Power Quality Improvement of Load Connected Grid Interfaced Inverter by using FLC Merged Cascaded Current–Voltage Control Technique

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ABSTRACT:

This paper proposes wind energy generation utilization and its grid penetration in electrical grid is popular in world wide. The voltage control strategy is proposed for inverters to simultaneously improve the power quality of the inverter local load voltage and the current exchanged with the grid. And also it enables seamless transfer of the operation mode from stand-alone to grid-connected or vice versa. Fuzzy control scheme includes an inner voltage loop and an outer current loop with both controllers designed by using Fuzzy logic control (FLC) and H∞ repetitive control strategy. It leads to a very low THD in both the inverter local load voltage and the current exchanged with the grid at the same time. The proposed control strategy can be used to single-phase inverters and three-phase four-wire inverters. It enables grid-connected inverters to inject balanced clean currents to the grid even when the local loads (if any) are unbalanced and/or nonlinear. Simulation under different scenarios, with comparisons made to the current repetitive controller replaced with a current proportional–resonant controller, is presented to demonstrate the excellent performance of the proposed strategy.

Key Words: Harmonics, Power quality, FLC.

I. INTRODUCTION

The application of distributed power generation has been increasing rapidly in the past decades. Compared to the conventional centralized power generation, distributed generation (DG) units deliver clean and renewable power close to the customer's end [1]. Therefore, it can alleviate the stress of many conventional transmission and distribution infrastructures. As most of the DG units are interfaced to the grid using power electronics converters, unbalanced utility grid voltages and voltage sags, which are they have the opportunity to realize enhanced power generation through a flexible digital control of the power converters. On the other hand, high penetration of power electronics based DG units also introduces a few
issues, such as system resonance, protection interference, etc. In order to overcome these problems, the microgrid concept has been proposed, which is realized through the control of multiple DG units. Compared to a single DG unit, the microgrid can achieve superior power management within its distribution networks. In addition, the islanding operation of microgrid offers high reliability power supply to the critical loads. Therefore, microgrid is considered to pave the way to the future smart grid [1]. It is advantageous to operate inverters as voltage sources because there is no need to change the controller when the operation mode is changed. A parallel control structure consisting of an output voltage controller and a grid current controller was proposed in [8] to achieve seamless transfer via changing the references to the controller without changing the controller. Another important aspect for grid connected inverters or micro grids is the active and reactive power control; see, e.g., [9] and [10] for more details. As nonlinear and/or unbalanced loads can represent a high proportion of the total load in smallscale systems, the problem with power quality is a particular concern in micro grids [11].Moreover, unbalanced utility grid voltages and utility voltage sags, which are two most common utility voltage quality problems, can affect micro grid power quality [12], [13].

II. RELATED WORK

2.1. Harmonic Distortion

Harmonic problems are almost always introduced by the consumers' equipment and installation practices. Harmonic distortion is caused by the high use of non-linear load equipment such as computer power supplies, electronic ballasts, compact fluorescent lamps and variable speed drives etc., which create high current flow with harmonic frequency components. The limiting rating for most electrical circuit elements is determined by the amount of heat that can be dissipated to avoid overheating of bus bars, circuit breakers, neutral conductors, transformer windings or generator alternators. Ratio of the square root of the sum of squares of the rms value of harmonic component to the rms value of the fundamental components defined as Total Harmonic Distortion (THD) If the waveform under discussion is current, then the THD definition is called Current Harmonic Distortion. If the waveform under discussion is voltage, then the THD definition is called Voltage Harmonic Distortion.

2.2. Wind Turbine Generators

The wind turbine generator converts mechanical energy to electrical energy. Wind turbine generators are a bit unusual, compared to other generating units you ordinarily find attached to the electrical grid. One reason is that the generator has to work with a power source (the wind turbine rotor) which supplies very fluctuating mechanical power (torque). The main drawback of wind power is that its availability is somewhat statistical in nature and must be supplemented by additional sources to supply the demand curve. Traditionally, wind generation systems used variable pitch constant speed wind turbines (horizontal or vertical axis) that were coupled to squirrel cage induction generators or wound-field synchronous generators and fed power to utility grids or autonomous loads. The recent evolution of power semiconductors and variable frequency drives technology has aided the acceptance of variable speed generation systems. In spite of the additional cost of power electronics and control, the total energy capture in a variable speed wind turbine (VSWT) system is larger and, therefore, the life-cycle cost is lower. The following generator converter systems have been popularly used:

- Doubly fed induction generator with cascaded converter slip power recovery;
- Doubly fed induction generator with cyclo-converter slip power recovery.
- Synchronous generator with line-commutated and load commutated thyristor converters. In addition to the above schemes, squirrel cage generators with shunt passive or active VAR (volt ampere reactive) generators have been proposed which generate constant voltage constant frequency power through a diode rectifier and line-commutated thyristor inverter. Recently, a variable reluctance machine and doubly stator-fed induction machine have also been proposed in wind generation systems.

III. PROPOSED METHOD

The design of the voltage controller will be outlined Here in after, following the detailed procedures proposed in. A prominent feature different from what is known is that the control plant of the voltage controller is no longer the whole LCL filter but just the LC filter, as shown in Fig. 2. Lineal control theory uses mathematical models of a process and some specifications of the expected behavior in close loop, to design a controller [9]. These control strategies are highly used in systems that can be assumed as linear in certain range of their operation. Besides, it is absolutely necessary to obtain a linear model that represents the relationship between input and output in order to design the controller [17]. However, for some systems it is difficult to find out that linear model. Sometimes, it is necessary to use sophisticated tools of identification in order to find out a linear input-output transfer function [8]. Despite this, the found out model only describes the system in a narrow range accurately. In addition, when the system does not have constant parameters or has interdependence with others parameters the found out model is less accurate.

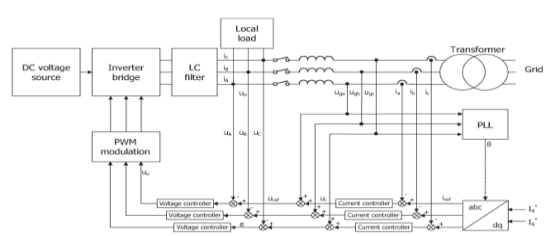

Fig 3: Sketch of a grid-connected three-phase inverter using the proposed strategy.

Given the above points, linear control strategies could be limited in design and performance. On the other hand, non-linear strategies such as knowledge Based Fuzzy Control (KBFC) [10], outperform linear controllers in many of the cases exposed above. KBFC is based on human knowledge which adds several types of information and can mix different control strategies that cannot easily be added through an analytical control law. On top of that, like human knowledge, KBFC does not need an accurate mathematical model in order to work out a control action [9]. What is more, KBFC uses the experience and the knowledge of an expert about the behavior of the system in order to work out the control action. A kind of KBFC is the rule-based fuzzy control, where the human knowledge is approximated by means of linguistic fuzzy rules in the form if then. Each rule describes the control action in a particular condition of the system [9]. –Control action that would be done by a human operator [9]- .Therefore, under a specific condition of the system (if condition1) can be specified an action (then action1). A. State-Space Model of the Plant Pi Since it can be assumed that uo = uref , there is uo = ug + ui or ui = uo − ug from Figs. 3 and 4, i.e., ui is actually the voltage dropped on the grid inductor. The feed forwarded grid voltage ug provides a base local load voltage conditions of a system in which each rule defines an action for a specific condition. In the same way, both condition and action are represented by linguistic terms such as (large, medium, small) for condition and (increase a few, increase a lot) for actions, those linguistic terms belong to fuzzy sets with overlapped boundaries. Therefore, by means of fuzzy sets it is possible to get smooth interpolation between different rules, in order to describe completely the behavior of the system with few rules [9]. That characteristic allows the fuzzy control to represent the qualitative knowledge of a human expert [9]. T he controllers are based on a Mamdani fuzzy inference system, that kind of controllers are usually used into feedback systems because the rule base represents a static mapping between antecedents and consequents

IV. SIMULATION RESULTS

The above-designed controller was implemented to evaluate its performance in both stand-alone and grid connected modes with different loads. The seamless transfer of the operation modes was also carried out. The *H*∞ repetitive current controller was replaced with a proportional–resonant (PR) current controller for comparison in the grid-connected mode. In the stand-alone mode, since the grid current reference was set to zero and the circuit breaker was turned off (which means that the current controller was not functioning), the simulation results with both the repetitive current controller and the PR current controller are similar, and hence, no comparative results are provided for the stand-alone mode.

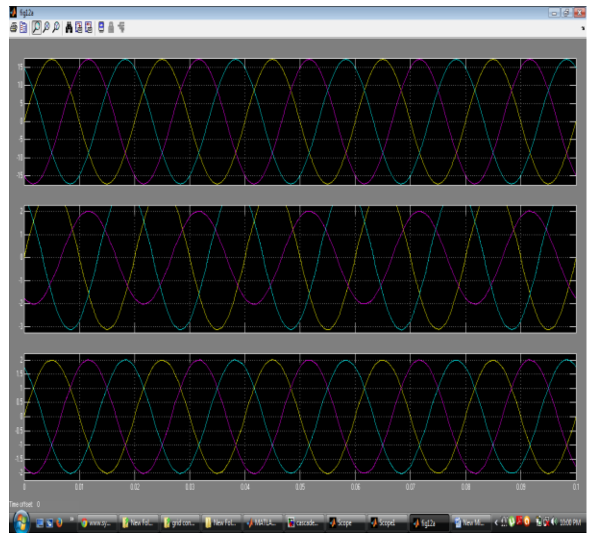

Fig. 1. Stand-alone mode with an unbalanced load. (a) (Upper) Inverter local load voltage and (lower) local load currents. (b) (Upper) Voltage THD and (lower) current THD.

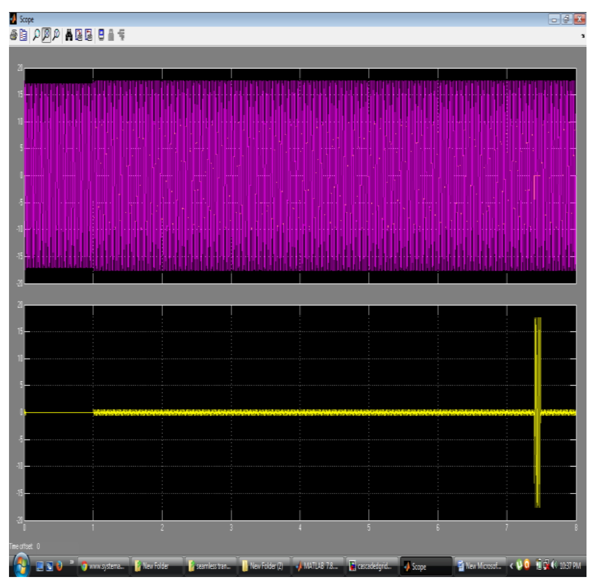

Fig. 2. Transient response of the inverter when transferred from the standalone mode to the grid-connected mode and then back.

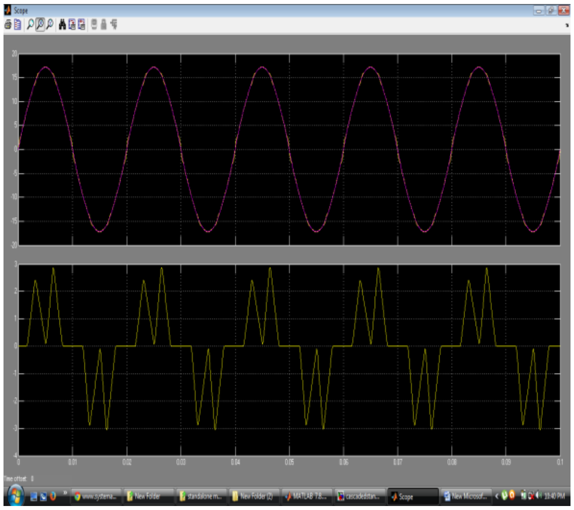

Fig. 3. Stand-alone mode with a nonlinear load. (a) (Upper) *uA* and its reference *u*ref and (lower) current *iA*. (b) (Upper) Voltage THD and (lower) current THD.

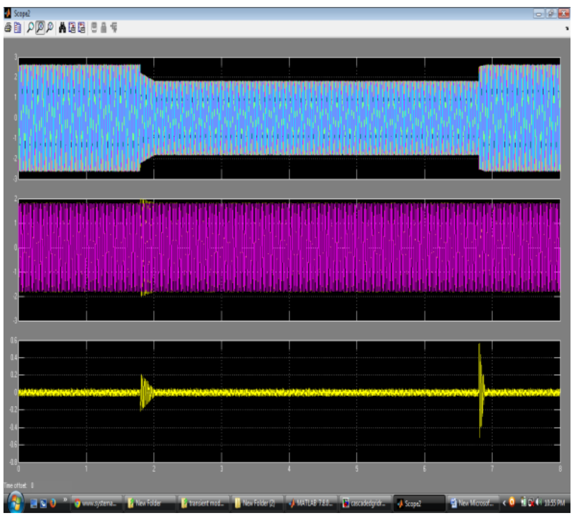

Fig.4. Transient responses of the inverter and grid currents when the local load was changed. (a) Filter inductor current *iA*. (b) Grid current *ia*, its reference *i*ref , and the current tracking error *ei*.

V. CONCLUSION and FUTURE SCOPE

The proposed article shows a cascaded current voltage control strategy has been proposed for inverters in micro grids. It consists of an inner voltage loop and an outer current loop and offers excellent performance in terms of THD for both the inverter local load voltage and the grid current. In particular, when nonlinear and/or unbalanced loads are connected to the inverter in the grid-connected mode, the proposed strategy significantly improves the THD of the inverter local load voltage and the grid current at the same time. The controllers are designed using the $H\infty$ repetitive current control and fuzzy based voltage control in this paper. The proposed strategy also achieves seamless transfer between the standalone and the grid-connected modes. The strategy can be used for single-phase systems or three-phase systems. As a result, the nonlinear harmonic currents and unbalanced local load currents are all contained locally and do not affect the grid. Simulation results under various scenarios have demonstrated the excellent performance of the proposed strategy.

The graph of Power demand is always is of positive slope and progressive. The power quality problems are also following the same trend in their aspect. There's a need to reduce the complex power problems and supply an efficient and sufficient power to the utilities. There's always a continuous research carried out to improve the power quality. Unified Power Flow Controller is one of such a promising technology.

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