are covered in respectively. The stability of a power system is determined by its capacity to return to balance after a disturbance.

A MG reacts to a disturbance differently in the absence of a synchronous machine than a steady power system with synchronous machine in which the new equilibrium point is where post-disturbance operations occur. Furthermore, should a fault arise in an islanded inverter-based MG, the fault current should be supplied by the inverter. For network protection, fault detection and analysis are just as crucial as power converter and MG design. The limitations of fault detection techniques applied to inverter-dominated MG in traditional distribution networks are examined in an analysis of MG behavior in the context of line-line-ground and three-phase balanced faults is provided.

One method for finding a flaw such that fast protection can be enabled plan is predicated on errors in the MG's d-q converted voltage waveforms. However, this method offers no insight into how the MG behaves in relation to fault current waveform transients. The current waveform can be analysed using HHT and PVT. PVT is an online fault detection technique that may be used for fast-real-time control and protection techniques, and HHT, which is described as an offline technique in this study, offers a deeper understanding of the transients in the current waveform. Although fault detection in various power apparatus has been studied using HHT and PVT, its applicability in MG.

II. MICROGRID MODEL DESCRIPTION:

In this study, an MG is defined as three parallel connected inverters feeding a 25kW resistive load across an inductive transmission line. The use of three identical six-pulse, three-phase bridge inverters, each equipped with an LCL filter, and the failure to take source and load dynamics into account restrict the study's scope.

The typical droop (P-f/Q-V) control provided in each inverter is used to provide active power sharing in this MG type, and the power electronic converter's switching frequency is kept constant at 50 kHz.

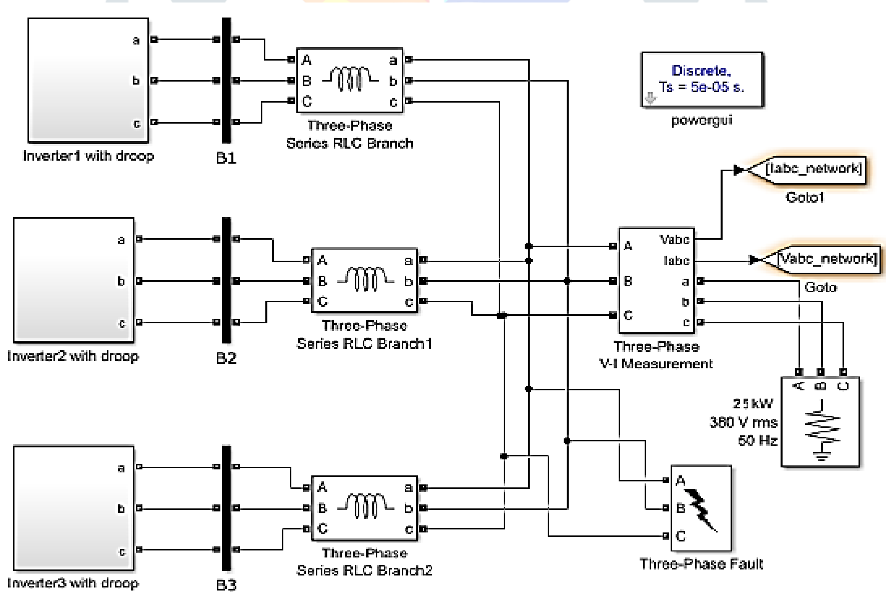

Fig 1: Microgrid Model

III.TYPES OF LINE FAULT AND FAULT SCENRIOS:

The majority of transmission line defects are short circuit faults, which are categorised as either symmetrical or unsymmetrical faults. Unsymmetrical faults can lead to system unbalance, whereas symmetrical faults maintain the system's balance.

The L-L-L fault, in which all three phases are shorted, and the L-L-L-G fault, in which all phases are shorted to ground, are examples of three-phase symmetrical faults. Common unsymmetrical line faults are Single line to ground (LG), Double line to ground (LLG), and Line to Line fault (LL).

IV.PARK`S VECTOR TRJECTORY AS ONLINE TECHNIQUE:

Three-phase load currents are represented by a three-dimensional vector that is produced by the simulation of various fault scenarios.

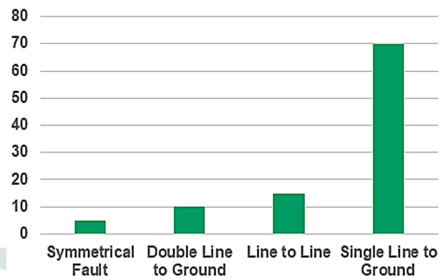

Fig 2: The percentage frequency at which faults occur

V.HILBERT-HUANG TRANSFORMATION AS OFF-LINE TECHNIQUE:

First, Empirical Mode Decomposition (EMD) is used to determine the signal's Intrinsic Mode Functions (IMFs). Next, each IMF's instantaneous frequency is acquired by applying the Hilbert-Transform to it.

A.*EMD Method:*

$$m(t) = \frac{e_m(t)+e_M(t)}{2} \quad (1)$$

$$h(t)= s(t)-m(t) \quad (2)$$

$$r(t) = s(t) - \sum_{i=1}^{n} IMF\ i \quad (3)$$

$\boldsymbol{B. Hilbert - Transform}$:

The s(t) Hilbert-Transform is given by

$$y(t) = \frac{1}{\pi} \cdot p \cdot \int_{-\infty}^{\infty} \frac{s(\tau)}{t-\tau} d\tau \quad (4)$$

$$z(t) = s(t) + jy(t) \quad (5)$$

Amplitude of z(t) is given by

$$a(t) = [s(t)^2 + y(t)^2]^{1/2} \quad (6)$$

And the phase of z(t) is given as

$$\theta(t) = \tan^{-1} \frac{y(t)}{s(t)} \quad (7)$$

Instantaneous frequency can then be calculated from phase of z(t) using,

$$f(t) = \frac{1}{2\pi} \frac{d\theta(t)}{dt} \quad (8)$$

The phase of z(t) is able to be utilised to derive the instantaneous frequency.

VI. RESULTS AND DISCUSSION:

The three-phase load current collected at 20 kHz from 4-4.5 sec in all simulations. All fault scenarios are simulated in MATLAB/SIMULINK.

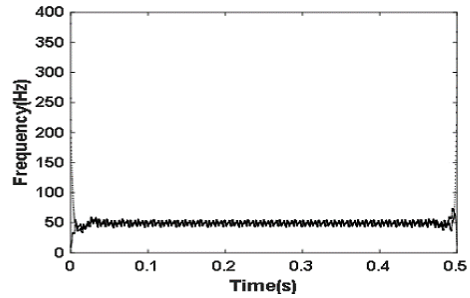

Fig 3: Plotting frequency-time in a case that no defect is identified by HHT

A. Detection by PVT analysis

Only in the event of a pure sine wave output—which occur in the NF case—can a pure circle be obtained in the park's transformation.in this investigation. The calculated α and β components of the load current get shifted during the fault period. They will therefore no longer be the same in magnitude.

B. HHT analysis-based detection.

The frequency-time charts during the fault show different fault cases' natures. Once more, the frequency Pre- fault and post-fault durations have different distributions and magnitudes, which are denoted as "region 1" and "region 2" in Figure 8. In comparison to the other two faults and in no fault condition, the frequency component magnitude for the LLG and LLL faults is observed to be greater.

For all fault situations taken into consideration in this work, HHT analysis is carried out for each phase current of the three-phase load current data, and the related frequency-time response is shown here.

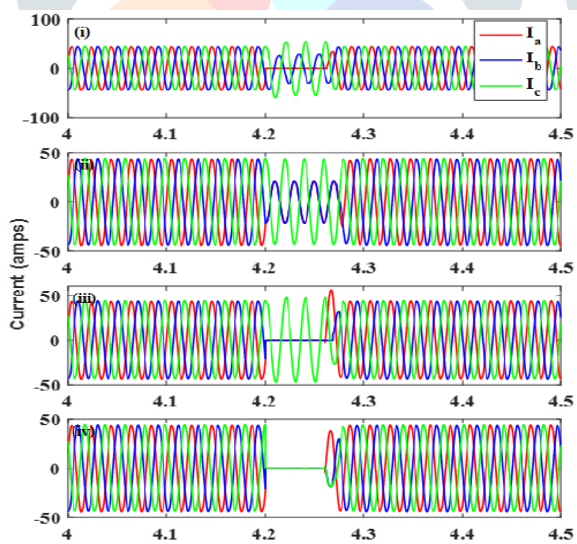

Fig 4: The load current is displayed in (ii) LG fault, (iii) LL fault, (iv) LLG fault, and (v) LLL fault for various fault situations.

The Normalised Maximum Instantaneous Frequency (NMIF) for various failure scenarios is shown in Table I. It was derived from frequency-time response plots for various phase currents around the fault time.

Fault case	At Fault			After Fault Clearance		
	A	*B*	*C*	*A*	*B*	*C*
LG	1	0.0009	0	0.235	0.001	0.0001
LL	0.003	0.061	0.0004	0.881	1	0
LLG	0.174	1	0	0.0271	0.313	0.0001
LLL	1	0.212	0.435	0	0.014	0.533

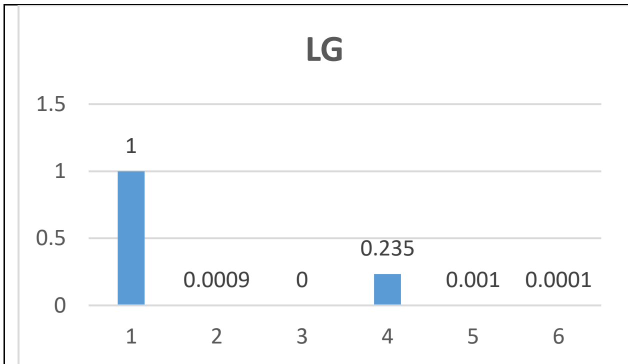

Fig.1

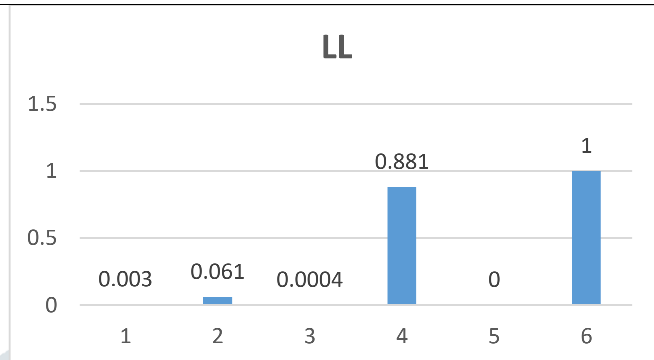

Fig.2

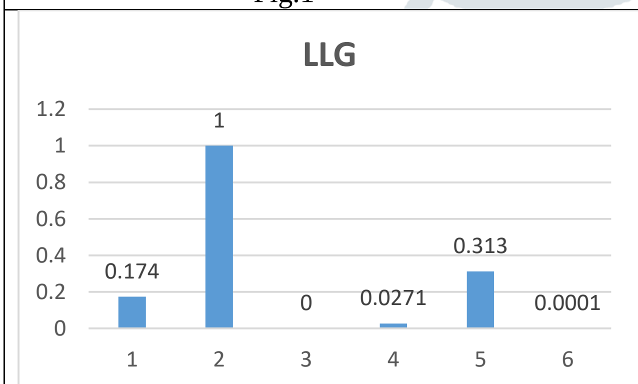

Fig.3

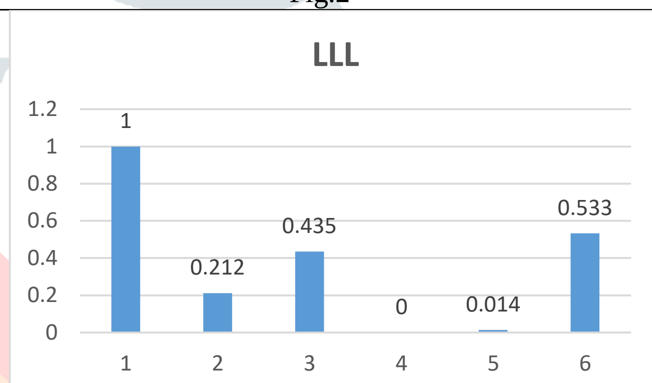

Fig.4

Fig 5: Maximum instantaneous frequency of various phase currents compared during LG, LG, LLG, and LLL faults.

TABLE II:

Fault Case	At Fault	After Fault Clearance
LG	$IF_{Pa}>>IF_{Pb}>IF_{Pc}$	$IF_{pa}>>IF_{pb}>IF_{pc}$
LL	$IF_{Pb}>IF_{Pa}>IF_{Pc}$	$IF_{pb}>IF_{pa}>IF_{pc}$
LLG	$IF_{Pb}>>IF_{Pa}>>IF_{Pc}$	$IF_{pb}>>IF_{pa}>>IF_{pc}$
LLL	$IF_{Pa}>IF_{Pc}>IF_{Pb}$	$IF_{pc}>>IF_{pb}>>IF_{pa}$

VII. CONCLUSION:

In order to manage power quality events in an islanded MG, transient fault current analysis is needed. This work presents an On-line and Off-line technique for fault identification of the three-phase load current for symmetrical and unsymmetrical gearbox line faults in MG. Although the frequency-time response acquired using HHT can also be utilised for fault detection, the additional steps required in the process result in a longer computation time. Both EMD and HT, hence this paper views it as an offline approach.

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