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Synchrophasor Application For Distributed Generation Control

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Abstract *-- Distributedgeneration(DG)isgainingpopularityacrosstheworld.Recentlyrules encouraging theuseof renewableresources ispassed.IntegratingDG withtheutility network poseschallengesforanti-is landing schemes .Distributed generation are generating interest due to the desire to increase the use of renewable electrical energy sources .For broader adoptionofDG,areliablewaytoconnectsystemstothebulkpowergridisneeded.Soitis necessarytoaddressthechallengesassociatedwiththeintegrationofdistributedgeneration (DG). This paper discusses a wide area measurement based islanding detection scheme that uses time synchronized measurements to calculate voltage difference. This paper shows the performance of the IEEE 6 bus system during islanding condition.*

Keywords *: Distributed generation control, Synchrophasor Technology, Islanding Detection, IEEE 6 Bus System, Synchrophasor Application.*

I.INTRODUCTION

In this modern generation, Renewable energy is very important as renewable energy offers economically viable solutions which does not harm the environment and the social life. Hence we can integrate it with the energy development with proper plan. Currently, innovations in new technologies and power electronics havemade DGasignificantsubstituteforextra cogenerationsupport.The challenges for integratingDG withtheservice network are enormous. Islanding can be explained aswhenaunitofthegenerationsystemisisolatedfromthemainutilitysystem, the damage to the existingequipment,utilityliabilityconcerns,reductionof power reliability and power quality occurs which is undesirable.

A. Events Causing Islanding [1]

- Afaultproducedinthegridwhichresultsinadisconnectionthatmaynotbe detected by the photovoltaic inverteror the protection equipment.
- An accidental opening ofthe connection point with the electrical company
- Programmed disconnection
- An intentional opening ofthe connection point with the electrical company
- Human errors
- Naturalcauses

B. Anti Islanding System Requirement [1]

- Generally,voltageandfrequencyantiislandingcontrolsystemsarenotincorporated intheElectricalGridSCADA systems.Duringanislanding condition,thevoltageand frequencymaybewithinthebanddefinedfornominalvalues,buttheinverterisnot capableofregulatingtheseparametersandthereforeahazardoussituationmayresult for the clientequipment.
- Theelectricalcompaniescanbepenalizedbytheuserswhentherearehazardsinthe PVdevicesasaresultofhavingthevoltageandfrequencyparametersoutofthe acceptable ranges.
- Theislandingsituationcancreateahazardoussituationfortheoperatorsin the electricinstallationsandforthepublicingeneral,sincecircuitswhichareassumedto be disconnected fromtheir sources,are actuallyenergized.
- Thereconnectionoftheelectricsystemwiththeislandingcanhaveasaresultanew disconnectionorahazardintheequipmentiftheconnectionishappensinanoutof phase situation, sincethere is no control ofthe islanding voltage and frequency.

- Theislandingconditioncaninterferewiththemanualorautomaticservice reestablishment processafter an important eventin the electric system.

II. SYNCHROPHASOR MEASUREMENT CONCEPT

A phasor is a complex number with magnitude and phase angle that is used to represent a sinusoidal signal under a specific frequency (50 Hz or 60 Hz) at a specific point of time. Where, the phase angle is the distance between the sinusoidal peak of the signal and a specified reference point of time (for example time = 0) and is expressed using an angular measure. The phasor magnitude is related to the amplitude of the sinusoidal signal.

When a phasor measurement is time stamped against the UTC time by GPS, it is called a synchrophasor. . With the help of synchrophasor, we can have measurements from different sites at a time using time stamped measurement. This synchrophasor measurement will help to have completeviewofanentireregionor interconnection.

2.1 Devices and Networks [2]

2.1.1 Phasor Measurement Unit (PMU)

APMUisastandalonedevicethatmeasures50/60HzACvoltageand/orcurrentsignalsto providephasorandfrequencymeasurements.Theanalog to digital converter is used in each phase to convert the analogACwaveformsinto digital AC waveforms. For high-speedtimesynchronized sampling, phase-lockoscillatorandaGPSreference timesource also known as PPS is used.APMUcalculates the current phasors, voltage phasors, linefrequency atahigh samplingrate. This measured data are sent via a communication channels using GPS time stamp.

2.1.2. Phasor Data Concentrator (PDC)

PDCs aligns the data to form a time- synchronized set using a time reference. The data collected at PDC comes from either various PMUs or several PDCs. This information from PDC is forwarded to otherinformationsystems. Other functions of the PDC includes the dataqualitychecks and problematicdata. It also waits fora setperiodoftimeforallthedatatocomeinbeforesendingthecombineddataset. SomePDCsalsostore datawhich can use for applications that use dataat slowersample rates, such as a SCADAsystem.

2.1.3 Time Synchronization Option

APMUinvolvesUTCtimeandhighaccuracytimingsignaltoprovide synchronizedmeasurements. The existing methods include the direct GPS signal, IRIG-B/PPS and IEEE 1588 PTP.

A direct way for a PMU to refer UTC time is using a GPS signal. Such PMU should be equipped with internal or external GPS receiver, which is specially designed to receive and synchronize a local timing reference to UTC using the GPS signal.

IRIG-B is commonly used by PMUs for synchronizing to UTC time. It may be provided in a level shift, a 1 kHz amplitude modulated signal, or in the bi-phase Manchester modulated format. A PPS in timing systems is a pulse train of positive pulses at a rate of 1 Hz. The rising edge of the pulses coincides with the seconds change in the clock and provides a very precise time reference.

IEEE 1588 PTP is a protocol used to synchronize distributed clocks with an accuracy of less than 1 microsecond via Ethernet networks.

2.2. Different Synchrophasor Application in Distribution

Different problems identified in distribution system which can be solved by synchrophasor application are [3]:

- Islanding detection
- Phase identification
- Load Characterization
- System Monitoring

III. ISLANDING DETECTION METHOD

The idea behind the islanding detection is to observe the output and the system parameters of distributed generation and from that we can decide if the islanding situation will occur or not.

3.1 Traditional Islanding Detection Method

3.1.1. Passive Detection Schemes

Passive detection schemes uses voltage and current signals. Based on the measurements the islanding condition can be detected.

3.1.1.1 Voltage Based Detection

The undervoltage and overvoltage occurs due to the reactive power mismatch. This measurement of undervoltage and overvoltage can help to detect if any islanding condition would occur or not. Avoltagerelay is used to measure such mismatch.Voltage-baseddetectionbalancesfrequency-baseddetection.Also, voltage-baseddetectiongives faster response than frequency-based detection because generally the voltage changes occur faster than frequency changes.

3.1.1.2 Frequency Based Detection

When there is a difference between the generation and the load, the frequency is changed. If the generation exceeds the load, the frequency increases, whereas if the load exceeds the generation, frequency decreases. Hence islanding condition can be easily detected by frequency changes.The allowable frequency changes are 60Hz± 20 mHzor 50 Hz ± 20 mHz.

3.1.2 Active Detection Schemes

When there is a difference between the generation and the load, the frequency is changed. If the generation exceeds the load, the frequency increases, whereas if the load exceeds the generation, frequency decreases. Hence islanding condition can be easily detected by frequency changes.The allowable frequency changes are 60Hz± 20 mHzor 50 Hz ± 20 mHz

3.1.3 Communication Based Detection Schemes

In communication based detection, the status of the circuit breaker is used to detect the islanding condition. Based on the already known logic, a centralprocessor is used to observe the status of the circuit breaker. Based on the status of the CB, the islanding condition can be detected. Thesemethod can be easily applied.

3.2 Islanding Detection Using Synchrophasor [1]

ThePMUsareimplementedtoidentifytheseparationofonepartoftheElectricalSystem (Island)wheretheislandcontainsonephotovoltaicsourceandseveralloadsofdifferent characteristics.ForthatpurposetwoPhasorMeasurementUnits(PMU)wereinstalled:one insidetheislandandotheroneinthemaingrid,connectedtoaPhasorDataConcentrator (PDC),whichwilltimealignthedatareceivedfromPMU'sandforwardingittoaPC running a soft PLC.

3.2.1 Angle Difference

Angledifferencemethodindicatedanislandingconditionifthedifferenceofanglesof respectivevoltagesignalsreceivedfromtwopointsofthesystemexceedsaprogrammable threshold.Theanglesofthepositivesequencevoltageandthevoltagecalculatedfromthe Clarke transformation were bothtested and compared.

$$\delta_{Diff}(t)=\delta_{v1}(t)-\delta_{v2}(t)$$

3.2.2 Voltage Difference

Thevoltagedifferencemethodoperatessimilarlytotheangledifferencemethod.Itcompares the magnitudes ofthe voltage phasors obtained from Clarke transformation.

$$V_{Diff}(t)=V_1(t)-V_2(t)$$

3.2.3 ROCPAD(Rate Of Change Of Phase Angle Difference)

3.2.3.1 Single Ended

This method calculates the rate of change of the angle difference between respective voltage and current signals. It is using measurements only from one PMU attached to the island area.

$$ROCPA(t)= \Delta(\delta v(t)-\delta i(t))/\Delta t$$

The islanding condition is detected whenever the value of ROCPAD exceeds a settable threshold.

3.2.3.2 Double Ended

The double ended ROCPAD uses values from both sides of the system and operates whenever the result of differences exceeds a programmable threshold. Alternatively, ROCPAD can also be calculated using rate of change of angle differences at two end synchrophasor voltages.

$$\text{ROCPADDiff(t)} = \text{ROCPAD2(t)} - \text{ROCPAD1(t)}$$

3.2.4 THD Difference

This novel method calculates the sum of Total Harmonic Distortion (THD) of the voltages from each PMU and compares the difference of the sums of THD.

$$\text{THDDiff(t)} = [\text{THDVa1 (t)} + \text{THDVb1 (t)} + \text{THDVc1(t)}] - [\text{THDVa2 (t)} + \text{THDVb2 (t)} + \text{THDVc2(t)}]$$

IV CASE STUDY

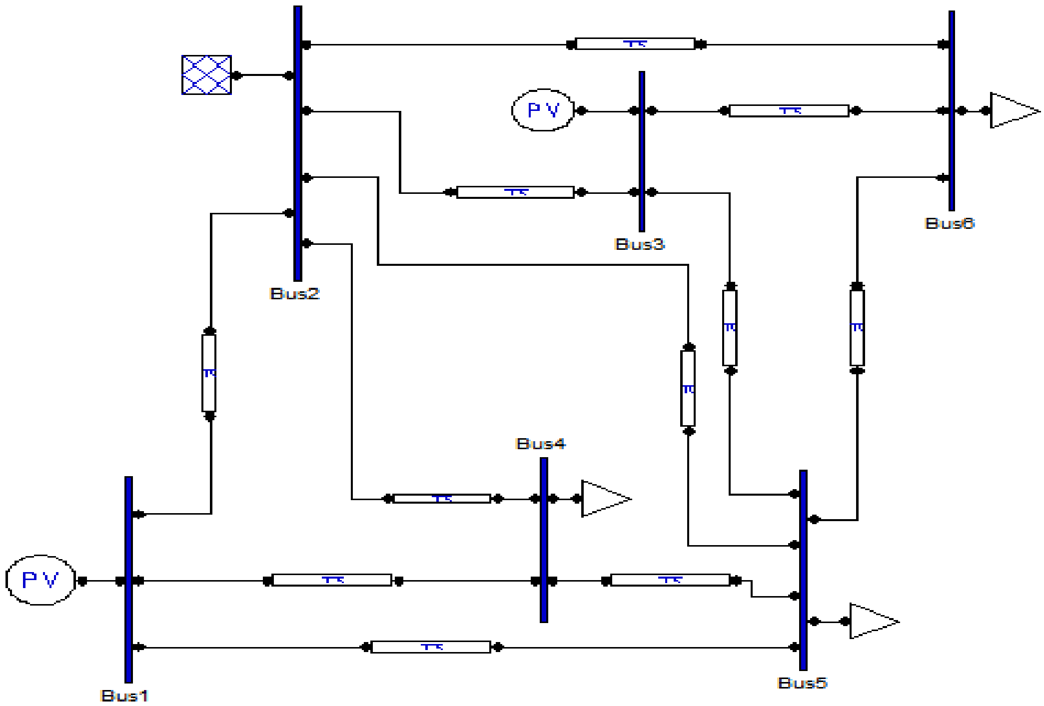

Figure 1. IEEE 6 Bus System

Above figure shows the IEEE 6 bus system having base MVA =100 MVA, base kV = 34.5 kV and system frequency = 60 Hz. The other system details are given below:

BUS	REALPOWER(P.U)	REACTIVE POWER(P.U)
At bus 4	0.90	0.60

At bus 5	1.00	0.70
At bus 6	0.90	0.60

TABLE1.LOADDATAofIEEE6 Bus system

GENERATOR NO	P+ jQ (P.U)	V (P.U.)	MVA	BUSTYPE
G1	0.9 + j1.5	1.05	100	PV
G2	1.4 + j1.5	1.05	100	SLACK
G3	0.6 + j1.5	1.05	100	PV

TABLE 2. GENERATORDATA ofIEEE6Bus system

LINE NO	BUSCODE	RESISTANCE (P.U.)	REACTANCE (P.U.)
1	3-6	0.02	0.10
2	3-5	0.12	0.26
3	5-6	0.10	0.30
4	2-4	0.05	0.10
5	1-2	0.10	0.20
6	1-4	0.05	0.20
7	1-5	0.08	0.30
8	2-6	0.07	0.20
9	2-5	0.10	0.30
10	4-5	0.20	0.40
11	2-3	0.05	0.25

TABLE3.LINE DATAofIEEE6bus system

Following Islanded Case is considered of the above IEEE 6 Bus system.

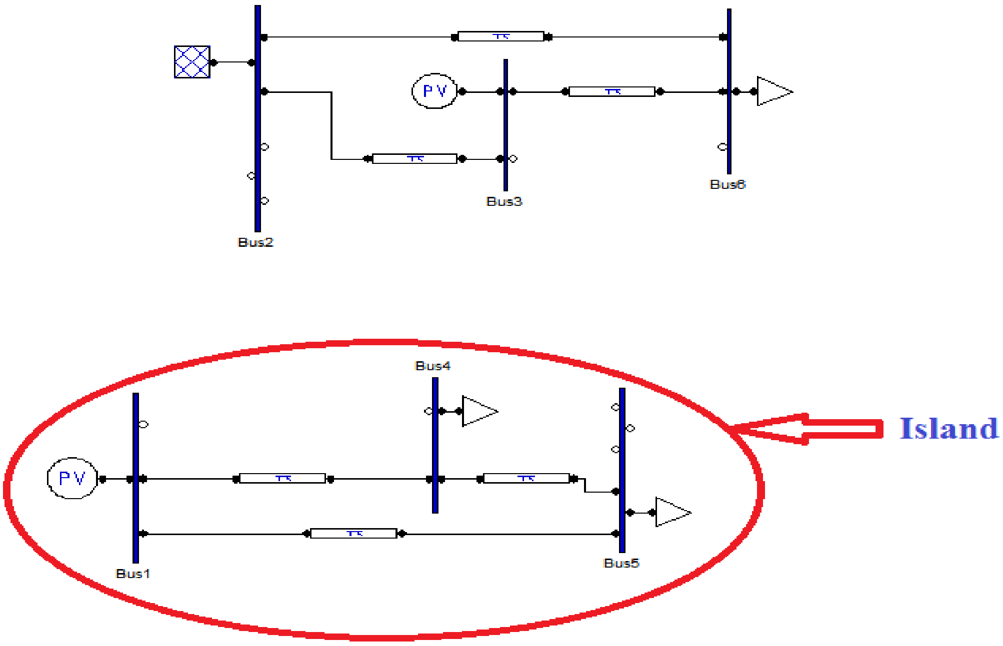

Figure 2. Islanded case of IEEE 6 Bus System

A. MATLAB Model

The MATLAB model of the above given IEEE 6 Bus system is shown in figure 3.

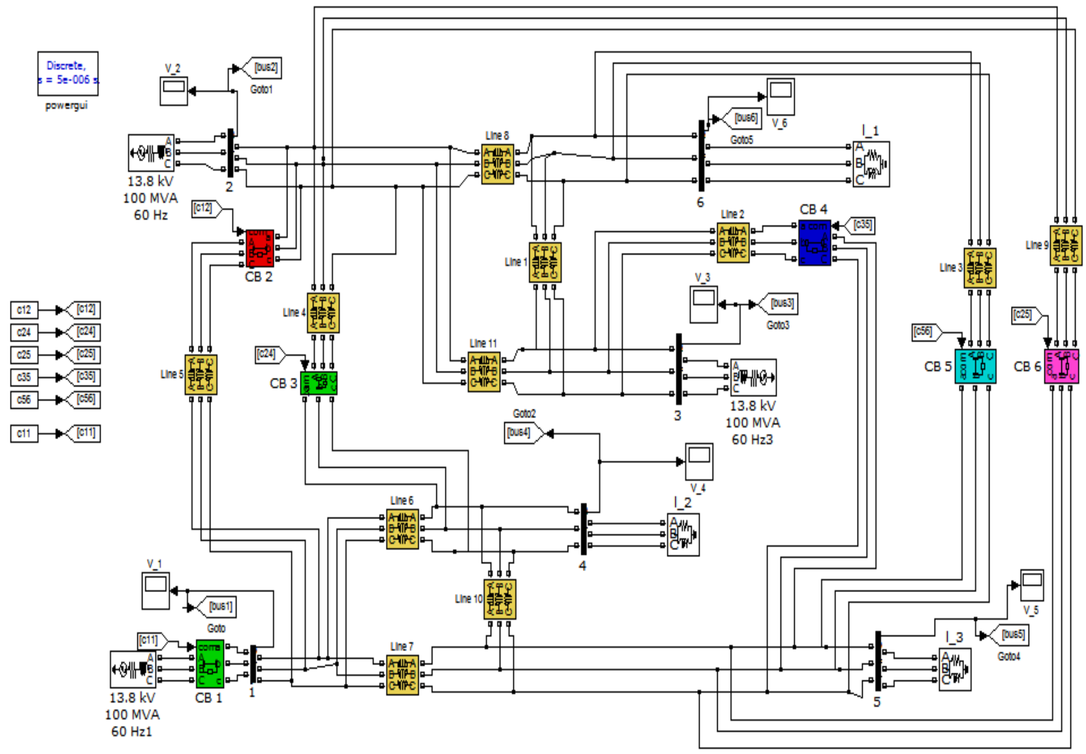

Figure 3. MATLAB Model of IEEE 6 Bus System

The above given MATLAB Model of IEEE 6 bus system is operated using traditional method and synchrophasor method at both normal condition and in the islanded condition. Now according to IEEE 1547 Standard, the permissible voltage difference allowed in the distributed system is 1%. Hence the system can be smoothly operated when the system voltages is between 0.9 > V < 1.1 P.U.

But during the islanding condition, the system voltages will be out of the permissible values. Hence the DG connected at the Bus 1 should be tripped as soon as possible.

BUS NO	NORMAL VOLTAGES	ISLANDED VOLTAGES
1	1.07	0.6221
2	1.048	1.263
3	1.049	1.241
4	0.9934	0.5288
5	0.9763	0.5062
6	0.9944	1.187

Table 4.Comparison of Voltages

We can see that during the islanding condition, the voltages goes out of range. Hence the DG is tripped as shown in figure.

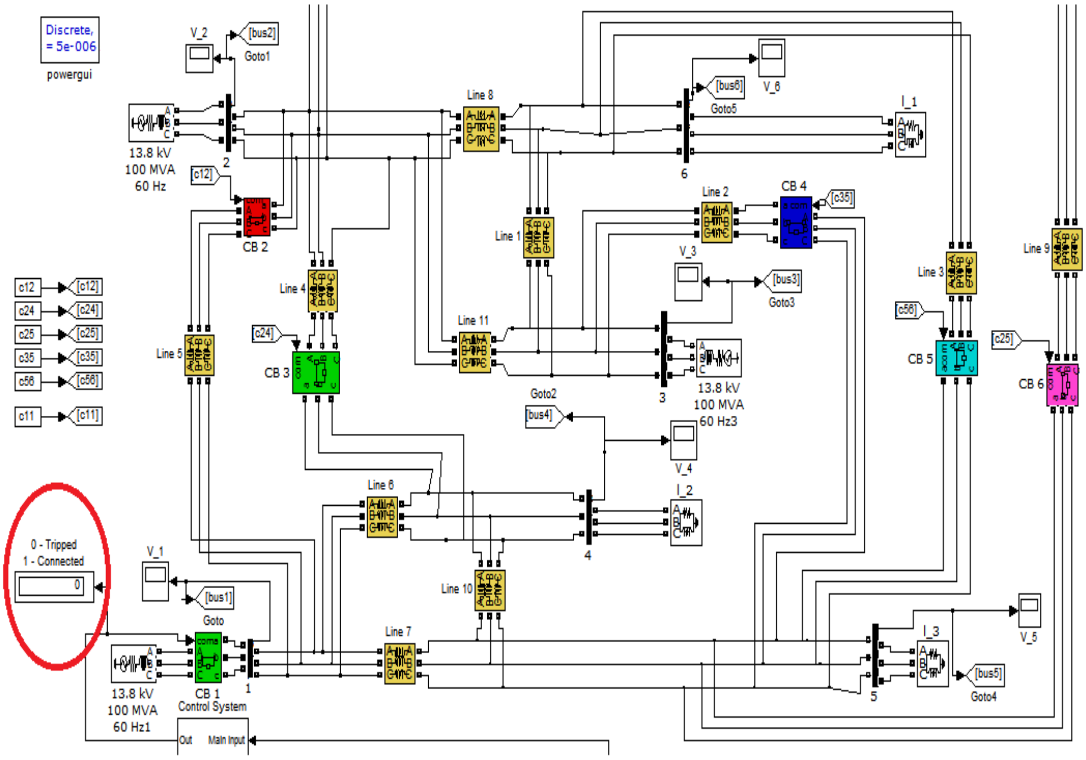

Figure 4. DG tripped

Now the same model is operated by installing the PMU (Phasor Measurement Unit) at both normal operation and islanded operation. During the normal operation there is no change in the voltage magnitudes but during the islanding condition, the voltage changes drastically and the DG is tripped.

BUS NO	NORMAL VOLTAGES	ISLANDED VOLTAGES
1	0.9245	0.4467
2	0.9537	1.263
3	0.9704	1.241
4	0.8888	0.3807
5	0.8812	0.3844
6	0.9127	1.187

Table 5.Comparison of Voltages.

Comparison of the islanding condition between the traditional method and synchrophasor method will get us to know which method works faster to detect the islanding condition.

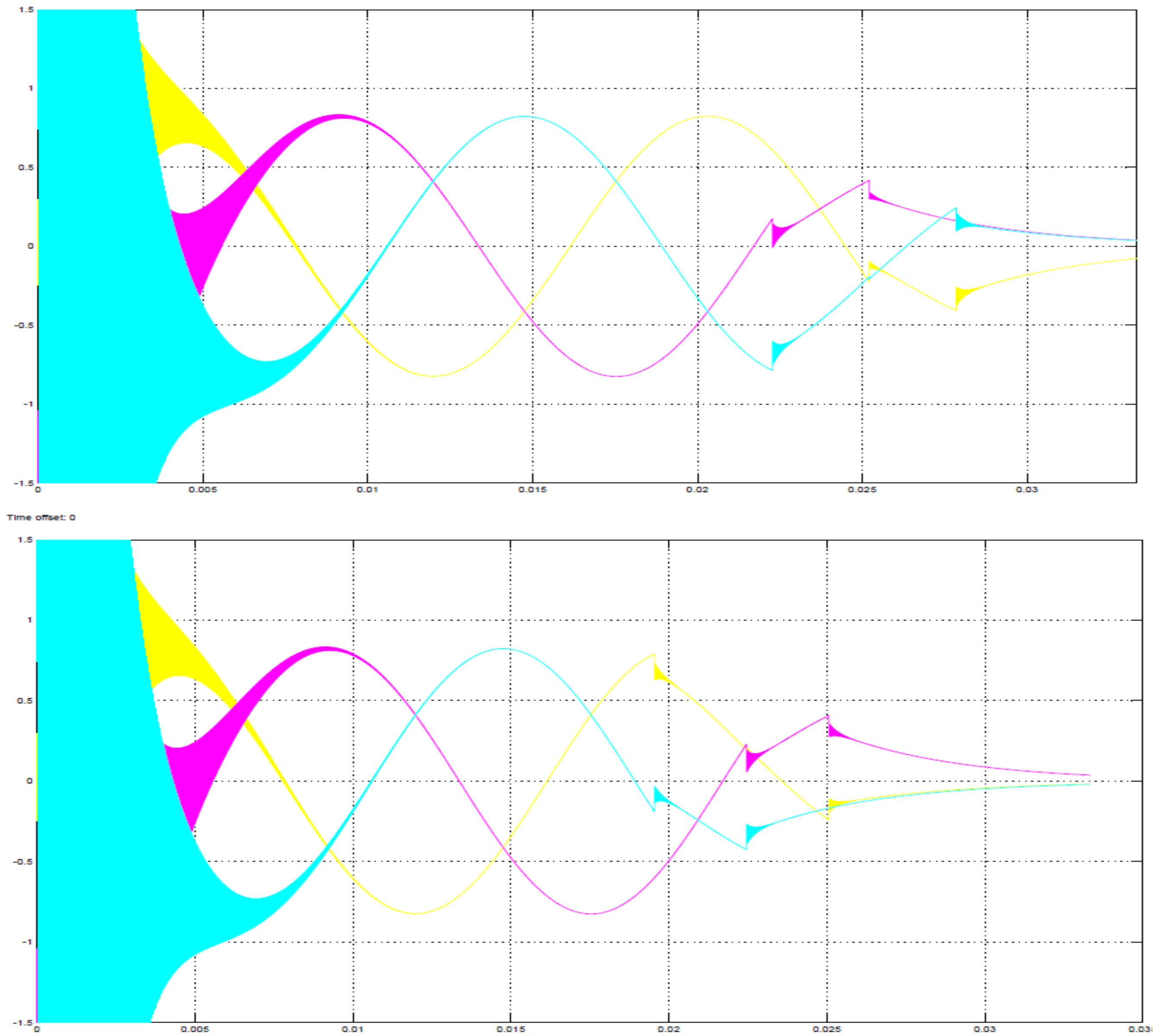

Figure 5. Comparison of the voltage waveform of traditional method and synchrophasor method when the generator is tripped at bus 1 during islanding condition

From figure 5 we can see that the time required for both the method is different. In case of traditional method the time taken for DG tripping is 0.0224 seconds, whereas in case of synchrophasor method the time taken for DG tripping id 0.0195.

Hence we can say that the synchrophasor technology works faster and gives accurate result faster which will help to control and protect the distribution system in case of any fault.

V. REFERENCES

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