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An active islanding detection scheme for inverter-based DG with frequency dependent ZIP–Exponential static load model

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ABSTRACT

In this paper an analytical design method is proposed for constant voltage controlled inverter based DG with frequency dependent ZIP–Exponential static load model to obtain proper inverter output control and successful islanding detection. The proposed technique is aimed to eliminate the dependency of DG operation point on anti-islanding performance which is unavoidable in case of traditional control strategy. The generalized formulae are derived for calculating the upper and lower limits of the voltage gain, and it is recommended to select the voltage gain within the designed range for effective islanding detection. The proposed approach is tested in MATLAB/Simulink environment and result shows that the proposed scheme is found to be highly effective in islanding detection considering complex network configurations with single and multiple DG systems. The proposed control scheme is able to detect islanding within 10 ms (half cycle) from the event inception, showing the fastness of the developed technique. It is also observed that the percentage of voltage and current THD of the proposed scheme is within permissible limits, indicate that the power quality of the inverter is not degraded by the proposed control strategy, and thus overcomes the drawback of existing active anti-islanding techniques.

Introduction

In the context of distributed resource (DR) units, an islanding is formed when one or more DR units and a set of loads, usually at a distribution voltage level, are disconnected from the utility system and remain operational. Islanding creates hazard for personnel and equipment and thus, the islanding condition needs to be detected and prevented accurately. IEEE 929-2000 standard [1] requires the disconnection of DG once it is islanded and IEEE 1547-2003 standard [2] stipulates a maximum delay of 2 s for detection of an unintentional islanding and all DGs ceasing to energize the distribution system. Islanding detection methods can be classified into three major groups: (1) passive, (2) active and (3) communication based methods. Passive techniques are based on measuring a system parameters and comparing it with a preset threshold. The main problem when designing a passive islanding detection technique is the choice of a suitable measure for adjusting its threshold value. Passive techniques have a large Non-Detection-Zone (NDZ) compared to active techniques. The islanding detection based on passive methods that have been developed includes the Rate Of Change Of Voltage (ROCOV) [4], the vector surge technique [5], the Rate Of Change Of Frequency (ROCOF) [6], etc. Active methods introduce an external perturbation at the output of the inverter and thus degrade the Power Quality (PQ). The main advantage of the active techniques over passive techniques is the small Non Detection Zone (NDZ). Active methods include active frequency drift or frequency bias [7], sandia frequency shift [8], harmonic distortion based islanding detection technique [9] voltage positive feedback [10], etc. Communication based methods [3] are based on communication between the grid and the DG. It has better reliability and negligible NDZ than passive and active techniques, however it is more expensive. The islanding detection based on inverter based DG is proposed in [11]. Load representation has a significant impact on power system analysis and control functions. The detailed static load representations for transient stability analysis are given in [12–14].

This work proposes an active islanding detection where instead of commonly used RLC load, a complex frequency dependent ZIP–Exponential static load [12–14] is considered for the inverter-based DG to validate the proposed scheme. In islanding, the instability occurs during the transition from the grid connected mode to the islanded mode. The voltage dynamics in this situation depends on DG operation point. It is desirable that DG must be stable during this transition to continue supply to the load demand. Active methods inject disturbance signal to the target DG location and the system response is used for islanding detection. In this study the designed control strategy enables the

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adjustment of the injected disturbance at DG end by controlling the *d*-axis current command.

In the proposed scheme, generalized formulae are derived for calculating the upper and lower limits of the voltage gain, for constant voltage controlled inverter based DG in terms of frequency dependent ZIP–Exponential static load model. It is recommended to choose the voltage gain within the estimated range in order to achieve successful islanding detection. This method is beneficial over traditional control strategy [10] as the inverter output control is independent of the inverter operation point. The theoretical investigations are extensively tested using the MATLAB/Simulink to justify the proposed anti-islanding algorithm. The results, based on extensive study, indicate that the proposed technique can reliably detect islanding condition. The effectiveness of the developed control technique has been demonstrated considering different testing conditions with single and multiple inverter based DG configurations.

Initial test system with traditional and proposed control scheme

The initial sample test system studied is shown in Fig. 1. This system consists of a radial distribution system, connected to the

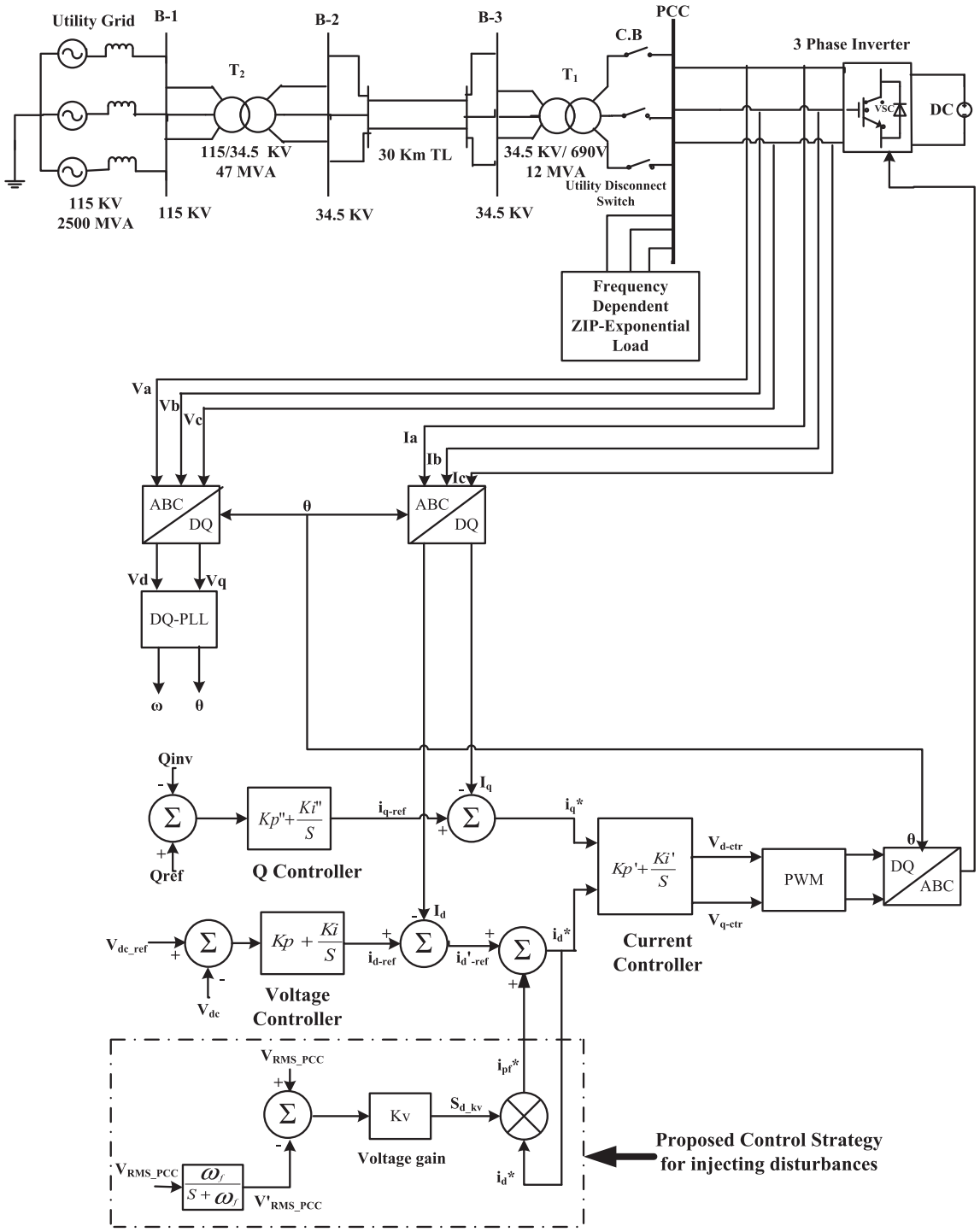

Fig. 1. Control schematic of the three-phase constant voltage controlled inverter based DG with proposed control strategy.