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Research Paper

MODELING AND ANALYSIS OF IMPEDANCE NETWORK VOLTAGE SOURCE CONVERTER FED TO INDUSTRIAL DRIVES

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This paper presents a small-signal impedance of grid-connected three-phase converters for wind and solar system stability analysis. In the proposed approach, a converter is modeled by positive-sequence negative-sequence impedance directly in the phase domain. It is further demonstrated that the two sequence subsystems are decoupled under most conditions and can be studied independently from each other. The proposed models are verified by experimental measurements and their applications are demonstrated in a system. This project applies the harmonic linearization technique to develop impedance models of three-phase VSCs with PLL-based grid synchronization.

Keywords: Converter stability, Grid-connected converters, Harmonic resonance, Impedance modeling

INTRODUCTION

Three-phase voltage-source converters (VSCs) are the basic building blocks for many applications in power systems, including grid integration of renewable energy and energy storage high-voltage dc transmission , as well as flexible ac transmission systems. They are commonly referred to as grid-connected VSC in this paper. As for other power electronic circuits, external behavior of such VSC can be characterized by the impedances measured at the dc and the ac terminals. Depending on the direction of power flow, the ac terminal impedance can be considered the input impedance (in rectification mode) or the output impedance (in inversion mode), and will be simply referred to as the impedance.

One important use of the impedance of a grid-connected VSC is in the analysis of stability and resonance between the converter and the grid, including that with the filter of the converter . In particular, it was shown in that a grid-connected VSC used for grid integration of renewable energy can be modeled as a current source in parallel with an impedance, and the inverter grid system stability can be determined by applying the Nyquist stability criterion to the ratio between the grid impedance and the VSC impedance.

Most grid-connected VSCs use current control in a rotating (*dq*) reference frame , which is

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synchronized to the fundamental component of the grid voltages by means of a phase-locked loop (PLL) . Both the *dq*-domain current control and the PLL-based grid synchronization introduce nonlinearities which cannot be removed by reduced-order modeling techniques .

A key step in the development of the impedance models is the linearization of the grid synchronization scheme. Since there exist several synchronization schemes, the approach taken here is to consider a basic PLL, and show how it can be incorporated into the impedance models. Possible variations are reviewed to highlight their modeling approach. The rest of this paper is organized as follows: it develops impedance models assuming perfect knowledge of the grid voltage angle. And also to shows how to model the PLL, and the approach to incorporate it into the impedance models. Finally it includes verifications of the proposed impedance models from both impedance measurements and their application in analysis of harmonic resonance.

VOLTAGE SOURCE CONVERTER

The name voltage source converter signifies those circuits which are used to convert or transfer one type of voltage source to another. Voltage source converter means which device converts a AC voltage source into DC voltage source and vice versa. So, there are two types of voltage converter, namely voltage inverter and voltage rectifier. As the name suggests, a voltage inverter is used to convert DC voltage source into AC voltage source. And voltage rectifier is used to convert DC voltage source into AC voltage source. There are two types of rectifier circuit, one is half wave rectifier and another is full wave rectifier.

Actually, all voltage source converters use semiconductor technology to perform their operation. The basic circuit is arranged with diodes, opamps and transistors. Converting the voltage AC to DC is very much essential, specialy for industrial purpose. Or sometime, AC voltage is needed from DC source (as an inverter). These all necessitates the use of voltage source converter. Mainly, the power generated is plants is AC in nature. But in several applications, DC power is required like DC motor etc. Voltage regulation is also easier in DC operation. Overall, all voltage converting devices are nomenclature as the voltage source converter.

IMPEDANCE MODELING

Proper impedance models are required for the application of the impedance-based system stability criterion presented in the previous section. The grid can usually be modeled by an inductor or an inductor in series with a resistor. Such simple RL model, however, will no longer be valid in the future when a significant portion of system power is supplied from renewable sources through inverters.

More specifically, the grid impedance would be dominated more by inverters that integrate renewable sources than traditional generators and transmission/distribution networks. Since all inverters are nonlinear, small signal analysis is necessary in order to develop their output impedance models for system stability analysis. Since both the amplitude and phase of a phasor are constant when the system is in steady-state, the nonlinear phasor model can be linearized by conventional small signal methods to develop a linear system model for stability analysis and control design.

A. phase-locked loop

A phase-locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. The phase detector compares the phase of that signal with the phase of the input periodic signal and adjusts the oscillator to keep the phases matched. Bringing the output signal back toward the input signal for comparison is called a feedback loop since the output is 'fed back' toward the input forming a loop.

A phase-locked loop is a feedback system combining a voltage controlled oscillator (VCO) and a phase comparator so connected that the oscillator maintains a constant phase angle relative to a reference signal.

Vsc-based smes

A six-pulse pulse width modulation (PWM) rectifier/inverter using insulated gate bipolar transistor (IGBT), a two-quadrant dc-dc chopper using IGBT, and a superconducting coil or inductor. The PWM converter and the dc-dc choper are linked by a dc link capacitor. The PWM VSC provides a power electronic interface between the ac power system and the superconducting coil.

The proportional integral (PI) controllers determine the reference d- and q-axis currents by using the difference between the dc link voltage and reference value, and the difference between terminal voltage and reference value , respectively. The reference signal for VSC is determined by converting d- and q-axis voltages which are determined by the difference between reference d-q axes currents and their detected values.

Single Grid Connected Inverter

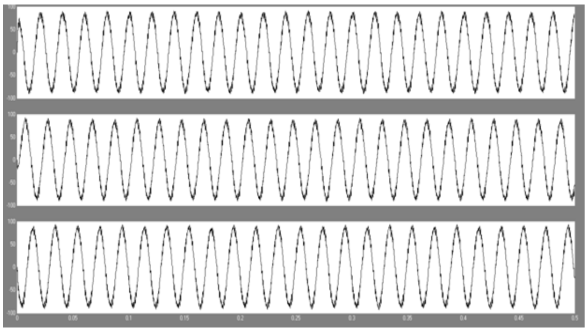
The well-known three-phase grid connected converter topology with *L*-filter is used to do a generalized analysis. Even though the widely used *LCL*-filter also can be considered as another case, this can also be modeled as an *L*-filter in the frequency range below the *LCL*-resonance frequency [17, 18]. Hence, analysis based on the *L*-filter topology is adaptable in low frequency harmonic analysis. Further p.u systems are adopted to define the output filter and controller gain to compare the system according to the power rating for the harmonic compensation. Grid impedance values are regarded as the %Z (percent Impedance), which can be calculated from the grid Short Circuit Ratio (SCR=(1/(%Z)), are also derived from a system p.u value.

The controller and the circuit diagram of the converter, where the Proportional Resonant (PR) controller for current harmonic compensation G_c, the control delay G_d, inverter side filter inductor L_f, inductor parasitic resistance R_f, current sensor gain H, and $Z_s(=L_s + R_s)$ is describing the grid impedance.

GRID IMPEDANCE

Grid-connected inverters are known to become unstable when the grid impedance is high. Existing approaches to analyzing such instability are based on inverter control models that account for the grid impedance and the coupling with other grid-connected inverters. A new method to determine inverter-grid system stability using only the inverter output impedance and the grid impedance is developed in this paper. It will be shown that a grid-connected inverter will remain stable if the ratio between the grid impedance and the inverter output impedance satisfies the Nyquist stability criterion. This new impedance-based stability criterion is a generalization to the existing stability criterion for voltage-source systems, and can be applied to all current-source systems.

Figure 1: Grid phase voltages



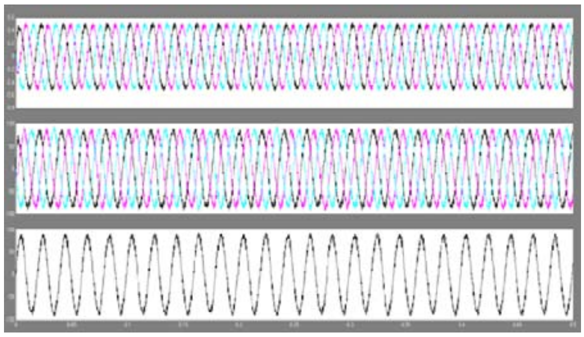
An advanced controller suitable for three-phase phase-locked loops (PLLs), which are employed in grid-connected power converters. This controller is formed of one or more lead compensators cascaded to the main proportional integral regulator. The proposed lead compensators are second order with pure imaginary roots: they have both a notch peak and a resonant peak (the notch frequency is lower than the resonant frequency). Hence, their phase versus frequency response exhibits phase wraps of ± 180°. Consequently, the parameters of each lead compensator are tuned with two objectives: to eliminate a specific frequency in the synchronous reference frame (SRF) and to enhance stability by a phase lead (phase boost).

PLL TECHNIQUE

Nowadays, the PLL technique is the state-of-the-art method to extract the phase angle of the grid voltages . The PLL is implemented in *dq* synchronous reference frame. As it can be noticed, this structure needs the coordinate transformation form *abc ! dq*, and the lock is realized by setting the reference *U" d* to zero. A regulator, usually PI, is used to control this variable, and the output of this regulator is the grid frequency.

This algorithm has a better rejection of grid harmonics, notches, and any other kind of disturbances, but additional improvements have to be done to overcome grid unbalance. In the case of unsymmetrical voltage faults, the second harmonics produced by the negative sequence will propagate through the PLL system and will be reflected in the extracted phase angle. To overcome this, different filtering techniques are necessary such that the negative sequence is filtered out. As a consequence, during unbalanced conditions, the three-phase *dq* PLL structure can estimate the phase angle of the positive sequence of the grid voltages.

Figure 2: Shows the output phase voltage



PROPOSED METHOD

One important use of the impedance of a grid-connected VSC is in the analysis of stability and resonance between the converter and the grid, including that with the filter of the converter . In particular, it was shown in that a grid-connected VSC used for grid integration of renewable energy can be modeled as a current source in parallel with an impedance, and the inverter grid system stability can be determined by applying the Nyquist stability criterion to the ratio between the grid impedance and the VSC impedance.

Most grid-connected VSCs use current control in a rotating (*dq*) reference frame , which is synchronized to the fundamental component of the grid voltages by means of a phase-locked loop (PLL) . Both the *dq*-domain current control and the PLL-based grid synchronization introduce nonlinearities which cannot be removed by reduced order modeling techniques

Figure 3: Shows the input voltage of 24V

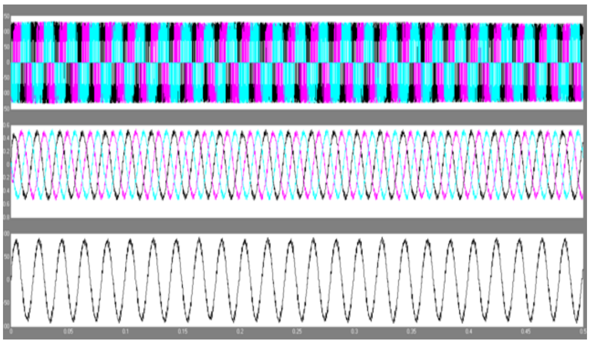
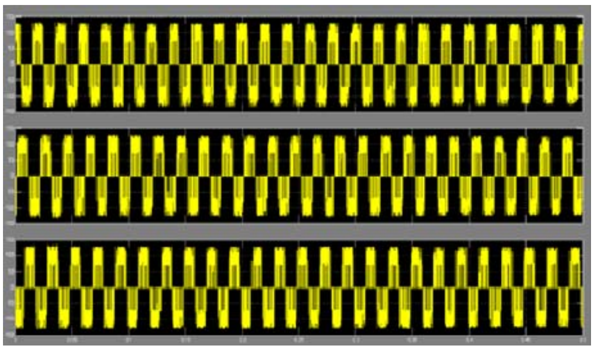


Figure 4: Inverter output voltage and current



One method to deal with the control non linearitiesis to transform the converter model into the *dq* reference frame. This method, however, has several limitations and disadvantages. The harmonic linearization method overcomes these limitations by modeling three phase VSC impedance directly in the phase domain. This paper applies the harmonic linearization technique to develop impedance models of three-phase VSCs with PLL-based grid synchronization.

CONCLUSION

All models are analyzed based on the impedance basis analysis methods. Also, the low-order harmonic compensation error is analyzed under the various grid conditions, the relationship between the analyzed converter impedance and grid impedance is assessed by means of impedance based analysis method. Grid connected VSC impedance models can be used to assess system level converter-grid compatibility and power quality. Impedance modeling in the phase domain yields decoupled positive- and negative-sequence converter impedances, when phase- or *dq*-domain current control systems are implemented. As a result, the contributions in this paper enable single-input single-output stability analysis of balanced three-phase converter systems. For the kind of nonlinearity in Park's transformation, coupling of converter sequence impedances may occur during unbalanced phase voltage conditions. For most practical conditions with small voltage unbalance, the coupling can be neglected. Besides, a gain design method, which can improve the harmonic compensation error and harmonic instability, is proposed. Finally, the results including various grid conditions are proved by the simulation in order to verify theoretical approaches.

REFERENCES

1. Blaabjerg F, Zhe C, and Kjaer S B (2004), "Power electronics as efficient interface in dispersed power generation systems," *IEEE Trans. Power Electron.*, Vol. 19, No. 5, pp. 1184–1194.

2. Ali M H, Wu B, and Dougal R A (2010), "An overview of SMES applications in power and energy systems," *IEEE Trans. Sustainable*

Energy, Vol. 1, No. 1, pp. 38–47.

3. Flourentzou N, Agelidis V G, and Demetriades G D (2009), "VSC-based HVDC power transmission systems: An overview," *IEEE Trans. Power Electron.*, Vol. 24, No. 3, pp. 592–602.

4. Xia J, Fang X, Chow J H, Edris A, Uzunovic E, Parisi M, and Hopkins L (2008), "A novel approach for modeling voltage-sourced converter based FACTS controllers," *IEEE Trans. Power Del.*, Vol. 23, No. 4, pp. 2591–2598.

5. He J and Li Y W (2012), "Generalized closed-loop control schemes with embedded virtual impedances for voltage source converters with *LC* or *LCL* filters," *IEEE Trans. Power Electron.*, Vol. 27, No. 4, pp. 1850–1861.

6. Sun J (2011), "Impedance-based stability criterion for grid-connected inverters," *IEEE Trans. Power Electron.*, Vol. 26, No. 11, pp. 3075–3078.

7. Middlebrook R D (1976), "Input filter considerations in design and application of switching regulators," in *Proc. Rec. IEEE Ind. Appl. Soc. Annu. Meet.*, pp. 366–382.

8. Blaabjerg F, Teodorescu R, Liserre M, and Timbus A V (2006), "Overview of control and grid synchronization for distributed power generation systems," *IEEE Trans. Ind. Electron.*, Vol. 53, No. 5, pp. 1398–1409.

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