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Examination of Resonance Propagation in Grid Connected and Islanding Microgrids for Hybrid Power System

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Abstract:
This paper also focuses on developing a voltage-controlled DG unit-based active harmonic damping method for grid-connected and islanding microgrid systems. An improved virtual impedance control Method with a virtual damping resistor and a nonlinear virtual capacitor is proposed. The nonlinear virtual capacitor is used to compensate the harmonic voltage drop on the grid-side inductor of a DG unit LCL filter. The virtual resistor is mainly responsible for microgrid resonance dampin. The application of underground cables and shunt capacitor banks may introduce power distribution system resonances. In this paper, the impacts of voltage-controlled and current-controlled distributed generation (DG) units to microgrid resonance propagation are compared. It can be seen that a conventional voltage-controlled DG unit with an LC filter has a short-circuit feature at the selected harmonic frequencies, while a current-controlled DG unit presents an open-circuit characteristic. Due to different behaviors at harmonic frequencies, specific harmonic mitigation methods shall be developed for current controlled and voltage-controlled DG units, respectively.

Keywords: Active power filter, distributed power generation, droop control, grid-connected converter, microgrid, power quality, renewable energy system, resonance propagation, virtual impedance.

I. INTRODUCTION:

The Increasing application of nonlinear loads can led to significant harmonic pollution in a power distribution System. The harmonic distortion may excite complex resonances, especially in power systems with underground cables or subsea cables. In fact, these cables with nontrivial parasite shunt capacitance can form an *LC* ladder network to amplify resonances. In recent years, an increasing number of renewable energy resources or micro sources such as photovoltaic panels, small wind turbines, and fuel cells have been integrated into the grid in the form of distributed generation (DG) with the development of DG, the concept of microgrid which contains a number of systematically organized DG units is proposed. Compared to conventional power distribution systems, microgrids can operate in both grid-connected and intentional islanding modes, which provide enhanced reliability and power quality. To facilitate the smooth operation mode transitions, voltage control for the DG interfacing converters in both grids connected and islanding modes is an attractive option for a microgrid. In order to mitigate system resonances, damping resistors or passive filters can be placed in the distribution networks. To achieve better operation of grid-connected and islanding microgrids, the paper considers a simple harmonic propagation model in which the microgrid is placed at the receiving end of the feeder. To mitigate the feeder harmonic distortions, a modified virtual impedance-based active damping method that consists of a virtual resistor and a virtual nonlinear capacitor is Also proposed. The policy of injecting all available power to the grid is a good one as long as renewable power sources constitute a small part of the grid power capacity. Indeed, any random power fluctuation of the renewable power generators will be compensated by the controllers associated with the large conventional generators, and some of these generators will also take care of the overall power balance, system stability, and fault ride through. The virtual capacitor eliminates the impacts of *LCL* filter grid-side inductor and the virtual resistor is interfaced to the receiving end of the feeder to provide active damping service.

Circuit Diagram:

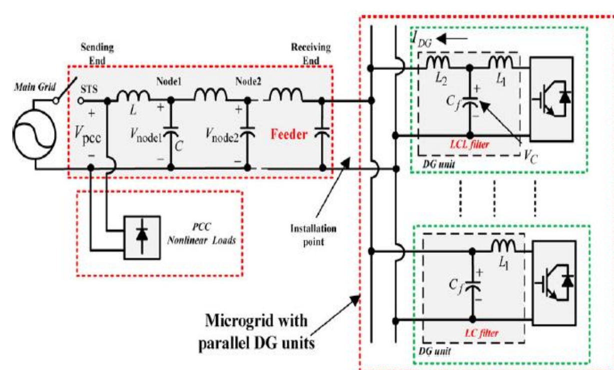


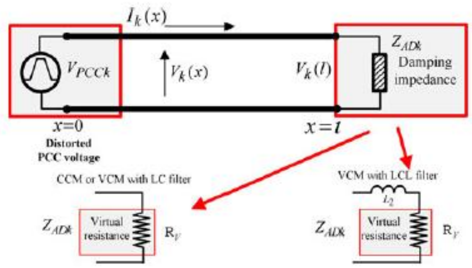
Figure.1. Circuit Diagram

For the sake of simplicity, this paper only adopts a simple microgrid configuration to demonstrate how the microgrid power quality is affected by resonance propagation. In addition, this paper also assumes that shunt capacitor banks and parasitic feeder capacitances are evenly distributed in the feeder.

A. Distributed Parameter Model in Grid-Tied Operation:

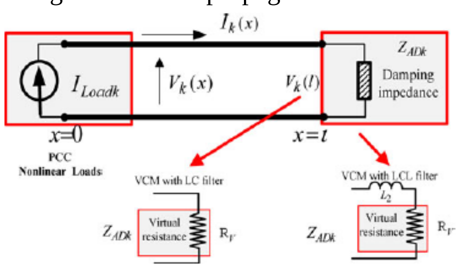
To make the discussion more straightforward, we assume that the microgrid in the feeder receiving end only consists of one

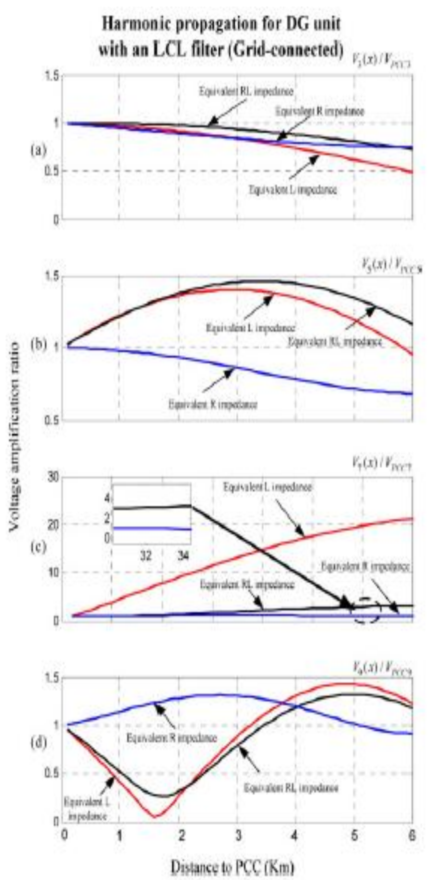
DG interfacing converter. In the next section, the modeling of resonances in multiple DG-unit-based microgrid is discussed. With the aforementioned assumption, the equivalent circuit model of a grid-tied microgrid at the *k*th harmonic frequency is presented.



B. Distributed Parameter Model in Islanding Operation:

The previous section focuses on the analysis of grid-tied DG units. For an islanding microgrid system, the VCM operation of DG units is needed for direct voltage support. To the best of the authors' knowledge, the quantitative analysis of islanding microgrid harmonic propagation is not available.





DAMPING PERFORMANCE

In this section, the performance of VCM-based DG units at different operation modes is investigated.

A. Evaluation of a Single DG Unit at the End of the Feeder

1) Grid-Tied Operation: First, the performance of a gridtied DG unit with an *LCL* filter is investigated. The system parameters are listed in Table I. Fig. 4 shows harmonic voltage distortions along a 6 km feeder. The harmonic voltage distortion factor here is normalized to the voltage distortions at PCC as

$V\,(x)k/V\text{PCC}k$.

When the conventional VCM without damping

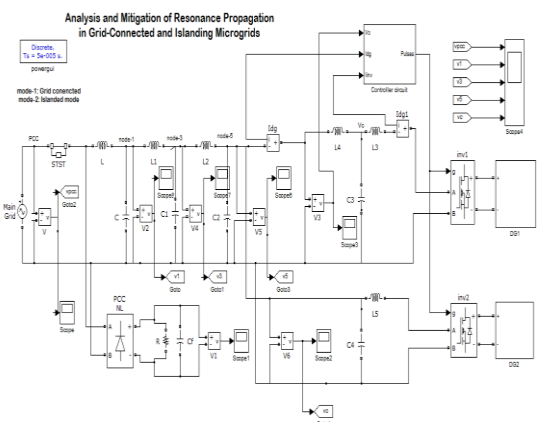
TABLE I

FEEDER PARAMETERS

System Parameter	Value
Feeder length	6 km
Number of nodes	7
Line inductance *L*	1 mH/km
Capacitance *C*	20 μF/km
DG unit parameter	Value
With *LCL* filter	$L_1 = 2\text{mH}\ L_2 = 3.5\ m\text{H}\ C_f = 20\mu F$
Command virtual resistance	$RV = 5.5\ \omega$

II. SIMULATION REULTS

Analysis and Mitigation of Resonance Propagation in Grid-Connected and Islanding Microgrids :

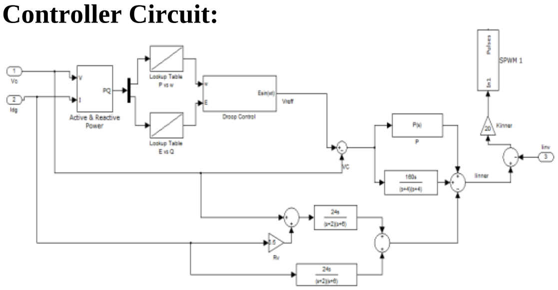


Extension:

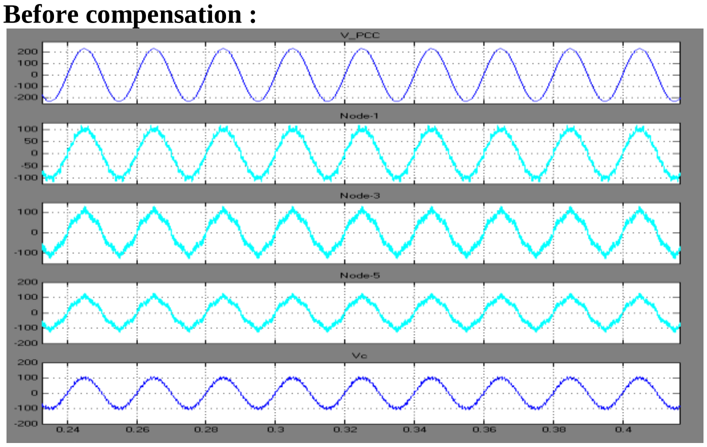
EXAMINATION OF RESONANCE PROPAGATION IN GRID CONNECTED AND ISLANDING MICROGRIDS FOR HYBRID POWER SYSTEM

Hybrid renewable energy systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system, or hybrid power, usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. To improve the system reliability in micro grid operation, a hybrid combination of PV and wind is utilized at the source end. A series- parallel ‘si’ cells combination and induction generator based medium power wind turbine is designed to meet the required power demand. To actively mitigate the resonance using DG units, an enhanced DG unit control scheme that uses the concept of virtual impedance is proposed. Specifically, the capacitive component of the proposed nonlinear virtual impedance is used to compensate the impact of DG unit *LCL* filter grid-side inductor. The resistive component is responsible for active damping. With properly controlled DG equivalent harmonic impedance at selected harmonic frequencies, the proposed method can also eliminate the harmonic circulating current among multiple DG. In this paper a hybrid power system is designed with wind energy and PV source using MATLAB/Simulink software.

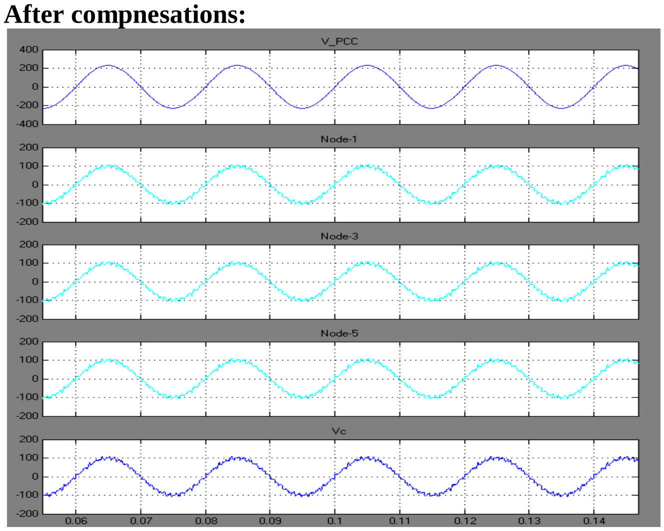
Controller Circuit:



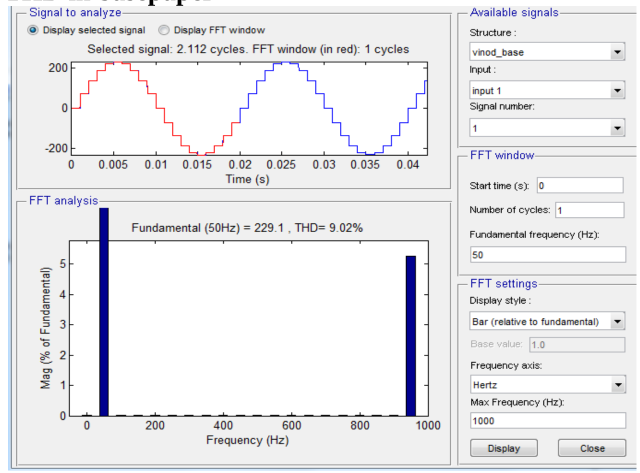
Before compensation :



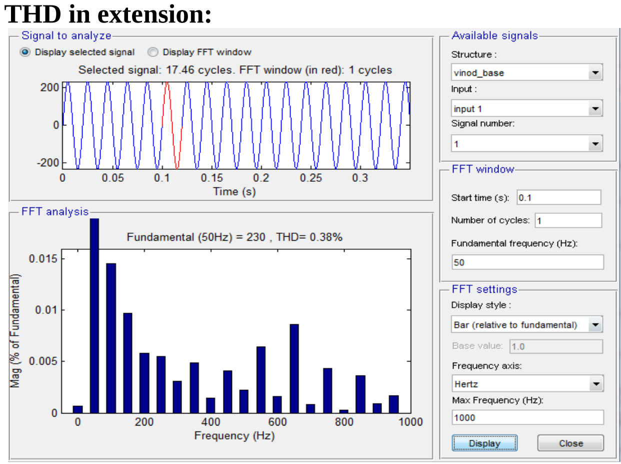
After compnesations:



THD in basepaper



THD in extension:



III. CONCLUSION:

In this paper, a microgrid resonance propagation model is investigated. To actively mitigate the resonance using DG units, an enhanced DG unit control scheme that uses the concept of virtual impedance is proposed. Specifically, the capacitive units with mismatched output filter parameters. Comprehensive simulations are conducted to confirm the validity of the proposed method.

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