MODELLING OF SOLAR BASED POWER GENERATION GRID AND ISLANDING EFFECT ANALYSIS PV CONNECETD LOAD FLOW BUS

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Abstract—

Islanding detection and protection is an important aspect in grid connected solar photovoltaic power generation system. This paper presents the analysis, design, implementation and evaluation of passive anti-islanding methods in solar PV plants. Over/Under Voltage Protection (OVP/UVP) and Over/Under Frequency Protection (OFP/UFP) are basic passive islanding detection method (IDM) for detecting an islanding condition by monitoring parameters at Point of Common Coupling (PCC) such as voltage amplitude and frequency and then cause the inverter to shut down when there is sufficient transition from normal specified threshold range. The performance of the proposed method has been studied by using simulations in MATLAB/SIMULINK.

Keywords— PV System, Islanding, Anti-islanding protection, Passive anti-islanding protection, NDZ.

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I. Introduction

Distributed Generation (DG), unlike centralized generating power plants, generate electricity from small scale renewable energy sources like solar PV, wind energy, fuel cell, micro turbine etc. The main advantages of using DG are that it can be installed near the load, economy in maintenance, reduction in transmission line losses, reduced congestion in transmission and distribution network, reduced environmental impacts in global warming and other forms of pollution. According to IEEE Standard 929-2000 [1], “IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) systems”, the operation of grid connected roof-top solar PV systems will give rise to many problems in power quality and safety. Some of the power quality problems are voltage regulation, frequency regulation, flickering, harmonics, waveform distortion etc. Some of the problems associated with safety are islanding protection, response to abnormal utility conditions like voltage and frequency disturbances, ability to reconnect after a utility disturbance, grounding etc. Among all the associated problems, unintentional islanding is one of the most important safety concerns associated with grid connected roof-top solar PV systems. According to IEEE Standard 1547 [2], islanding is defined as “A condition in which a portion of an Area Electric Power System (EPS) is energized solely by one or more Local EPS's through the associated Point of Common Coupling (PCC) while that portion of the Area EPS is electrically separated from the rest of the Area EPS”. The occurrence of islanding can be fatal to utility workers who may not realize that the local area is still powered and encounter severe electric shock. For this reason, DG must be equipped to detect islanding and isolate itself from the grid immediately, which is commonly referred to as anti-islanding. There are many anti-islanding schemes reported in the literature [3]-[5] which can be broadly classified as active and passive schemes. Passive anti-islanding schemes [3], [6] are used in the detection of islanding with the help of protective devices which monitors the changes in system parameters like voltage, frequency, phase shift etc. These methods are traditionally economical and simple in technology. But there exists a scenario in which exact balance of PV generation and load would result in negligible change in voltage and frequency at PCC, thus making it difficult to detect absence of electric utility and hence resulting in failure of passive schemes. This problem if rectified by changing the upper and lower threshold limit of overvoltage (OV)/under voltage (UV) relay and over frequency (OF)/ under frequency (UF) relay, would result in nuisance tripping which causes further malfunction of the protection system. Thus, there is a need to explore the shortcomings of standard passive anti-islanding schemes by implementing novel active anti-islanding schemes. Active antiislanding schemes [3]-[6] such as Impedance Measurement, Active Frequency Drift, Slip Mode Frequency Shift etc. are used in the detection of islanding by creating perturbation in the same system parameters which otherwise fail to get detected by the traditional passive schemes [7].

II. Related work

Synthesis of Distributed Generations (DGs) in the distribution network is expected to play an increasingly important role in the electric power system groundwork and market. As more DG systems become part of the power grid, there is an increased safety peril for personnel and an increased risk of damage to the power system. Despite the favorable aspects grid-connected DGs can supply to the distribution system, a critical demanding concern is islanding detection and interception. Islanding operation is a condition that occurs when a part of a network is disconnected from the remainder of power system but being energized by interconnected DG units to the distribution system, which normally consist multiple DGs with diverse technologies. Misstep to trip islanded DG can lead to a number of problems for these resources and the connected loads, which affects power quality, safety and operating problems [8,9].

III. Islanding detection

The islanding detection methods are classified into two main parts as shown in fig 1. The remote methods and local methods. The local methods is further sub divided into Passive methods, Active methods and Hybrid methods. And remote methods are the communication based methods.

A) Passive detection

Passive methods include any system that attempts to detect transient changes on the grid, and use that information as the basis as a probabilistic determination of whether or not the grid has failed, or some other condition has resulted in a temporary change. Passive methods work on measuring system parameters such as variations in voltage, frequency, harmonic distortion, etc[10,11].

a) Under/over Voltage and under/over Frequency

When islanding effect happened, the imbalance of active power will cause the change of frequency and the imbalance of reactive power will cause the change of voltage. If the change of frequency and voltage exceeds the threshold value, the over/under voltage and over/under frequency detection device will send alarm and stop the output of inverter or switch to island operation mode.

b) Phase mutation detection method

When distributed power supply is connected to the power grid, power factor for 1, the output current, frequency and phase is completely consistent, and the phase difference is zero between the output voltage and current. When the powers supply loss, the load will be supplied by photovoltaic grid-connected generation system. At the same time, the phase of the voltage and current depends on the load. Phase mutation detection method is simple and can be realized easily. But when the load impedance angle is close to zero, it will be failure due to the limitation of the set threshold value. [6]

c) Harmonic detect

When distributed power supply is connected to the power grid, because the resistance is small in the big power grid, the total harmonic distortion rate is very low at a point.[7]

B) Active detection

Active islanding detection method is based on the injection of a small disturbance signal to certain parameters at the PCC [12,13]. The concept of this method is that small disturbance signal will become significant upon entering the islanding mode of operation in order to help the inverter to cease power conversion. Hence, the values of system parameter will be varying during the cessation of power conversion, and by measuring the corresponding system parameters, islanding condition can be detected [14], as shown in Fig.1.

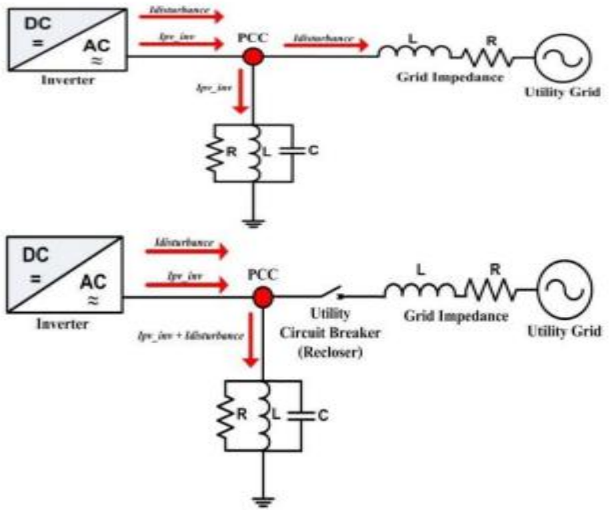

Fig. 1 The path of disturbance signals during an islanding condition, (a) before the circuit breaker is opened, (b) after the circuit breaker is opened.

Grid Support Functions

The four grid support functions whose impacts on anti-islanding were investigated are:

1. Low- and high-voltage ride-through (VRT): The inverter must remain connected during certain defined excursions of voltage away from nominal.
2. Low- and high-frequency ride-through (FRT): The inverter must remain connected during certain defined excursions of frequency away from nominal.
3. Volt-VAr control (VVC): The inverter controls its reactive power output following a predefined curve based on the AC voltage at its terminals.
4. Frequency-Watt control (FWC): The inverter controls its real power output following a predefined curve based on the AC frequency at its terminals.

IV. Photovoltaic and islanding detection

A long-standing requirement for distributed energy resources (DERs), such as photovoltaic (PV) systems, connected to the electric power system (EPS) is that they must disconnect from the EPS when an electrical island is formed. As used here, the term island refers to a portion of the EPS that remains energized by one or more DERs following disconnection from the remainder of the EPS. Intentional islands, also known as microgrids, are not in the scope of this report. This report is concerned with unintentional islands, which form when a breaker or other protective device opens, isolating a part of the EPS containing at least one DER. Unintentional island detection helps prevent potential hazardous conditions such as unexpected contact with energized lines within an island, and closing of a breaker between an EPS and an island with out-of-phase voltages. In the IEEE 1547-2003 Standard for Interconnecting Distributed Resources with Electric Power Systems, inverters paired with DERs are required to disconnect from the EPS within two seconds of the formation of an electrical island [15]. For inverter-based DERs, such as PV systems and most energy storage systems, this is often achieved through autonomous island detection controls resident in the inverter that connects the DER to the EPS. Such controls use one or more of a wide variety of active or passive methods to detect an island [2]. Many such methods rely at least partially on the EPS voltage or frequency either going outside normal operating regions or changing faster than would occur in a non-islanded situation to detect an island. In addition to requiring DERs to disconnect during unintentional islands, standards such as IEEE 1547-2003 have also required DERs to quickly disconnect when EPS conditions migrated outside of relatively narrow operating regions and have typically prohibited DERs from attempting to regulate grid voltage or frequency [1]. This was a feasible solution with only a small number of DERs interconnected to the EPS. However, as the number and aggregate power output of DERs – especially PV systems – increase, many utilities, regulators, and standards setting organizations are considering or imposing new requirements that DERs remain connected during (or ride through) various abnormal grid conditions and even help stabilize the grid in abnormal conditions [3], [4][5].

Anti-islanding Solutions

According to IEEE 1547 section 4, an Area EPS must be de-energized within two seconds of the formation of an island. In other words, for an unintentional island in which the PV Plant energizes a portion of the grid through the interconnection point, the PV Plant interconnection system shall detect the island and cease to energize the grid within two seconds of the formation of an island.

We have two methods for ensuring that happens. We have a passive method that monitors the voltage and frequency. Secondly we have an active anti-islanding method where we vary the output of the reactive power to help destablize the island and accelerate the dissolving of the system to extinguish the island.

Anti-islanding or islanding protection

To avoid this problem, it is recommended that all distributed generators shall be equipped with which devices to prevent islanding. The act of preventing islanding from happening is also called **anti-islanding**.

Problems caused by islanding

Islanding causes many problems, some of which are listed below:

1. **Safety Concern:** Safety is the main concern, as the grid may still be powered in the event of a power outage due to electricity supplied by distributed generators, as explained earlier. This may confuse the utility workers and expose them to hazards such as shocks.
2. **Damage to customers' appliances:** Due to islanding and distributed generation, there may be a bi-directional flow of electricity. This may cause severe damage to electrical equipment, appliances, and devices. Some devices are more sensitive to **voltage fluctuations** than others and should always be equipped with surge protectors.
3. **Inverter damage:** In the case of large solar systems, several inverters are installed with the distributed generators. Islanding could cause problems in the proper functioning of the inverters.

V. Proposed methodology

The system topology consists of a grid connected solar photovoltaic power plant, three phase full bridge inverter, digital controller hardware and islanding test set up. Grid interconnection of photovoltaic power generation system has the advantage of more effective utilization of generated power. Grid interconnection of PV system is accomplished through the inverter, which converts DC power generated by PV module to AC power used for ordinary power supply for electrical equipments .Inverter technology is very important to have reliable and safety grid interconnection operation of PV system. A filter is required between a VSI and the grid to reduce harmonics of the output current. A simple series inductor can be used, but the harmonic attenuation is not very pronounced. In addition, a high voltage drop is produced and the inductor required in the design is very bulky. Commonly a high-order LCL filter has been used in place of the conventional L-filter for smoothing the output currents from a VSI. The LCL filter achieves a higher attenuation along with cost savings, given the overall weight and size reduction of the components. LCL filters have been used in grid-connected inverters and pulsewidth modulated active rectifiers, because they minimize the amount of current distortion injected into the utility grid. The higher harmonic attenuation of the LCL filter allows the use of lower switching frequencies to meet harmonic constraints as defined by standard such as IEEE-1547.

Non-Detection Zone Despite its simplicity and easiness to implement, passive methods suffer from large non detection zones (NDZs). NDZs could be defined as the loading conditions for which an islanding detection method would fail to operate in a timely manner. However, if the DG generation active and reactive power (PG, QG) matches the power requirements of the local load active and reactive power (PL, QL), no electric parameter changes occur at the DG connection point. Moreover, with an increasing penetration of DG in the power system, new grid codes require not to disconnect the DG during voltage and frequency excursions that may occur during normal operation. Thus, protection thresholds for these variables must be consistently widened, resulting in larger non detection zones (NDZ).

Therefore, more sophisticated detection methods can be needed to detect the island situation.

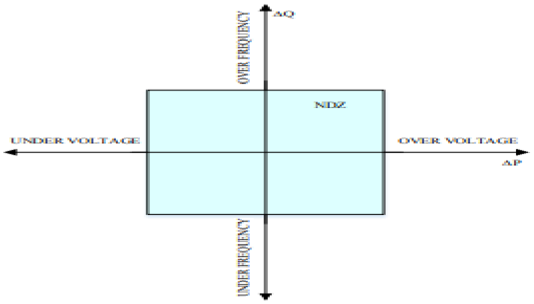

Fig. 2. NDZ Representation Usually there is always some power mismatch ΔP+jΔQ between the PV inverter output and the RLC load. Before the grid is disconnected, this power mismatch ΔP+jΔQ are supplied by the grid.

VI. Simulation result

The simulation block diagram of the grid connected solar photovoltaic system and the controllers with associated are shown in Fig.3 and the output board in detail in Fig. 4. Under grid connected mode of operation, the voltage and current waveform will be sinusoidal as shown in Fig. 5 and the voltage and current profile remain unchanged throughout the grid connected mode of operation. However when islanding occur there will be a corresponding change in voltage and current as represented in Fig. 6.

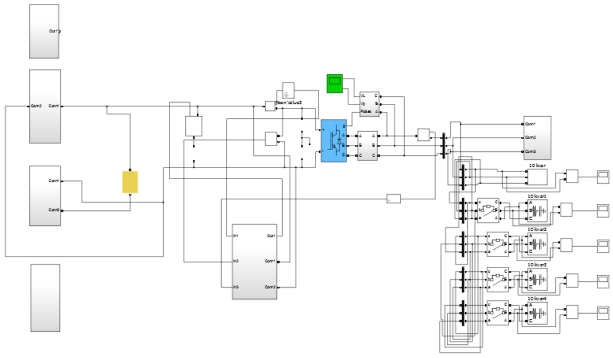

Fig.3 Simulink Model.

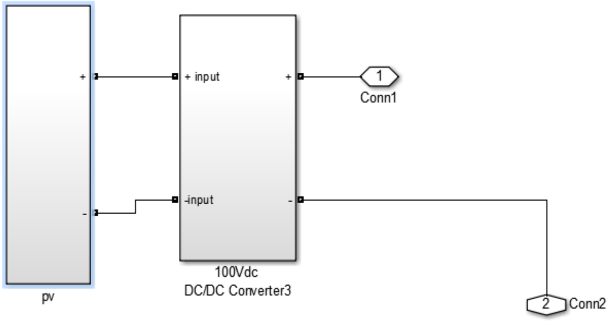

Fig.4 PV generation.

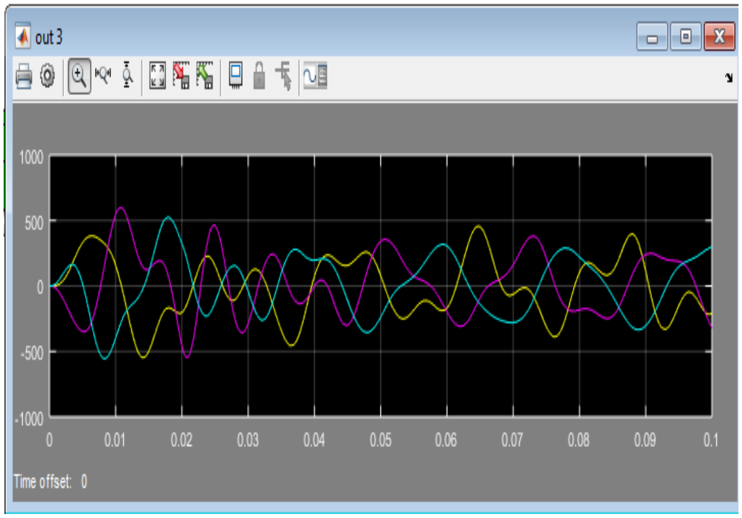

Fig.5 Islanding Effects in PV generation in terms of voltage.

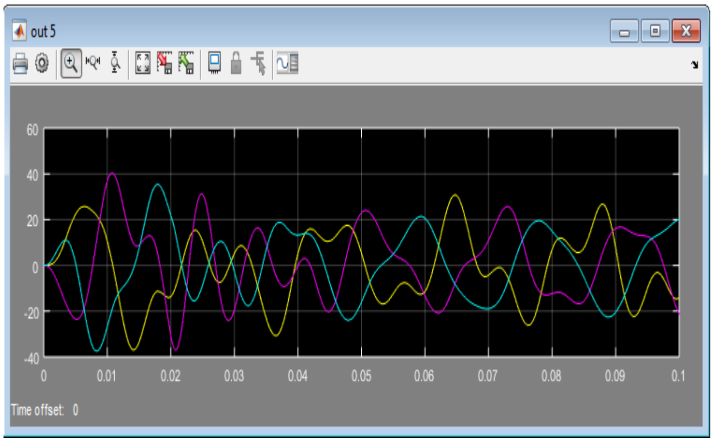

Fig.6 Islanding Effects in PV generation in terms of Current.

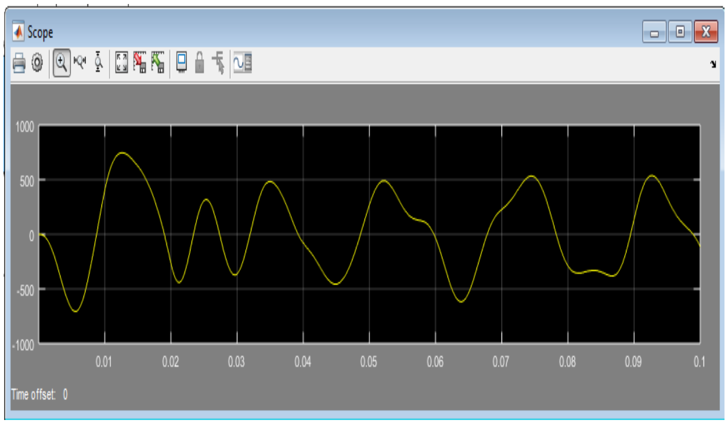

Fig.7 Islanding Effects in PV generation across bus.

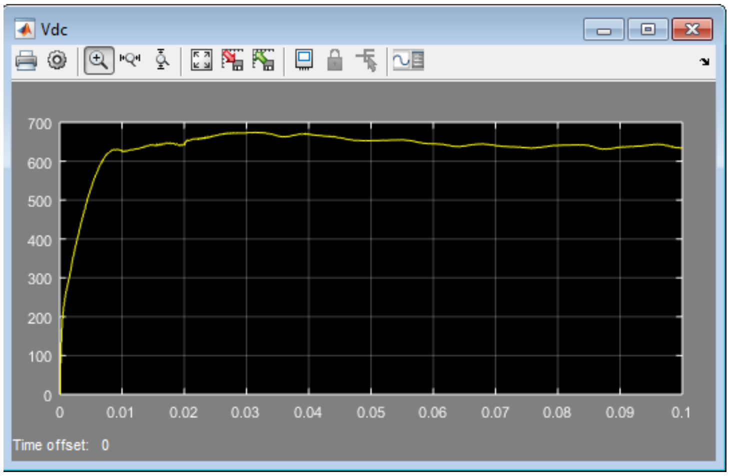

Fig.8 Islanding Effects in PV generation across battery ant islanding.

VII. Conclusion

In the last few years, distributed generation systems (DGSs) have acquired popularity amongst which the photovoltaic based generation has gained prominence. In this paper, analysis, design, implementation and evaluation of passive anti-islanding methods for grid connected solar photovoltaic power plant was done. The developed algorithm comprises of system components and an appropriate controller. The model has been implemented using the MATLAB/SIMULINK software package. The dynamic behavior of the proposed model was examined under different operating conditions. The developed system and its control strategy exhibit excellent performance in the simulation.

References

[1] X. Yaosuo, L.-C. Chang, Sren, B. Kjaer, J. Bordonau, and T. Shimizu, "Topologies of single-phase inverters for small distributed power generators: an overview," IEEE Transactions on Power Electronics, 2004, vol. 19, no. 5, pp.1305-1314.

[2] Merino, J.; Mendoza-Araya, P.; Venkataramanan, G.; Baysal, M. Islanding detection in microgrids using harmonic signatures. IEEE Trans. Power Deliv. 2015, 30, 2102–2109

[3] Yu, B.; Abokhalil, A.G. Optimized AFD anti-islanding method for grid connected PV system. Int. Conf. Converg. Technol. 2013, 2, 1783–1784.

[4] Schweitzer, E. Synchrophasor-Based Power System Protection and Control Applications. In Proceedings of the 2010 Proceedings of the International Symposium Modern Electric Power Systems (MEPS), Wroclaw, Poland, 20–22 September 2010.

[5] Ebadollah, K.; Javad, S. Islanding detection method for photovoltaic distributed generation based on voltage drifting. IET Gener. Transm. Distrib. 2013, 7, 584–592.

[6] L. Asiminoaei, R. Teodorescu, F. Blaabjerg et al., "A Digital Controlled PV-Inverter With Grid Impedance Estimation for ENS Detection," IEEE Trans. Power Electron, vol. 20, no. 6, pp: 1480- 1490,2005.

[7] Y. Gwon-jong, S. Jeong-Hoon, J. Young-Seok, C. Ju-yeop, J. Seung-Gi, K. Ki-Hyun, and L. Ki-ok, "Boundary conditions of reactive-power-variation method and active-frequency-drift method for islanding detection of grid-connected photovoltaic inverters," in Proc. Conference Record of the Thirty-first IEEE on Photovoltaic Specialists Conference, 2005, pp.1785-1787.

[8] M. Karimi-Ghartemani and A Synchronization, Scheme Based on an Enhanced Phase-Locked Loop System,2004.

[9] IEA International Energy Agency, Evaluation of Islanding Detection Methods for Photovoltaic Utility Interactive Power systems, in Task V Report IEA PVPS T509: 20022002

[10] Funabashi, T., K. Koyanagi, and R. Yokoyama. A review of islanding detection methods for distributed resources. in Power Tech Conference Proceedings, 2003 IEEE Bologna. 2003.

[11] Noor, F., R. Arumugam, and M.Y. Vaziri. Unintentional islanding and comparison of prevention

techniques. in Power Symposium, 2005. Proceedings of the 37th Annual North American. 2005.

[12] Ward Bower and M. Ropp., Evaluation of Islanding Detection Methods for Utility-Interactive Inverters in Photovoltaic Systems, in SAND20023591 Unlimited Release2002.

[13] Kunte, R.S. and G. Wenzhong. Comparison and review of islanding detection techniques for distributed energy resources. in Power Symposium, 2008. NAPS '08. 40th North American. 2008.

[14] Lopes, L.A.C. and S. Huili, Performance assessment of active frequency drifting islanding detection methods. Energy Conversion, IEEE Transactions on, 2006. 21(1): p. 171-180.

[15] Gwon-jong, Y., et al. Boundary conditions of reactive-powervariation method and active-frequency-drift method for islanding detection of grid-connected photovoltaic inverters. in Photovoltaic Specialists Conference, 2005. Conference Record of the Thirty-first IEEE. 2005.

[16] A. Vaccaro, G. Velotto, et. al. "A decentralized and cooperative architecture for optimal voltage regulation in smart grids." IEEE Transactions on Industrial Electronics 58.10 (2011): 4593-4602.

[17] B.M.S. Muhammad Ramadan, R. T. Naayagi, et. al. "Modelling, simulation and experimentation of grid tied inverter for wind energy conversion systems." Green Energy and Applications (ICGEA), International Conference on. IEEE, 2017.

[18] P. Mahat, Z. Chen, et. al. "Review on islanding operation of distribution system with distributed generation." Power and Energy Society General Meeting, 2011 IEEE. IEEE, 2011.

[19] H. Zeineldin, E.F. El-Saadany, et. al. "Intentional islanding of distributed generation." Power Engineering Society General Meeting, 2005. IEEE. IEEE, 2005.

[20] Z. Ye, L. Li, et al. "A new family of active antiislanding schemes based on DQ implementation for grid-connected inverters." Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual. Vol. 1. IEEE, 2004.