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ISLANDING DETECTION USING INVERTER DC-LINK VOLTAGE

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ABSTRACT

Integration of Renewable Energy Resources (RERs) such as wind turbines and photovoltaic (PV) in to the electric power distribution network is on the increase. One of the integration requirements, in accordance with IEEE 1547 and UL 1741, is the islanding detection, basically implemented as Under Over Voltage (UOV) protection. This method has high Non Detection Zone (NDZ) due to the standard utility allowable voltage operation limits. In this paper, an inverter DC-Link voltage is used as an alternative for islanding detection with reduced NDZ compared with the UOV. MATLAB/ Simulink were used to simulate a 0.1 MW inverter-based, grid-connected PV system, as a test bench for the proposed islanding detection method.

Keywords: renewable energy resources, photovoltaic, DC-Link voltage, and islanding detection.

INTRODUCTION

The growing demand of electricity as well as the environmental green-house gaseous emission of the conventional electricity generators is alleviated by the integration of renewable energy resources (RERs) into the current electric grid network. Other RER integration benefits include peak shaving, reliability improvement, transmission lines deferral, decreased transmission and distribution power losses etcetera. Despite the numerous advantages, the integration suffers some drawbacks, paramount of which is the occurrence of unintended islanding defined as a condition in which the RER continues to sustain its local load in the absence of the grid supply. This condition is not allowed as spelled out by many standards including IEEE 1547, UL 1741, ECC etc. This is due to the safety hazards caused by the potential island on the connected load, unsuspecting utility maintenance crew and the RER itself. Therefore, it is necessary for every grid-connected RER to detect the occurrence of islanding and consequently be isolated from its connected load within a maximum of two seconds, in post islanding [1], [2], [3], [4].

There are many islanding detection methods for the synchronous and inverter-based RER. These methods can be broadly classified into two main categories; RER-based and communication-based. The latter uses a transmitter and receiver between a RER and the utility which is very expensive for small capacity RERs. The former method can further be classified as passive, active and hybrid islanding detection methods [1], [5].

The passive islanding detection methods evaluate some parameters taken at the Point of Common Coupling (PCC) against a threshold for detecting the occurrence of islanding [6]. The parameters include voltage, frequency, phase angle and their derivatives. This method is very simple, cost-effective and devoid of power quality problems, though associated with large Non Detection Zone (NDZ). NDZ is a condition in which the occurrence islanding cannot be detectable when the RER capacity and its connected load are with little or no disparity. Examples of passive islanding detection include under/over voltage (UOV), under/over frequency (UOF) [7].

Active islanding detection methods, on the other hand, deliberately introduce disturbance through the RER interface controllers. The disturbance signals are measured at the PCC and compared with a certain threshold value for islanding detection [8]. In grid-connected mode, the grid provides a low impedance path for the disturbance signal thereby rendering its value at PCC insignificant. On the occurrence of islanding, the RER load provides a high impedance path for the signal, and the RER to become unstable due to its interface controller driving the measured signal to be continuously changing and ultimately surpasses the threshold value. This method has smaller NDZ value compared with the passive method but effects the system's power quality.

The hybrid islanding detection methods combine the strengths of the passive and active methods [9].

IMPLEMENTED STUDY SYSTEM

The system used for the study is shown in Figures-1 and 2 which are simulated in MATLAB Simulink/ Simpower Systems. It represents the implementation of a 0.10 MW, grid-connected photovoltaic (PV) system with design parameters as indicated in Table 1. The PV array is capable of generating the required power capacity of the RER at maximum power fixed by the Maximum Power Point Tracking (MPPT) system, which coordinates the DC-DC converter for any possible variation of solar insolation, which may occur due to clouds cover. The output of the DC-DC converter or inverter forms a constant input to the DC-AC converter through the DC-Link capacitor. The inverter requires a fixed DC voltage value for transformation to AC signal at Vt, which is consequently filtered by the LCL filter before it goes to the PCC. PCC is an AC bus connecting together the RER, electric distribution grid and the inverter local load. The local load is modeled as a

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parallel combination of resistance, R, inductance, L and capacitance, C. This combination represents typical loads at a given quality factor.

The inverter switch-gates are coordinated and fired in accordance with Pulse Width Modulation (PWM) scheme in order to inject pure sine current in to the grid at voltage determined by the grid. The constant power interface control is therefore used [7].

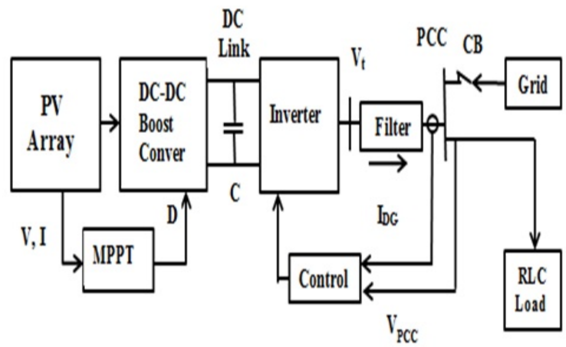

Figure-1. Block-diagram of the grid-connected RER [7].

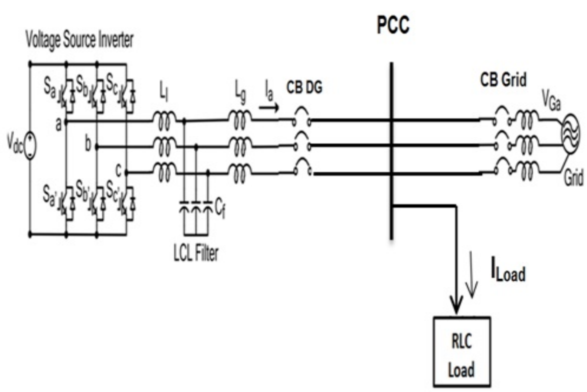

Figure-2. Implemented study system.

Table-1. RER design parameters.

Inverter	
Switching frequency (Hz)	1980
PV DC voltage (V)	800
Filter inductance, L_f (mH)	250
Filter capacitance, C_f (μH)	350
PCC Voltage (V)	400
RER capacity (MW)	0.10
RLC load	
R (Ω)	1.60
L (mH)	1.70
C (mF)	4.14
RER interface controllers	
Kp	0.3
Ki	20
K'p	14
K'i	800

ISLANDING FORMATION

From the block diagram of Figure-1, it can be noticed that the RER is connected to the grid via a circuit breaker, CB at the PCC. For the grid-connected mode CB is closed and the system is said to be grid-connected. In the event of grid-side faults or maintenance operation, CB is forced open, thereby isolating the grid from PCC. This is a situation known as islanding of the RER and the local load. According to IEEE 1547 and UL 1741 standards this condition is not acceptable due to safety hazards to the RER, local load and maintenance crew. The standards therefore require the islanding condition to be detected and the RER ultimately isolated from PCC within a maximum time of two seconds after the occurrence of islanding by tripping off CB DG in Figure-2.

UNDER / OVER VOLTAGE

The electric utility standards allow the grid voltage to vary within a maximum limit of 110 % of the nominal voltage and a minimum limit of 88 % of the nominal voltage value. Therefore, any voltage value within these limits is considered acceptable. A voltage level which transgresses these limits is considered to be a fault condition resulting to under or over voltage. As islanding is also abnormal situation, UOV is used for its detection when zero power mismatches between the local load and RER capacity is not considered critical. Thus, the threshold to determine the occurrence of islanding can be estimated using:

$$(V^2/V_{max})^2 - 1 \leq \Delta P/P \leq (V^2/V_{min})^2 - 1 \quad (1)$$

Where $V_{max} = 1.10*V$ and $V_{min} = 0.88*V$, ΔP = grid power and P = RER generated power.

Substituting the values into equation (1) we get the estimation of the NDZ for grid voltages within the acceptable limits.

$$-17.36\% \leq \Delta P/P \leq 29.13\% \quad (2)$$

Equation (2) gives the numerical limits of the NDZ of the UOV islanding detection. Therefore any power mismatch that falls within the limits renders islanding non-detectable.

METHODOLOGY

This research aims at using an alternative islanding detection for the grid-connected RER system described above. The DC power is generated by the PV system which forms the input for the inverter at the DC bus. The inverter, which is the heart of the system can operate in both grid-connected and islanding modes.

The DC-Link voltage, Vdc, is used as the parameter for the detection of islanding phenomenon. First, the impact of variations of the local load to Vdc was tested for the grid-connected mode. Secondly, the impact of a constant local load on Vdc was determined during islanding condition. Subsequently, different values of

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constant local loads were used and the corresponding impacts on the Vdc noted and recorded in the islanding mode. On each load value, Vdc is to be used for the detection of islanding.

The results obtained in the islanding mode are to be used to estimate the non-detection zone of the DC-Link voltage parameter, Vdc. The parameters used for the design are in accordance with the model in [7].

INVERTER DC-LINK VOLTAGE ISLANDING DETECTION

The proposed islanding detection method utilizes the inverter DC-Link voltage measurement corresponding to a particular power mismatch and compares it against a threshold value. If the threshold value is transgressed for a predetermined time delay, an islanding condition is detected. The islanding detection circuit is implemented in Simulink as shown in Figure-3.

The above method is repeated for different power mismatches to determine its NDZ. Plots of DC-Link voltage for load-generation mismatches of 10%, 15 %, 20%, 30 % and 40 % are shown in Figure-4 [7].

DC-LINK VOLTAGE AND LOAD DYNAMICS

It is a known fact that power demand in electric grid is dynamic in nature. Therefore, the effect of load dynamics on the DC-Link voltage was evaluated in both grid-connected mode and islanding mode.

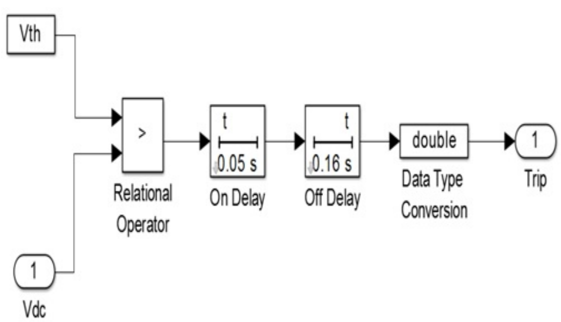

Figure-3. Proposed islanding detection method.

In Figure-3, V_{th} is the set threshold, V_{dc}, is the measured DC-Link voltage and Trip is the generated signal that causes the CB DG of Figure-2 to trip off in the event of islanding.

RESULTS AND DISCUSSION

For power load mismatches of 30 % and 40 % the variation of the post-islanding DC-Link voltage is vivid signifying same for greater mismatches. On the other hand, for a mismatch of 20 % the post-is lading voltage returns to the value in the pre-islanding condition. Similarly, the voltage value remains as it was before islanding for positive power mismatches less than 20% as shown in Figure-4.

Figures-5 shows the plots of load power dynamics and DC-Link voltage against time in grid-connected mode. The demand variations that signify load shedding and connections indicates steadiness of the DC-Link voltage. That is the connections and disconnections of load do not affect the DC-link voltage in grid-connected mode. However, the DC-Link voltage is affected only by the occurrence of islanding at time t = 4 s shown in Figure-6.

Figure-5 shows the traces of DC-Link voltage, PCC voltage, grid current and power after the RER attained steady-state and the subsequent islanding occurrence at time t = 3 s. Both the DC-Link and the PCC voltage increase in proportion with the power mismatch after the occurrence of islanding. The islanding condition was determined after a few cycles of its occurrence and the PV RER system consequently got disconnected from the PCC by the Trip signal generated by the circuit of Figure-3.

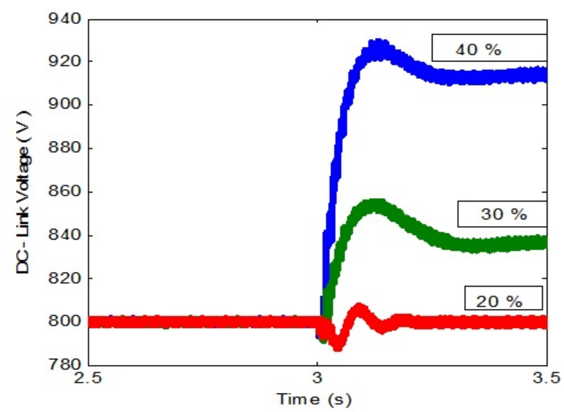

Figure-4. Non detection zone determination.

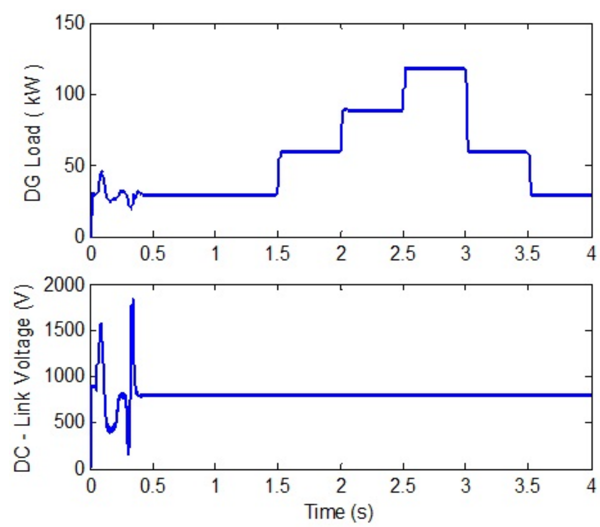

Figure-5. DC-link voltage with load dynamics grid-connected mode.

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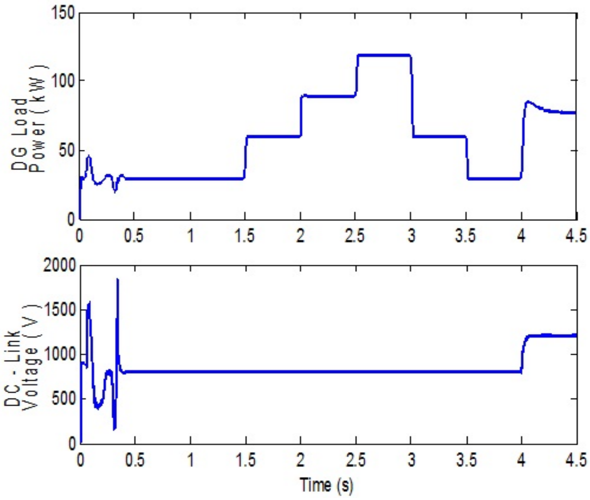

Figure-6. DC-link voltage with load dynamics islanding mode.

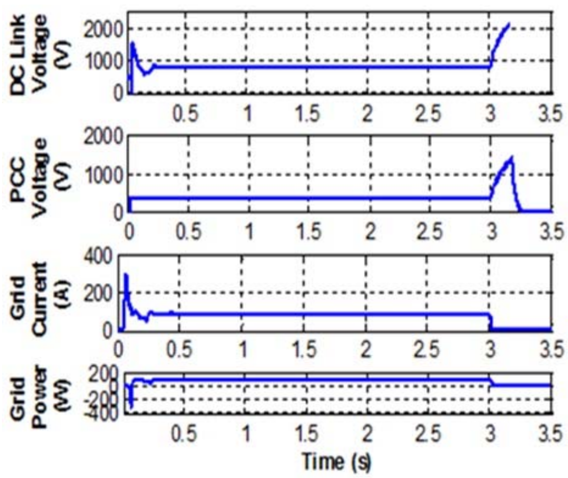

Figure-7. DC-Link islanding detection.

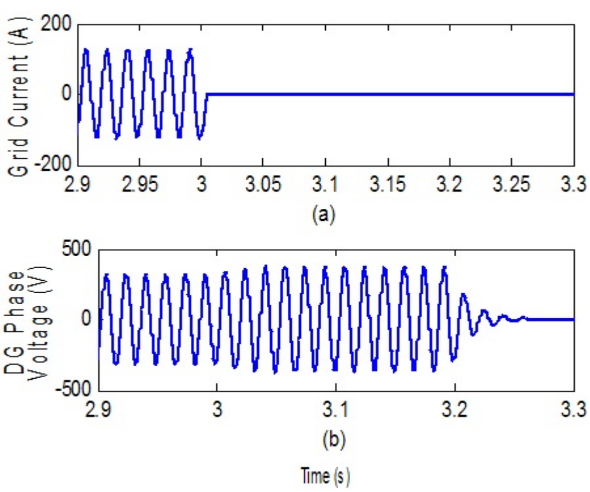

Figure-8. Islanding and its detection.

When the threshold was set to the equivalence of 25 % power mismatch between the RER and the local load, the occurrence of islanding at time t = 3 seconds was detected after a few cycles as shown in Figure-6. The upper trace shows the occurrence of the islanding when the grid current goes from steady-state to zero at t = 3 seconds. The second trace shows the representation of the RER's inverter phase voltage which indicates a little variation in amplitude. This amplitude variation corresponds with that of the DC-Link voltage as indicated in the first trace of Figure-5 which is used for the islanding detection. The RER was shut down at time t = 3.2 seconds isolating it from the PCC.

CONCLUSIONS

In this paper, a constant power-controlled photovoltaic RER was implemented in MATLAB/Simulink/ Sim Power Systems. This is to compare the effectiveness of a proposed islanding detection method using DC-Link voltage with the most basic passive islanding detection method of under/over voltage. It was shown that the proposed detection method is effective with reduced non detection zone (NDZ) in comparison with the UOV method, simpler measurement sensors and ultimately more cost-effective due to lesser component counts. It was also shown that the load dynamics does not have effects on the DC-Link voltage in grid-connected but varies in proportion to the load mismatch in islanding mode.

REFERENCES

[1] Y. Fayyad. 2010. Neuro-wavelet based islanding detection technique. Electr. Power Energy Conf., pp. 1–6.

[2] A. Llaria, O. Curea, J. Jiménez, and H. Camblong. 2011. Survey on microgrids: unplanned islanding and related inverter control techniques. Renew. Energy. Vol. 36, No. 8, pp. 2052–2061.

[3] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems. 2009. IEEE Std. pp. 1–207.

[4] B. Bahrani, H. Karimi, and R. Iravani. 2011. Nondetection zone assessment of an active islanding detection method and its experimental evaluation. IEEE Trans. Power Deliv. Vol. 26, No. 2, pp. 517–525.

[5] F. Wang and Z. Mi. 2009. Passive islanding detection method for grid connected PV system: Proc. Int. Conf. Ind. Inf. Syst. IIS 2009, pp. 409–412.

[6] D. Salles, W. Freitas, J. C. Vieira, and B. Venkatesh. 2014. A Practical Method for Nondetection Zone Estimation of Passive Anti-Islanding Schemes

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Applied to Synchronous Distributed Generators. IEEE Trans. Power Deliv, 8977, pp. 1–10.

[7] S. K. Mohammed, N. Marium, M. A. Mohd Radzi, N. I. A. Wahab. 2015. Impact of Inverter Controller on Efficiency and Islanding of Photovoltaic Distributed Generation. Appl. Mech. Mater.785, pp. 167–171.

[8] A. Samui and S. R. Samantaray. 2013. New active islanding detection scheme for constant power and constant current controlled inverter-based distributed generation. IET Gener. Transm. Distrib. Vol. 7, No. 7, pp. 779–789.

[9] V. Menon and M. H. Nehrir. 2007. A hybrid islanding detection technique using voltage unbalance and frequency set point. IEEE Trans. Power Syst. Vol. 22, No. 1, pp.. 442–448.