Stable inverter controller immune to system impedance

Gabriele Amico, Prof. Lie Xu, Dr. Paul Brogan

Wind & Marine Energy Systems CDT, Rm 3.36, Royal College Building
University of Strathclyde, 204 George Street, Glasgow, G1 1XW

gabriele.amico@strath.ac.uk

Introduction

With the increasing size of wind power plants, their interconnection to the power network is becoming more challenging. One of the critical aspect is the presence of electrical resonances introduced by long interconnecting cables with consequent risk for damage of the equipment as well as for unsafe operating conditions. The issue becomes more critical in offshore wind parks, as the use of submarine cables shifts the frequencies of these resonances closer to turbine's inverter controller bandwidth, reducing the margins of stability of its operation The presents works aims to analyse the above mentioned problem, and thereby to define, implement and test an improved grid controller architecture able to achieve an augmented controller stability performance.

System modelling and validation

Focus of this work is on the electrical interconnection between the grid side converter of the wind turbine and the connected electrical grid. In particular, attention is on the performance of the grid side current controller, as this is the one mostly affected bt the wind farm resonances.

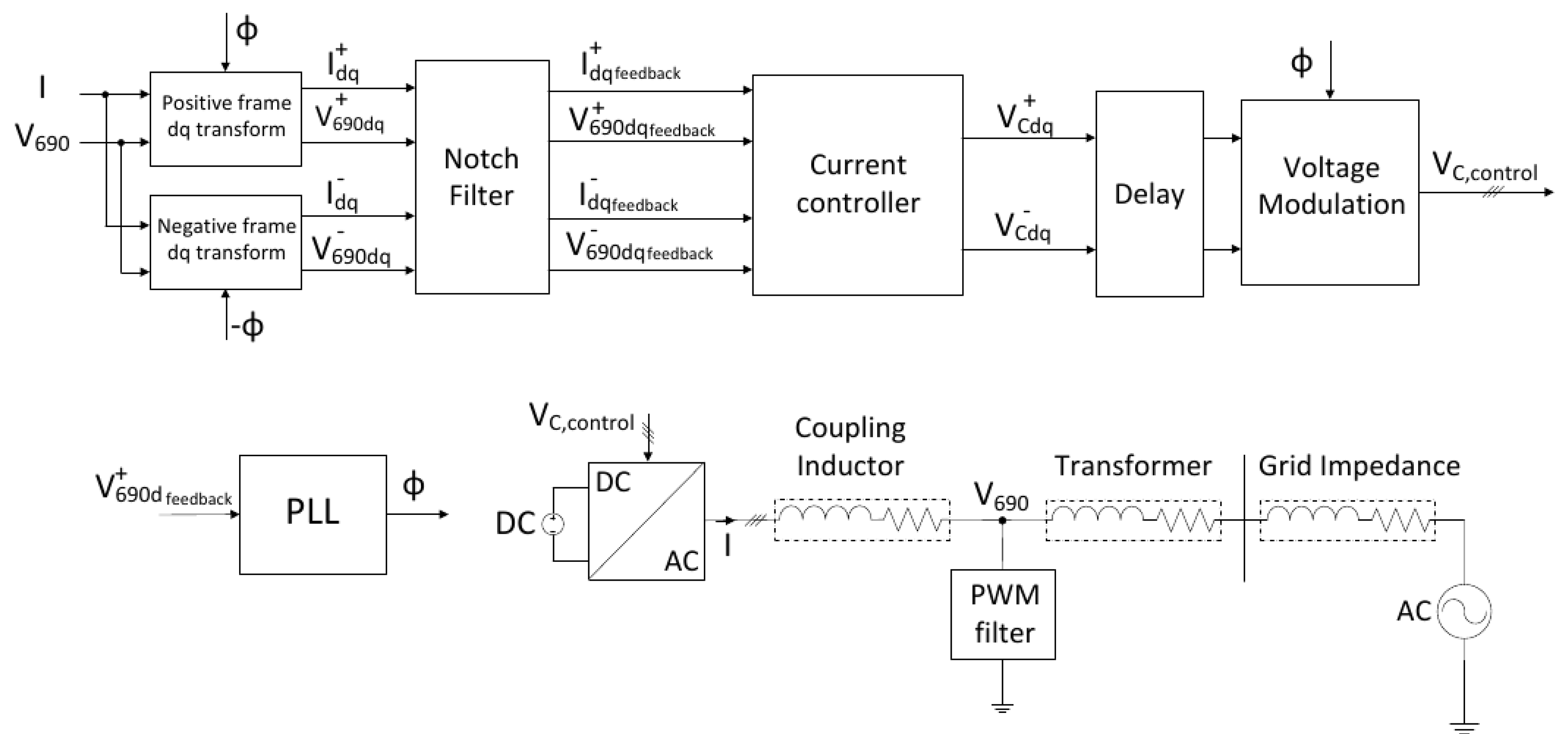


Figure 1. Inner current controller structure

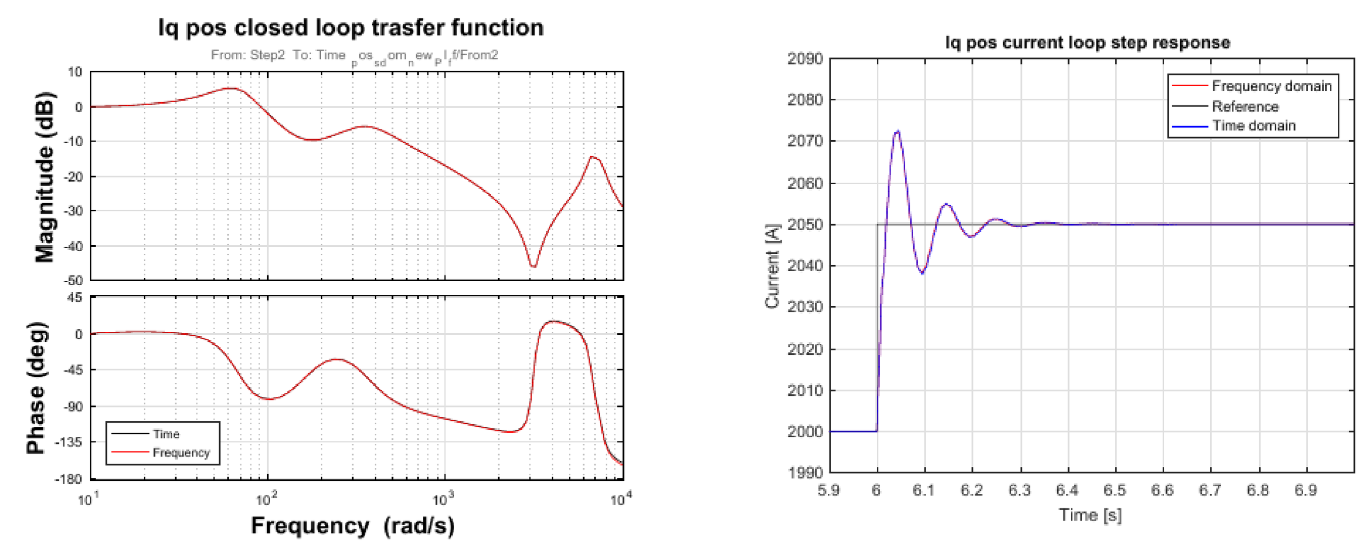
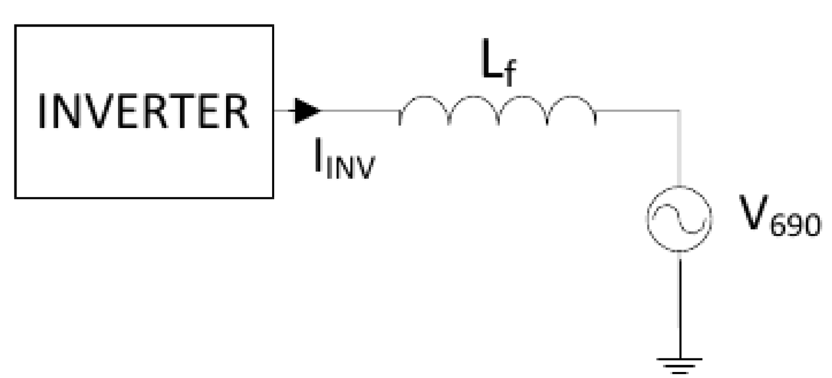


Figure 2. Validation of the small-signal linearised frequency domain model against the time domain counterpart. Closed loop transfer fucntion for the active Current positive sequence component current loop (left). Step response for the same controller loop (right).

Sequence domain analysis – Impedance based stability criterion

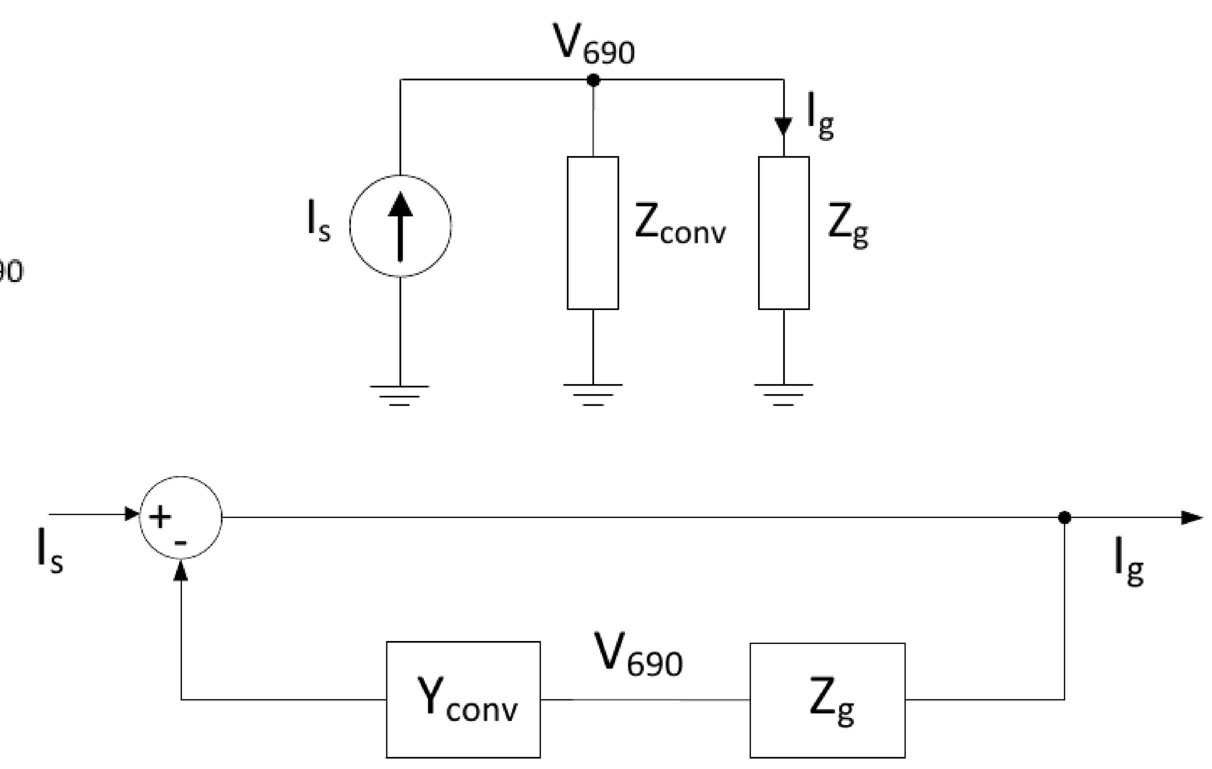
The preferred frame for the implementation of the controller is the dq frame. This is mainly because this allows an optimal use of PI controllers, which represent a simple to tune and effective controller solution. The stability analysis of grid tied voltage source inverter requires to deal with a MIMO system. This makes the analysis of the system more complex, as MIMO control methods need to be applied. The study is made more challenging by the coupling between the four current control loops identified in the modelled system. Research has been active to define alternative approaches, with the main aim to overcome the complexity of MIMO systems' analysis. One of the documented approaches is to represent the system as an electrical circuit composed of a source and a load. Following this methodology, application of the impedance-based stability method is possible, with the claimed advantage to simplify the study of the system. The representation of the system in the (sequence) pn domain allows to substantially decouple the positive and negative sequence current controller loops. The advantage is an affective diagonalization of the system open loop transfer function matrix. Under these conditions the MIMO system can be seen as a combination of two decoupled SISO systems.

Definition of converter admittance:



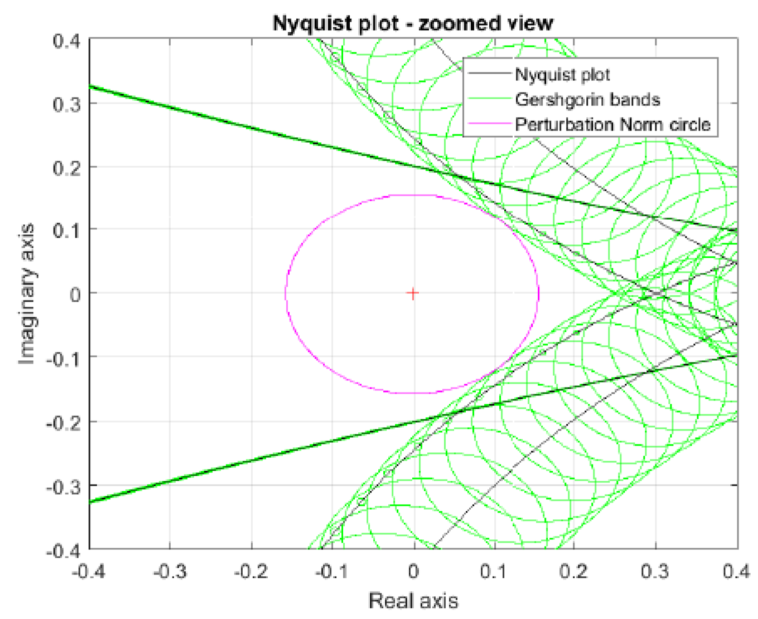
$$Y_{\text{conv}}(s) = -\frac{I_{\text{INV}}(s)}{V_{690}(s)}$$

Equivalent representation of the grid interface:

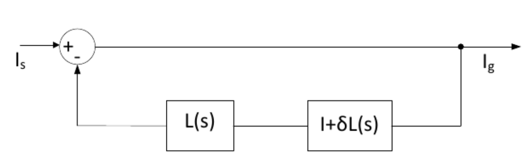


Absolute stability and stability margin:

In the pn frame the system is diagonally dominant. Based on pertubation norm a scalar stability margin can be defined for such a system



$$L(s) = Y_{\text{conv,PN}}(s) Z_{\text{g,PN}}(s)$$



$$d_\infty \triangleq \sup_{s \in \mathcal{D}} \|\delta L(s)\|_\infty$$