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RESEARCH ARTICLE

POWER QUALITY IMPROVEMENT FOR GRID CONNECTED WIND ENERGY SYSTEM USING UPFC

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Abstract: In this paper, a cascaded current–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. It also enables seamless transfer of the operation mode from stand-alone to grid-connected or vice versa. The control scheme includes an inner voltage loop and an outer current loop, with both controllers designed using the fuzzy logic control and H∞ repetitive control strategy. This leads to a very low total harmonic distortion 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.

Keywords: Harmonics, Power quality, wind energy, UPFC, STATCOM

I. INTRODUCTION

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. A UPFC based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. The proposed UPFC control scheme for grid connected wind energy generation for power quality improvement has following objectives.

• UPFC is independent of real and reactive power and it is a combination of STATCOM and SSSC.
• Reactive power support only from STATCOM to wind Generator and Load.
• STATCOM is used to achieve fast dynamic response.
• Injects current by SSSC the line and it is independent of current.

1.1 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.

II. SCOPE OF WIND IN RENEWABLE ENERGY SOURCES

2.1Wind 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. VOLTAGE CONTROLLER DESIGN

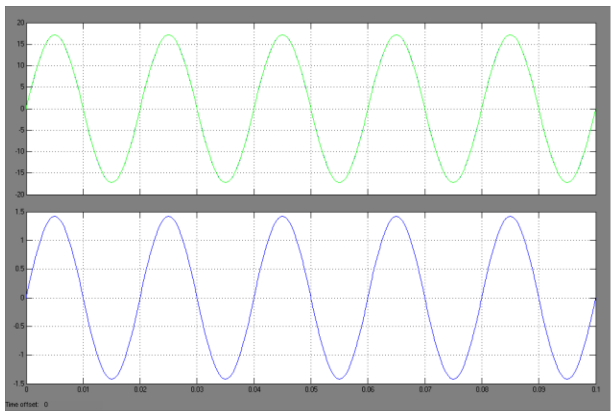
The design of the voltage controller will be outlined Here in after, following the detailed procedures proposed in. A prominent feature different from what is known is that the control plant of the voltage controller is no longer the whole *LCL* filter but just the *LC* filter, as shown in Fig. 2. Lineal 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. 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).

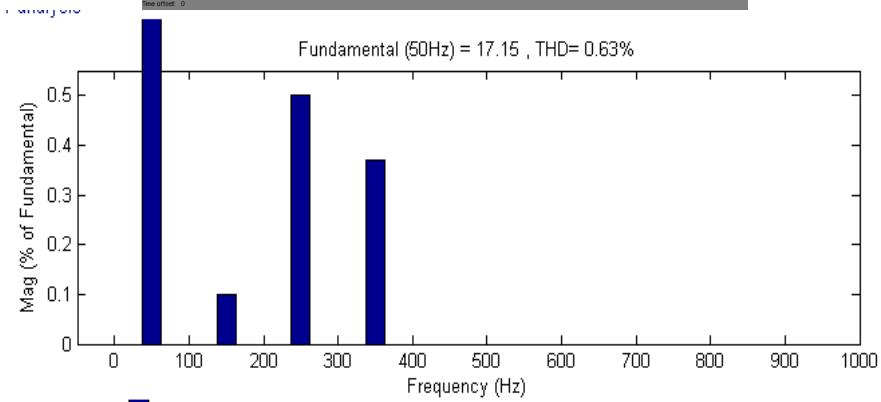
A. State-Space Model of the Plant Pi

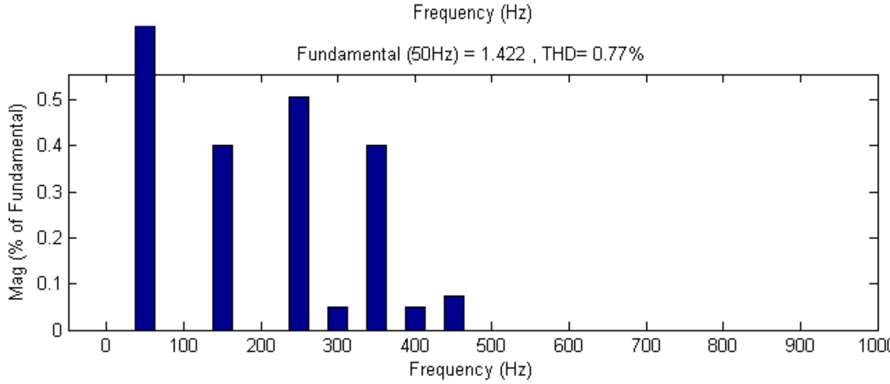
Since it can be assumed that $uo = u\text{ref}$, there is $uo = ug + ui$ or $ui = uo - ug$ from Figs. 3 and 4, i.e., ui is actually the voltage dropped on the grid inductor. The feed forwarded grid voltage ug provides a base local load voltage conditions of a system in which each rule defines an action 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

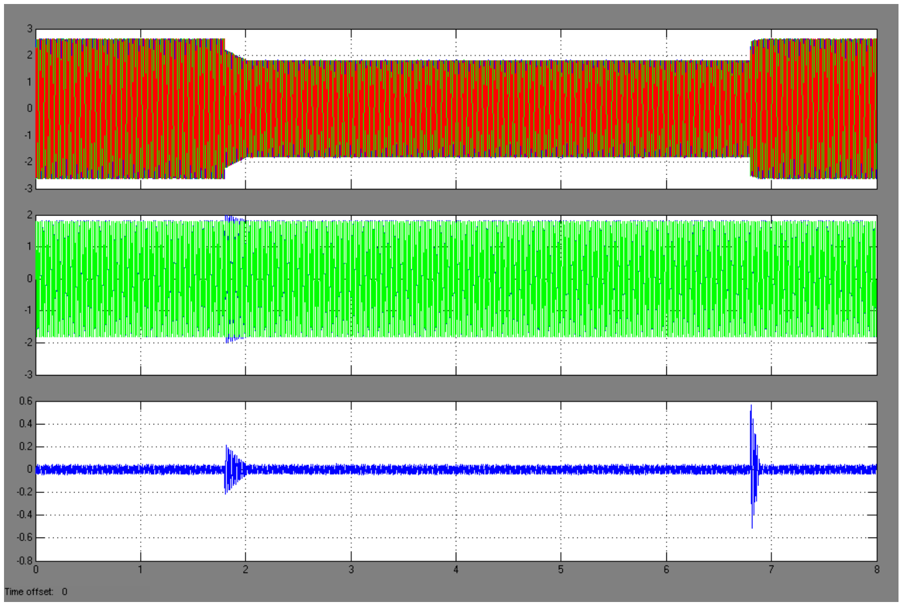
IV. SIMULATION RESULTS

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. The PR controller was designed according to with the plant used as









V. CONCLUSION

The 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.

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