ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

Anti-Islanding Scheme in Inverter Based PV Connected To Grid with Open Circuit Fault Detection in Inverter

Sasi vadhana.S
PG scholar
Power Systems Engineering
Valliammai Engineering College,
Chennai, India

Mrs.A.Anuradha M.E
Assistant professor
Electrical and Electronics Engineering department
Valliammai Engineering College,
Chennai, India

***Abstract*—this paper analyzes the anti-islanding scheme in grid connected PV system when open switch fault occurs in the voltage source inverter (VSI). Voltage source inverter plays a major role in islanding detection for grid connected DGs, any fault in the VSI will affect the islanding detection scheme. Hence in this paper a passive anti-islanding scheme is carried out considering single open switch fault in inverter. A simple algorithm is used to detect the open switch fault condition and location of the faulty switch, eliminating the need for additional sensors. An auxiliary switch is provided to bypass the open faulty switch. The overall scheme is modelled using MATLAB/Simulink.**

Index terms—anti-islanding, distributed generation(DG), open switch fault, microgrid, solar photovoltaic(PV), voltage source inverter(VSI).

I. Introduction

Solar photovoltaic (PV) based microgrids are gaining high attention nowadays due to the abundant supply of solar energy and complete depletion of fossil fuels. There are many issues related to grid connected distributed generation (DGs such as PV), one of the issues is the interconnection protection of utility and PV. The protection system must be designed in such a way that satisfies the state regulations and norms related to grid connected microgrid system. Anti-islanding protection is an additional protection scheme required by the utilities.

When the main utility is disconnected from the power system and the DG continues to supply the local load, the condition is termed as Islanding. The main aim of anti-islanding protection is to disconnect the PV system from the local load when there is loss of utility supply. In some cases the PV system may operate independently even though there is loss of utility supply, when the PV output matches the local load. But it is not desirable due to some factors such as

- It is a danger to utility workers, to work near energized power lines when the utility is disconnected.
- Poor power quality to end users.
- Damage to equipments if PV is not disconnected before auto reclosing time of utility.
- Loss of control and uncoordinated protection.

According to IEEE standard 1547[1], it is not desirable for PV system to operate during islanded operation. There are three main methods used for islanding detection - passive islanding detection, active islanding detection and communication based detection. Here in this paper passive islanding detection is implemented due its fast detection and improved power quality than the active method.

In the passive islanding detection, voltage source inverters (VSI) play a major role since the DGs are mostly inverter based [2]. Hence it is important to analyze the inverter based problems. Many faults can occur in the VSI, some of the important faults are open switch fault and short switch fault. The short switch fault can be easily identified since it causes over current in devices, but it is not easy to detect and locate open switch faults in inverter [3]-[4]. There are many reasons for the open switch faults like high collector current, thermal cycling and failure in gate driver circuits. When open switch fault is not detected quickly it will cause distortions and other secondary faults in the system which will also affect the islanding detection.

The passive anti-islanding method relies on the parameters measured at the point of common coupling (PCC). Many passive anti-islanding schemes were proposed earlier, a wide literature review is available for the passive anti-islanding [5]-[10]. Here in the proposed system, the voltage at the PCC is monitored continuously; also other parameters such as frequency, active power and reactive power are monitored and measured at the PCC. Any deviation from the nominal values will disconnect the PV from the load. If the open switch fault is not detected quickly, it will affect the parameters at the PCC which will affect the islanding detection causing the anti-islanding scheme to maloperate. Hence the open switch fault is detected soon by an algorithm using RMS current, average current and calculating the normalised current. The algorithm is discussed in detail in section III. An auxiliary switch is

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

provided to bypass the faulty switch to provide continuous supply.

In this paper, the description and modelling of PV is carried out in section II. The system model is discussed in section III. In section IV overall control scheme is explained and the simulation outputs are described in section V. Finally the conclusion is drawn in section VI.

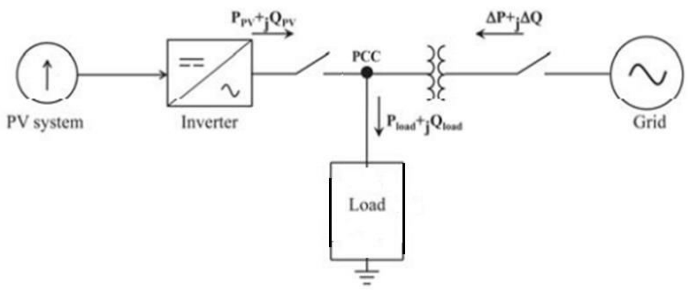


Fig.1.single line diagram circuit of the test system

II. PV MODEL

In this section PV modelling is shown in detail. In the proposed PV system, perturb and observe (P&O) algorithm is used for Maximum power point tracking. The PV module specification is given in Table.1.

A. *PV Module*

Solar cell equivalent is represented by a single diode mathematical model. It consists of photocurrent source I_{ph}, a nonlinear diode, internal resistance R_s and R_{sh} as shown in Fig.2. The relationship for the current and voltage in the solar cell equivalent can be given as

$$I = I_{ph} - I_s\left(e^{\frac{q(V+IR_s)}{AkT}} - 1\right) - \frac{V+IR_s}{R_{sh}} \qquad (1)$$

Where, I_{ph} is photocurrent; I_s is diode saturation current; q is coulomb constant (1.602e^{-19}C); *k* is Boltzmann's constant (1.381e^{-23} J/K); T is cell temperature (*K*); *A* is P-N junction ideality factor; R_s and R_{sh} are intrinsic series resistances. Photocurrent can be given as

$$I_{ph} = \left(\frac{S}{S_{ref}}\right)[I_{ph,ref} + C_T(T - T_{ref})] \qquad (2)$$

Where, S is the solar radiation (W/m^2); S_{ref} , T_{ref} , $I_{ph,ref}$ is the solar radiation, cell absolute temperature, photocurrent in standard test conditions; C_T is the temperature co-efficient (*A/K*).

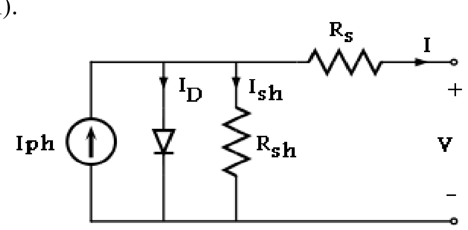


Fig.2. Equivalent circuit of solar cell

Diode saturation current in standard test conditions; E_g is the band-gap energy of the cell semiconductor (*eV*), depending on the cell material.

TABLE 1.
REFERENCE PV MODULE SPECIFICATIONS

Description	Rating
Voltage at maximum power (V_{MP})	22 V
Current at maximum power (I_{MP})	9 A
Open circuit voltage (V_{OC})	24 V
Short circuit current (I_{SC})	10 A

B. *P&O Algorithm*

In the proposed system, P&O algorithm is used for MPP tracking. The simulated block is shown in Fig.3.

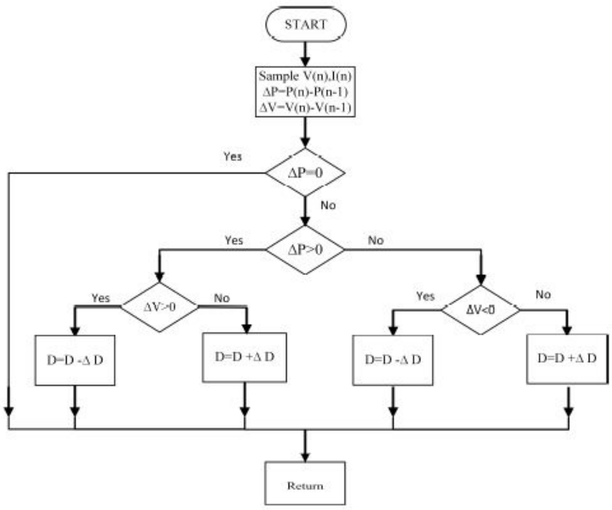


Fig.3. P&O algorithm flow chart

The P&O algorithm alters the duty cycle which controls the power converter, in this way it monitors the p-v characteristic to find the MPP. This perturbation causes a new operating point with a different output power. If this new output power is larger than the previous output power, this point is set as the new operating point or else the same power point is adjusted to a lower or higher working voltage, depending on the previous step direction. In several studies, it has been shown that P&O has led to efficiencies as high as 96.5% [11].

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

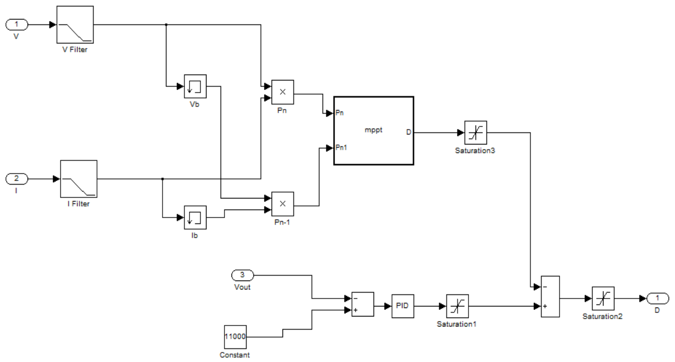


Fig.4. Simulink model of P&O algorithm

III. SYSTEM MODEL

We can assume the PV system is connected to the utility through the buck boost converter, inverter and circuit breakers. The main controller unit controls the overall scheme. The controller unit has information about the grid, PV generation and the load demand, it coordinates the overall scheme. The overall system scheme is shown in Fig.5.

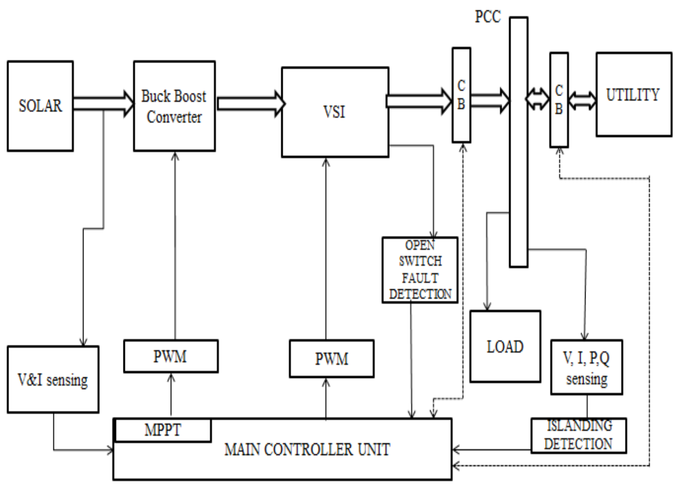


Fig.5. Block diagram of the proposed system

A. *Passive anti-islanding scheme*

The grid may be accidentally disconnected from the interconnected system due to human error or the circuit breaker may be opened due to some fault in the grid leading to islanding condition. The PV should be disconnected as soon as possible from the load and other devices in the system during this islanding condition. In the proposed passive anti-islanding scheme various parameters are measured at the PCC such as voltage, frequency, active and reactive power. During normal operation the grid supply and PV generation equals the load demand, but during the islanding condition the parameters at the PCC will considerably change when there is high mismatch between the PV generation and load demand. For analyzing the open switch fault condition we are considering high mismatch in this paper.

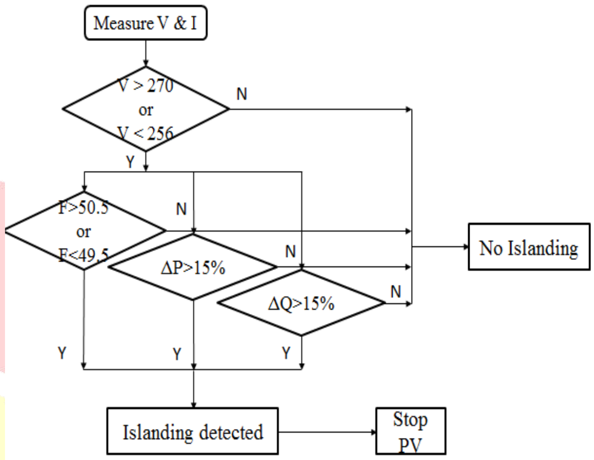


Fig.6. Anti-islanding scheme flow chart

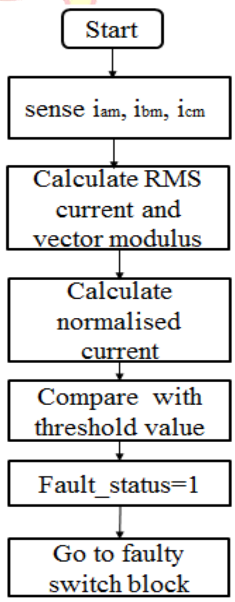
The threshold values must be set carefully, the measured parameter values are compared with the threshold values. When the measured parameters deviate from these set values the PV is disconnected from the system quickly. The ΔP and ΔQ values are as shown in the single line diagram. RLC load is used as local load in the system, RLC load's active/reactive power and its voltage/frequency relations are as follows

$$P = v^2/P \qquad (3)$$

$$Q = v^2(\omega C - 1\ \omega L) \qquad (4)$$

B. *Open switch fault detection*

The proposed open switch fault detection scheme is easy to implement, simple and cost effective, since it doesn't need any additional sensors or hardware. It uses only the information of phase, normalised and average currents. The flow chart for open switch fault detection is given below



ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

Fig.7. flow chart of open switch fault detection algorithm

The fault detection calculation is as follows, first the three phase currents i_{am}, i_{bm}, i_{cm} are measured and park's transformation is done to change it to stationary reference frame

$$i_d = \frac{2}{3} i_{am} - \frac{1}{3} i_{bm} - \frac{1}{3} i_{cm} \quad (6)$$

$$i_q = \frac{1}{\sqrt{3}} (i_{bm} - i_{cm}) \quad (7)$$

Using the above values, the park's vector modulus is calculated as shown below,

$$|\bar{\iota}_{sm}| = \sqrt{(i_d^2 + i_q^2)} \quad (8)$$

The normalised currents are calculated to detect the fault irrespective of the operating condition by dividing the inverter three phase currents by the park's vector modulus.

$$i_{an} = \frac{i_{arms}}{|\bar{\iota}_{sm}|} \quad (9)$$

$$i_{bn} = \frac{i_{brms}}{|\bar{\iota}_{sm}|} \quad (10)$$

$$i_{cn} = \frac{i_{crms}}{|\bar{\iota}_{sm}|} \quad (11)$$

Where i_{an}, i_{bn}, i_{cn} are normalised three phase RMS currents and i_{arms}, i_{brms}, i_{crms} are three phase RMS currents. When an open fault occurs in the system, one of the normalised three phase RMS currents is increased. This value is compared with the threshold value (twice as normal value) to check the fault occurrence. If the fault is identified fault count is increased till the fault is detected, then the fault location is identified using the three phase average current and normalised RMS current. The simulated scheme is shown below in fig.

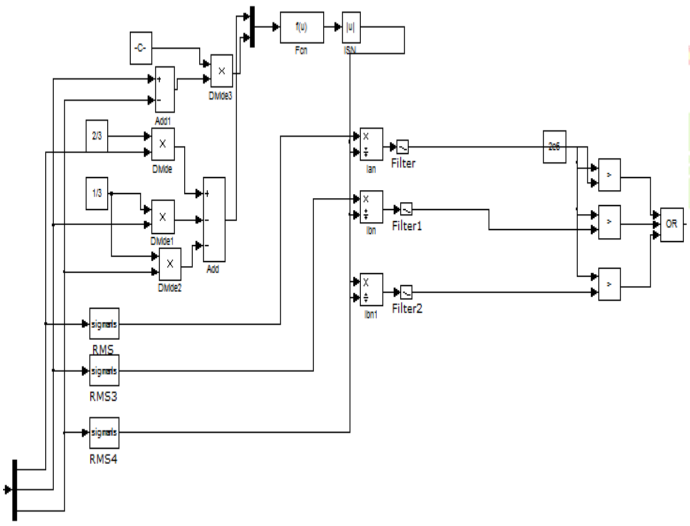


Fig.8. Open Switch Fault Detection Simulink model

IV. OVERALL SCHEME OPERATION

The open switch fault analyzed here is introduced in upper arm T5 switch. When the fault is introduced in the switch, the normal operation is affected and the fault is detected within 0.2ms. Sensing the fault in the T5 switch, an auxiliary switch is provided to bypass the open fault switch to provide continuous supply to the system. The switch is designed in such a way that it will bypass any fault switch in the inverter irrespective of the switch location.

The grid is disconnected from the system using circuit breaker and the islanding detection scheme is operated. The four parameters are measured in the PCC-voltage, frequency, active and reactive power. The voltage limit is fixed between 270 V and 256 V. The voltage value is monitored continuously and when there is deviation from the set value, other parameters are measured at the PCC. The change in active and reactive power should be below 15%. The frequency is fixed at 50 Hz. Any deviation from the fixed values will be detected and the PV is disconnected from the load. RLC load is used in this system. The system is analyzed for different scenarios like considering open switch fault alone, considering islanding condition alone and at last considering both open switch fault and islanding condition.

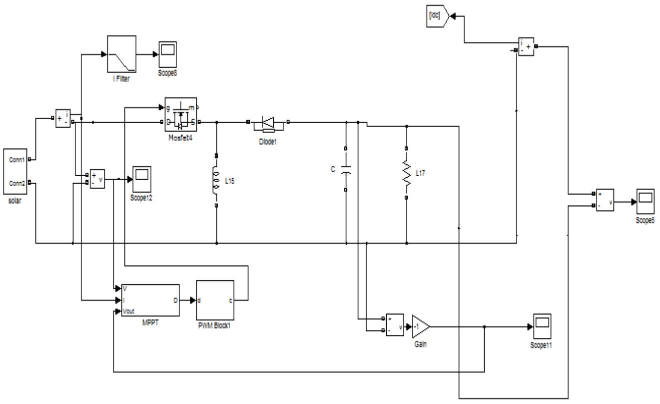


Fig.9. Simulink of PV with MPPT

The above fig.9 shows the Simulink model of PV with the buck boost converter.

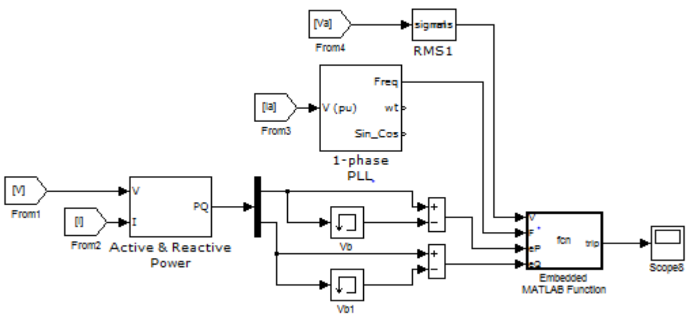


Fig.9. Islanding detection Simulink embedded block

V. SIMULATION OUTPUT

This section deals with the results obtained from Simulink model of the proposed system

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

TABLE II. BLOCK DIAGRAM PARAMETERS

System	Parameter	Value
Grid	Voltage	1MVA
Grid	Frequency	50 Hz
PV	Rated Voltage	420 V
Load	Rated Power	5KW

The above Table II gives the ratings of the system under study. The system results are as given below

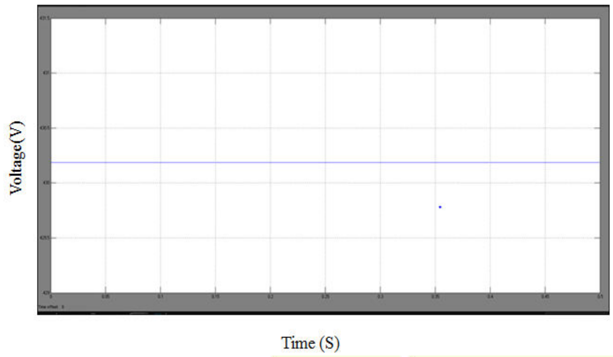


Fig.10. PV input voltage

The Grid output waveform is shown in Fig.11. This gives the grid output during islanding condition.

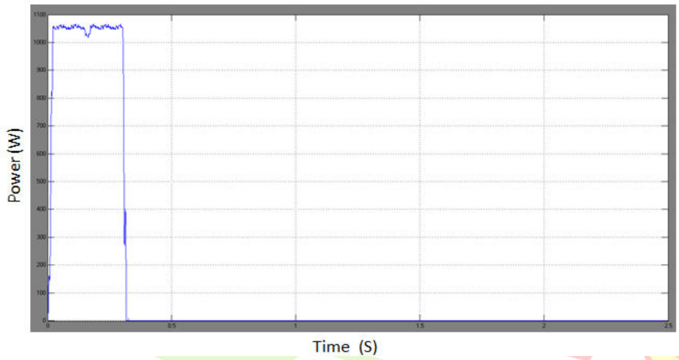


Fig.11.Grid output power

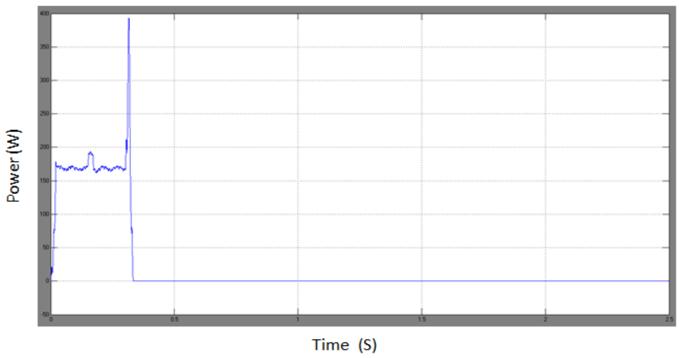


Fig.12.PV output during anti-islanding

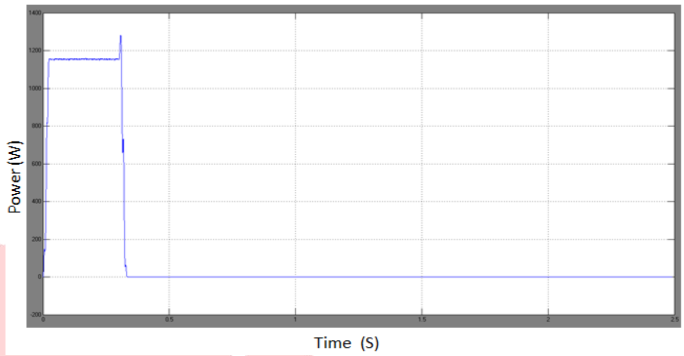


Fig.13 Load output during anti-islanding

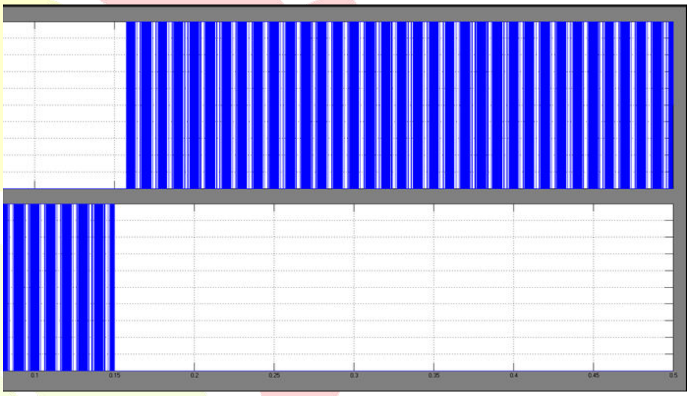


Fig.14 Faulty switch and Auxiliary switch conduction

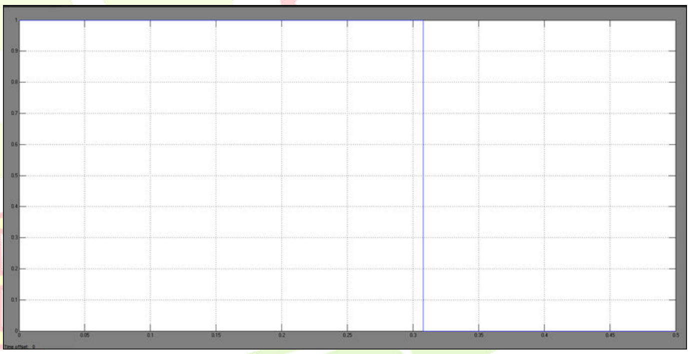


Fig.15.Breaker trip signal

VI. Conclusion

In this paper the passive anti-islanding scheme is analyzed with the open switch fault detection. The proposed anti-islanding and open switch fault detection is simple and easy to implement. The system under various scenarios is observed.

It can be observed from the system that the open switch fault affects the islanding detection and when an auxiliary switch is provided to give continuous supply, the system works well with the anti-islanding scheme. In future, multiple switch faults can be analyzed in the inverter with an effective anti-islanding scheme.

ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

References

[1.] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Standard 1547-2003, June 2003.

[2.] Ye, Z.; Walling, R.; Garces, L.; Zhou, R.; Li, L.; Wang, T. “Study and Development of Anti-Islanding Control for Grid-Connected Inverters.” NREL/SR-560-36243. Golden, CO: National Renewable Energy Laboratory, May 2004.

[3.] W. S. Im, J. S. Kim, J. M. Kim, D. C. Lee and K. B. Lee, “Journal of Power Electronics”, Diagnosis Methods for IGBT Open Switch Fault Applied to Three-phase AC/DC PWM Converter, vol. 12, no. 1, 2012.

[4.] N. M. A. Freire, J. O. Estima and A. J. M. Cardoso, “IEEE Trans. on Industry Electronics”, Open-Circuit Fault Diagnosis in PMSG Drives for Wind Turbine Applications, vol. 60, no. 9, 2013.

[5.] P. Mahat, Z. Chen, and B. Bak-Jensen, “Review of islanding Detection methods for distributed generation,” in Proceedings of the 3rd International Conference on Deregulation and Restructuring and Power Technologies (DRPT ’08), pp. 2743–2748, Nanjuing, China, April 2008.

[6.] P. Du, Operation of power system with distributed generation [Ph.D. thesis], Faculty of Rensselaer Polytechnic Institute, Rensselaer Polytechnic Institute, New York, NY, USA, 2006.

[7.] B. Yu, M.Matsui, and G. Yu, “A review of current anti-islanding methods for photovoltaic power system,” Solar Energy, vol. 84, no. 5, pp. 745–754, 2010.

[8.] Z.Ye, A.Kolwalkar,Y. Zhang, P.Du, and R.Walling, “Evaluation of anti-islanding schemes based on non-detection zone concept,” IEEE Transactions on Power Electronics, vol. 19, no. 5, pp. 1171–1176, 2004.

[9.] D.Velasco, C. L. Trujillo,G.Garcer´a, and E. Figueres, “Review of anti-islanding techniques in distributed generators,” Renewable and Sustainable Energy Reviews, vol. 14, no. 6, pp. 1608–1614,2010.

[10.] M. Valentini, S. Munk-Nielsen, F. V. Sanchez, and U. M. de Estibariz, “A new passive islanding detection method for grid connected PV inverters,” in Proceedings of the International Symposium on Power Electronics, Electrical Drives, Automation and Motion, pp. 223–228, IEEE, Ischia, Italy, June 2008.

[11.] M. E. Ropp D. P. Hohm “Comparative study of maximum power point tracking algorithms using an experimental, programmable, maximum power point tracking test bed”. Twenty-Eighth IEEE Photovoltaic Specialists Conference, 2000

[12.] M. Yingram and S. Premru deepreechacharn, “Investigation over/under-voltage protection of passive islanding detection method of distributed generations in electrical distribution systems,” in Proceedings of the International Conference on Renewable Energy Research and Applications (ICRERA ’12), pp. 1–5, Nagasaki, Japan, November 2012.

[13.] Z. Mi and F. Wang, “Power equations and non-detection zone of passive islanding detection and protection method for grid connected photovoltaic generation system,” in Proceedings of the Pacific-AsiaConference on Circuits, Communications and System (PACCS ’09), pp. 360–363, May 2009.

[14.] F. de Mango, M. Liserre, and A. Dell’Aquila, “Overview of anti islanding algorithms for PV systems. Part II: active methods,” in Proceedings of the 12th International Power Electronics and Motion Control Conference (EPE-PEMC ’06), pp. 1884–1889, September 2006.

[15.] B. J. Jin, J. K. Hee, H. B. Soo, and S. A. Kang, “An improved method for anti-islanding by reactive power control,” in Proceedings of the 8th International Conference on Electrical Machines and Systems (ICEMS ’05), pp. 965–970, September 2005.