ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Stability Analysis of Voltage Source Inverter Used in Grid Integrated Renewable Energy Sources

D.Karuna
M.Tech (Power Electronics),
Sahaja Institute of Technology and Science for Women, Karimnagar, T.S, India.

G.Anitha
Associate Professor,
Sahaja Institute of Technology and Science for Women, Karimnagar, T.S, India.

Abstract:

This paper addresses the harmonic compensation error problem existing with parallel connected inverter in the same grid interface conditions by means of impedance-based analysis and modeling.When voltage source converters are connected to the grid, thepower quality and the dynamic performance are affected by the line filter connected between theconverter and the grid, and by non-linearities caused by the switching converter.The VSC is used for reactive power compensation and active filtering, in addition to converting wind power. These additional features cause only a moderate increase in the VSC rating compared with only converting wind power.The proposed control method is based on a steady-state model of the system, which results in a low bandwidth but which is high enough to operate a wind turbine.

Key words:

impedance modelling, VSC, wind system, current control.

I.INTRODUCTION:

\

The utilization of wind energy is an area which is growing rapidly. In Europe, the installed wind power has increased by 36 % each year for 5 years, now. In northern Germany, wind turbine manufacture is the fastest growing industry. Furthermore, wind energy covers 7 % of Danish electricity consumption. Most countries in Europe have plans for increasing their share of energy produced by wind power. The increased share of wind power in the electric power system makes it necessary to have grid-friendly interfaces between the wind turbines and the grid in order to maintain power quality.

In addition, power electronics is undergoing a fast evolution, mainly due to two factors. The first factor is the development of fast semiconductor valves, which are capable of switching fast and handling high powers. The second factor is the control area, where the introduction of the computer as a real-time controller has made it possible to adapt advanced and complex control algorithms. These factors together make it possible to have cost-effective and grid-friendly converters connected to the grid. One important use of the impedance of a grid-connected VSCis in the analysis of stability and resonance between the converterand the grid, including that with the filter of the converter [1]. A grid-connected VSC usedfor grid integration of renewable energy can be modeled as acurrent source in parallel with impedance, and the inverter-gridsystem stability can be determined by applying the Nyquist stability criterion [2] to the ratio between the grid impedanceand the VSC impedance.This paper applies the harmonic linearization techniqueto develop impedance models of three-phase VSCs withPLL-based grid synchronization. A key step in the developmentof the impedance models is the linearization of the grid synchronization scheme. Since is there exists several synchronization schemes [3], the approach taken here is to consider a basicPLL, and show how it can be incorporated into the impedancemodels. Possible variations are reviewed to highlight their modelingapproach.

II.MODELLING WITHOUT PHASE LOCKED LOOP:

The three-phase VSC considered in this paper is depictedin Fig. 1. Phase voltages are denoted as va, vb , and vc , while phase currents as ia, ib, and ic . Considering the large dc buscapacitors, and the lower than fundamental frequency controlbandwidth of the dc bus voltage, Vdc is assumed constant in thisstudy.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

For the same reason, the active and reactive parts of th-ecurrent references (Idr and Iqr) are assumed constant. V1 corresponds to the magnitude of the fundamental volt-ageat frequency f1, Vp with φvp correspond to the mag-nitudeand phase of the positive-sequence perturbation at frequencyfp , and Vn with φvn correspond to the mag-nitude and phase ofthe negative-sequence perturbation at frequency fn.

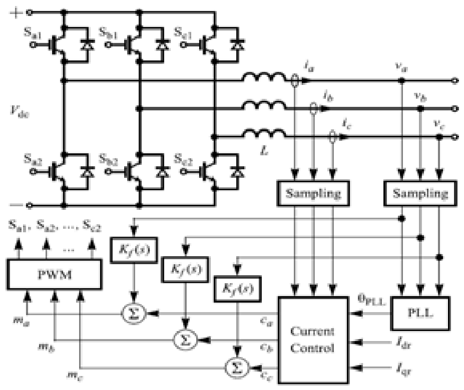

Fig 1: Block diagram of three-phase VSC for grid-connected applications.

The current response to the voltage perturbation can be foundfrom the converter averaged model

$$L\frac{d}{dt}\begin{bmatrix}\bar{i}_a\\ \bar{i}_b\\ \bar{i}_c\end{bmatrix}=\begin{bmatrix}\bar{m}_a\\ \bar{m}_b\\ \bar{m}_c\end{bmatrix}K_m V_{dc}-\begin{bmatrix}v_a\\ v_b\\ v_c\end{bmatrix}$$

Wherema,mb , andmc are the modulating (reference) signals forthe pulse width modulation (PWM), and Km is the modulatorgain. The relationship between duty ratios and the modulatingsignal is taken as follows:

da1 = Km ma’ + 1/2 (4)

da2 = 1 − da1

Fig. 2 depicts a phase-domain current controller. To findthe frequency-domain response of the controller to the harmonicperturbation, first neglect the PLL dynamics, such thatθPLL(t) = θ1 (t) ≡ 2πf1 t. Hence the reference currents iar, ibr,and icr are not affected by the perturbation.

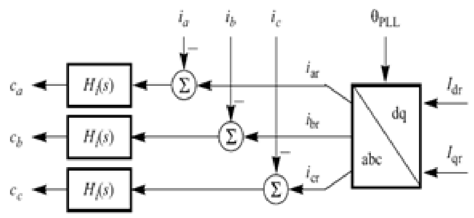

Fig 2: phase-domain current controller

Recall thatcurrents id and iq are outputs of a dq-domain transformation,which in the frequency domain involves a convolution of thefrequency components in the phase currents, with the frequencycomponents in Park’s transformation. Taking θPLL(t) = θ1(t),the frequency components in Park’s transformation are easy toderive, and the result of the convolution.

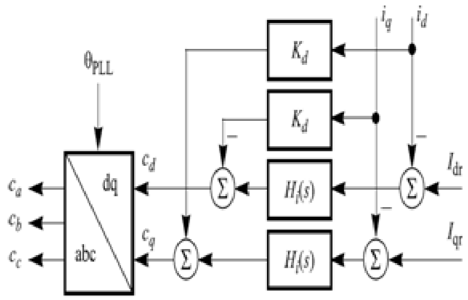

Fig 3: dq-domain current controller

III.MODELLING WITH PHASE LOCKED LOOP:

Fig. 4 depicts a basic PLL, where HPLL(s) is the loop compensator.The first step to develop a small-signal model for thisPLL is to model the response of vq (t) to the voltage perturbation.Phase-Domain Current Control and PLL: Due to the PLL, the current references contain a response tothe perturbation as follows:

Iar[f]=I1, f= ±f1

Iar[f]=[TPLL (s j2πf1) /V1] I1Gv (s)Vp, f = ±fp

Iar[f]=[TPLL (s ± j2πf1) /V1] I1 Gv (s)Vn, f = ±fn

Where I*1 is the complex conjugate of I1 = (1/2) (Idr± j Iqr).

Note that it is assumed that the actual converter current isequal to its reference at the fundamental frequency, such thatI1 ≡ (I1/2)e±jφi1 . The current regulator acts on the current reference and feedback to generate Ca. Dq-Domain Current Control and PLL: Due to the PLL, the current feedback after convolutionwith Park’s transformation includes frequency components proportionalto the voltage perturbation. Neglecting second-orderterms, the convolution of phase currents with Park’s transforma-tiongives

Id[±(fp − f1)]=I1 sin φi1Gp (±j2π (fp − f1))× Gv (±j2πfp)Vp + Gi (±j2πfp) Ip

Id[±(fn + f1)]=I1 sin φi1Gn (±j2π (fn + f1))× Gv (±j2πfn)Vn + Gi (±j2πfn) In

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Iq[±(fp − f1)]=−I1 cos φi1Gp (±j2π (fp − f1))× Gv (±j2πfp)VpjGi (±j2πfp) Ip
Iq[±(fn + f1)]=−I1 cos φi1Gn (±j2π (fn + f1))× Gv (±j2πfn)Vn ± jGi(±j2πfn) In

The current regulator acts on the feedback currents to generatethe dq-domain modulating signals. These signals are convolutedwith inverse Park's transformation to generate their phasedomaincounterparts. Table II lists the resulting frequency termsproportional to the first order of the perturbation, where nonlinearcoupling should be neglected.

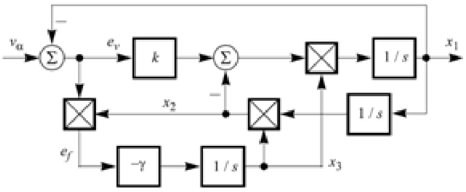

Fig 6: Block diagram of the SOGI-FLL

Other Grid Synchronization Methods: Some advanced PLL structures, such as the decoupled doublesynchronous PLL, use the same building block of Fig. 4 inmultiple stages, such that the same modeling method is applicableto them. Other forms of grid-synchronization, such as thosebased on the second-order generalized integrator frequency lockedloop (SOGI-FLL).Fig. 6 depicts the basic building block of the SOGI-FLL. Inthree-phase systems, two filters can be used in the αβ-referenceframe to extract sequence components. The basic functionalityof the filter is to extract a sinusoidal component in phase withvα in x1, and a quadrature component in x2 that lags x1 by 90◦. Applying a superimposed perturbation in vα.

IV.SIMULATION RESULTS:

A three-phase converter has been built and tested to verifythe proposed impedance models. The current controller wasimplemented in MATLAB, while the currentreferences were generated from a PLL implemented in simpower system tool box.

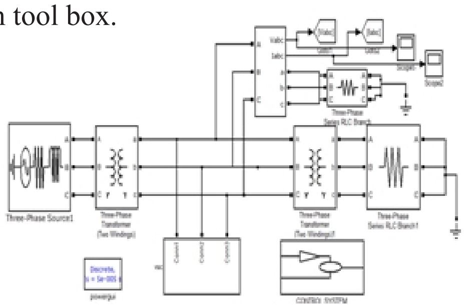
Fig 7:Simulation circuit of VSC interconnected to GRID

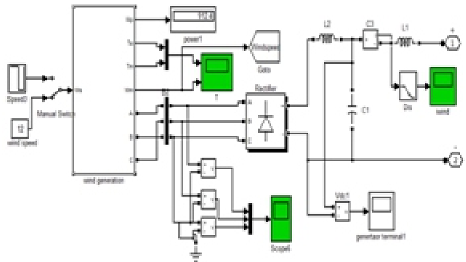
Fig 8: wind energy conversion system

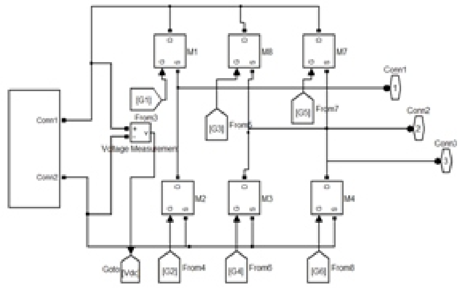
Fig 9: Voltage Source Converter

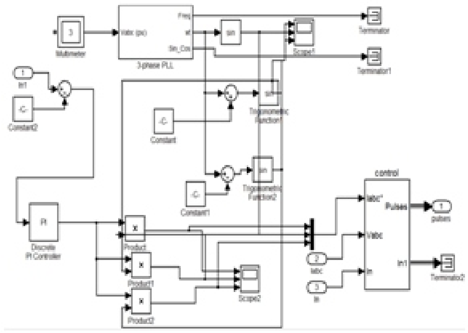
Fig 10: control system design

The grid impedance at the converter terminals is the same in thepositive- and the negative-sequence domain
Zg (s) = [(sLg)−1 + {Rd + 1/(sCf)}−1]−1
WhereLg is the grid inductance and Rd with Cf constitute adamped filter. The grid parameters used in the experiments areLg = 3.75 mH, Rd = 1.87 Ω, and Cf = 22 μF.

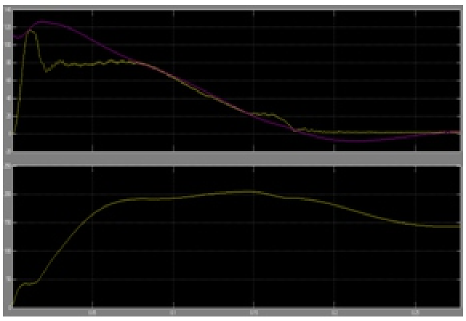
Fig 11: electrical torque, mechanical torque and machine speed.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

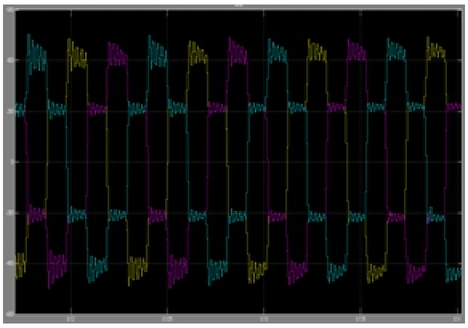

Fig 12: wind generator output voltage.

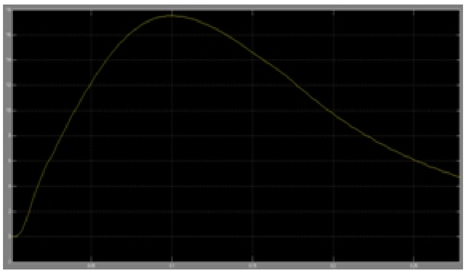

Fig 12: wind generator output rectified current.

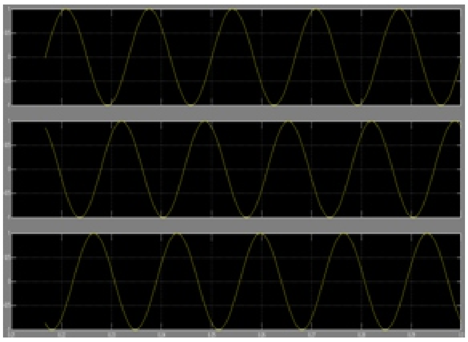

Fig 13: controller reference currents

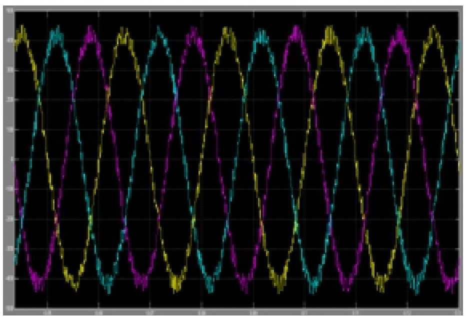

Fig 14: The converter-grid systemPhase current waveforms

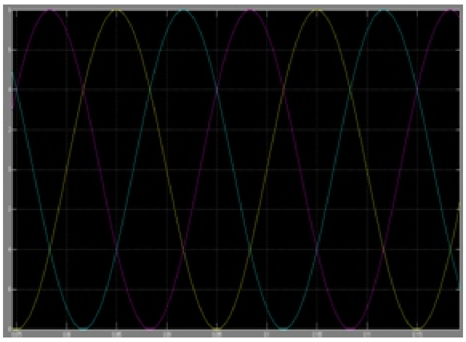

Fig 15: Phase current waveforms for the system.

To illustrate the coupling in the sequence impedances duringunbalance, a switching-circuit simulation model in Saber isused to sweep the inverter admittance, while a small grid voltageunbalance is imposed at 60 Hz. The converter power stage andcurrent control use the same parameters from the experimentalsetup with dq-domain current control, but the feedforward andtime delays are removed. The PLL bandwidth is set to 100 Hz.

One application of the proposed impedance models is in theanalysis and mitigation of harmonic resonance problems. Becauseof the decoupling between the two sequence subsystems,the stability criterion presented for grid-connected converterscan be applied to system each sequence impedance, separatelyto determine overall converter-grid system stability. Additionally,the analytical impedance models also provide a basis formodification of the converter control to mitigate any harmonicresonance and other instability problems.

The second harmonic componentin $\Delta\theta(t)$ can lead to coupling of sequence impedances.Consider, for example, a positive-sequence perturbation of thePLL, while a small negative-sequence voltage V2 is also impressedon the phase voltages at the fundamental frequency. The voltage vq (t) in this case responds at two different frequencies$\pm(fp-f1)$ and $\pm(fp+f1)$.

V.CONCLUSION:

Impedance modeling in the phase domain yields decoupledpositive- and negative-sequence converter impedances, whenphase- or dq-domain current control systems are implemented. As a result, the contributions in this paper enable single-inputsingle-output stability analysis of balanced three-phase convertersystems.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Grid-connected VSC impedance models can be used to assesssystem level converter-grid compatibility and power quality.Possible variations are reviewed to highlight their modelingapproach. The paper Verified of the proposedimpedance models from both impedance measurements andtheir application in analysis of harmonic resonance.

REFERENCES:

[1] F. Blaabjerg, C. Zhe, and S. B. Kjaer, “Power electronics as efficientinterface in dispersed power generation systems,” IEEE Trans. PowerElectron., vol. 19, no. 5, pp. 1184–1194, Sep. 2004.

[2] M. H. Ali, B.Wu, and R. A. Dougal, “An overview of SMES applicationsin power and energy systems,” IEEE Trans. Sustainable Energy, vol. 1,no. 1, pp. 38–47, Apr. 2010.

[3] N. Flourentzou, V. G. Agelidis, and G. D. Demetriades, “VSC-basedHVDC power transmission systems: An overview,” IEEE Trans. PowerElectron., vol. 24, no. 3, pp. 592–602, Mar. 2009.

[4] J. Xia, X. Fang, J. H. Chow, A. Edris, E. Uzunovic, M. Parisi, andL. Hopkins, “A novel approach for modeling voltage-sourced converterbasedFACTS controllers,” IEEE Trans. Power Del., vol. 23, no. 4,pp. 2591–2598, Oct. 2008.

[5] J. He and Y. W. Li, “Generalized closed-loop control schemes with embeddedvirtual impedances for voltage source converters with LC or LCLfilters,” IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1850–1861, Apr.2012.

[6] J. Sun, “Impedance-based stability criterion for grid-connected inverters,”IEEE Trans. Power Electron., vol. 26, no. 11, pp. 3075–3078, Nov. 2011.

[7] R. D. Middlebrook, “Input filter considerations in design and applicationof switching regulators,” in Proc. Rec. IEEE Ind. Appl. Soc. Annu. Meet,1976, pp. 366–382.

[8] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, “Overviewof control and grid synchronization for distributed power generation systems,”IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409, Oct.2006.