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IMPROVED ACTIVE POWER FILTER PERFORMANCE FOR RENEWABLE POWER GENERATION

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Abstract

A predictive control algorithm specially developed for shunt active power filters aimed to compensate reactive power and current harmonics components is presented and analyzed. The proposed predictive control algorithm is implemented in a three-phase four-leg voltage source inverter (4L-VSI). The use of a 4L-VSI allows the compensation of current harmonics, reactive power and neutral current harmonics generated by single-phase non-linear loads. A detailed mathematical model of the filter, including the effect of the power system equivalent impedance is derived and used to design the proposed predictive control algorithm. The proposed active power filter and associated control scheme performance and compensation effectiveness are demonstrated by simulation and with experimental results.

Keywords: Active power filter, current control, four-leg converters, predictive control.

1. INTRODUCTION

Renewable generation affects power quality due to its nonlinearity, since solar generation plants and wind power generators must be connected to the grid through high-power static PWM converters [1]. The non uniform nature of power generation directly affects voltage regulation and creates voltage distortion in power systems. This new scenario in power distribution systems will require more sophisticated compensation techniques. Although active power filters implemented with three-phase four-leg voltage-source inverters (4L-VSI) have already been presented in the technical literature [2], the primary contribution of this paper is a predictive control algorithm designed and implemented specifically for this application. Traditionally, active power filters have been controlled using pre-tuned controllers, such as PI-type or adaptive, for the current as well as for the dc-voltage loops. PI controllers must be designed based on the equivalent linear model, while predictive controllers use the nonlinear model, which is closer to real operating conditions. An accurate model obtained using predictive controllers improves the performance of the active power filter, especially during transient operating conditions, because it can quickly follow the current-reference signal while maintaining a constant dc-voltage. So far, implementations of predictive control in power converters have been used mainly in induction motor drives. In the case of motor drive applications, predictive control represents a very intuitive control scheme that handles multivariable characteristics, simplifies the treatment of dead-time compensations, and permits pulse-width modulator replacement. However, these kinds of applications present disadvantages related to oscillations and instability created from unknown load parameters. One advantage of the proposed algorithm is that it fits well in active power filter applications, since the power converter output parameters are well known. These output parameters are obtained from the converter output ripple filter and the power system equivalent impedance. The converter output ripple filter is part of the active power filter design and the power system impedance is obtained from well-known standard procedures. In the case of unknown system impedance parameters, an estimation method can be used to derive an accurate R-L equivalent

impedance model of the system. This paper presents the mathematical model of the 4L-VSI and the principles of operation of the proposed predictive control scheme, including the design procedure. The complete description of the selected current reference generator implemented in the active power filter is also presented. Finally, the proposed active power filter and the effectiveness of the associated control scheme compensation are demonstrated through simulation

2. LITERATURE REVIEW

In the paper, A predictive control algorithm specially developed for shunt active power filters aimed to compensate reactive power and current harmonics components is presented and analyzed. The proposed predictive control algorithm is implemented in a three-phase four-leg voltage source inverter (4L-VSI). The use of a 4L-VSI allows the compensation of current harmonics, reactive power and neutral current harmonics generated by single-phase non-linear loads. A detailed mathematical model of the filter, including the effect of the power system equivalent impedance is derived and used to design the proposed predictive control algorithm. The proposed active power filter and associated control scheme performance and compensation effectiveness are demonstrated by simulation and with experimental results.

In the paper Described, Active filtering of electric power has now become a mature technology for harmonic and reactive power compensation in ac networks. In this project, a bidirectional control technique of active tuned hybrid power filter (ATHPF) based on the active reactor using active techniques is proposed to solve the problem of harmonic over-current in ATHPF. The proposed control is to continuously adjust the filter inductance of the active reactor by regulating active power filter (APF) output current in terms of its magnitude and direction. Therefore, the ATHPF using the bidirectional control principle can simultaneously supply different impedances at different selective suppressed harmonic frequencies. The bidirectional control principle can perform both the normal active tuning function and the abnormal active detuning function. Experimental results verify the effectiveness of the ATHPF with the bidirectional control principle in selective harmonic elimination and flexible protection against harmonic over-current.

This paper describes a three-phase four-wire shunt active power filter using a conventional three-leg converter, without the need of power supply at DC bus. Two approaches have been developed to control the active filter. Both control strategies consider harmonics and zero sequence components in the voltage and current simultaneously. The first one provides constant power and the second one sinusoidal current to the source, even under unbalanced voltage conditions. Simulation results from a complete model of shunt active filter are presented to validate and compare the control strategies.

This paper explain, The enabling of ac microgrids in distribution networks allows delivering distributed power and providing grid support services during regular operation of the grid, as well as powering isolated islands in case of faults and contingencies, thus increasing the performance and reliability of the electrical system. The high penetration of distributed generators, linked to the grid through highly controllable power processors based on power electronics, together with the incorporation of electrical energy storage systems, communication technologies, and controllable loads, opens new horizons to the effective expansion of micro grid applications integrated into electrical power systems. This paper carries out an overview about micro grid structures and control techniques at different hierarchical levels. At the power converter level, a detailed analysis of the main operation modes and control structures for power converters belonging to micro grids is carried out, focusing mainly on grid-forming, grid-feeding, and grid-supporting configurations. This analysis is extended as well toward the hierarchical control scheme of micro grids, which, based on the

primary, secondary, and tertiary control layer division, is devoted to minimize the operation cost, coordinating support services, meanwhile maximizing the reliability and the controllability of micro grids. Finally, the main grid services that micro grids can offer to the main network, as well as the future trends in the development of their operation and control for the next future, are presented and discussed.

This paper presents a predictive current control method and its application to a voltage source inverter. The method uses a discrete-time model of the system to predict the future value of the load current for all possible voltage vectors generated by the inverter. The voltage vector which minimizes a quality function is selected. The quality function used in this work evaluates the current error at the next sampling time. The performance of the proposed predictive control method is compared with hysteresis and pulse width modulation control. The results show that the predictive method controls very effectively the load current and performs very well compared with the classical solutions.

In this paper, A new predictive strategy for current control of a three-phase neutral point clamped inverter is presented. It is based on a discrete-time model of the system, used to predict future values of the load current and voltage of the capacitors in the DC-link, for each possible switching state generated by the inverter. The state that minimizes a given quality function "g" is selected to be applied during the next sampling interval. Several compositions of g are proposed, including terms dedicated to achieve reference tracking, balance in the DC-link and reduction of the switching frequency. The algorithm uses the redundancy of switching states, typical of a three-level inverter, by means of a simple strategy. In comparison with classic PWM current control, the strategy presents a remarkable performance. The proposed method achieves comparable reference tracking with lower switching frequency per semiconductor and a slightly improved transitory behavior. It requires a greater sampling frequency, which should not be a problem, considering the present technologies available in digital signal processors. The main advantage of the method is that it does not require any kind of linear controller or

3. EXISTING SYSTEM

CURRENT REFERENCE GENERATION

A dq-based current reference generator scheme is used to obtain the active power filter current reference signals. This scheme presents a fast and accurate signal tracking capability.

This characteristic

avoids voltage fluctuations that deteriorate the current reference signal affecting compensation performance [28]. The current reference signals are obtained from the corresponding load currents as shown in Fig. 4. This module calculates the reference signal currents required by the converter to compensate reactive power, current harmonic, and current imbalance. The displacement power factor ($\sin \varphi(L)$) and the maximum total harmonic distortion of the load ($THD(L)$) defines the relationships between the apparent power required by the active power filter, with respect to the load, as shown

4. PROPOSED SYSTEM

OUR-LEG CONVERTER MODEL

Fig. 1 shows the configuration of a typical power distribution system with renewable power generation. It consists of various types of power generation units and different types of loads. Renewable sources, such as wind and sunlight, are typically used to generate electricity for residential users and

small industries. Both types of power generation use ac/ac and dc/ac static PWM converters for

voltage conversion and battery banks for long term energy storage. These converters perform maximum power point tracking to extract the maximum energy possible from wind and sun. The electrical energy consumption behavior is random and unpredictable, and therefore, it may be single- or three-phase, balanced or unbalanced, and linear or nonlinear. An active power filter is connected in parallel at the point of common coupling to compensate current harmonics, current unbalance, and reactive power. It is composed by an electrolytic capacitor, a four-leg PWM converter, and a first-order output ripple filter, as shown in Fig. 1. This circuit considers the power system equivalent impedance Z_s , the converter output ripple filter impedance Z_f , and the load impedance Z_L . The four-leg PWM converter topology is shown in Fig. 2. This converter topology is similar to the conventional three-phase converter with the fourth leg connected to the neutral bus of the system. The fourth leg increases switching states from 8 (23) to 16 (24), improving control flexibility and output voltage quality [21], and is suitable for current unbalanced compensation

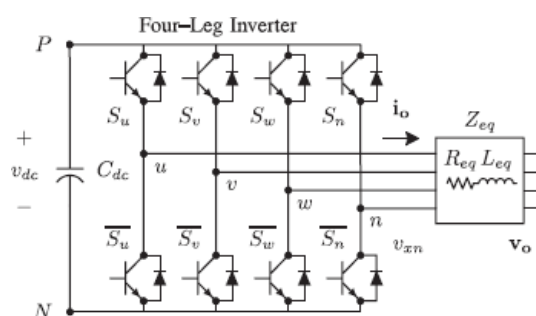


Fig. 1. Two-level four-leg PWM-VSI topology.

5. RESULTS AND DESCRIPTION

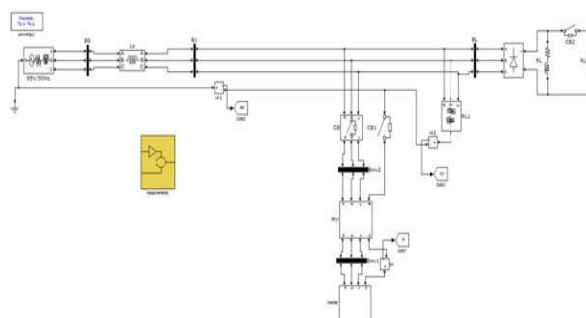


Fig 2: simulation model

A simulation model for the three-phase four-leg PWM converter with the parameters shown in Table I has been developed using MATLAB Simulink. The objective is to verify the current harmonic compensation effectiveness of the proposed controlscheme under different operating conditions. A six-pulse rectifier was used as a nonlinear load. The proposed predictive control algorithm was programmed using an S- function block that allows simulation of a discrete model that can be easily implemented in a real-time interface (RTI) on the R&D control board. Simulations were performed

considering a 20 [μ s] of sample time. In the simulated results shown in Fig. 8, the active filter starts to compensate at $t = t_1$. At this time, the active power filter injects an output current i_{ou} to compensate current harmonic components, current unbalanced, and neutral current simultaneously. During compensation, the system currents is show sinusoidal waveform, with low total harmonic distortion (THD = 3.93%). At $t = t_2$, a three-phase balanced load step change is generated from 0.6 to 1.0 p.u. The compensated system currents remain sinusoidal despite the change in the load current magnitude. Finally, at $t = t_3$, a single-phase load step change is introduced in phase u from 1.0 to 1.3 p.u., which is equivalent to an 11% current imbalance. As expected on the load side, a neutral current flows through the neutral conductor (i_{Ln}), but on the source side, no neutral current is observed (i_{sn}). Simulated results show that the proposed control scheme effectively eliminates unbalanced currents. Additionally, Fig. 8 shows that the dc- voltage remains stable throughout the whole active power filter operation

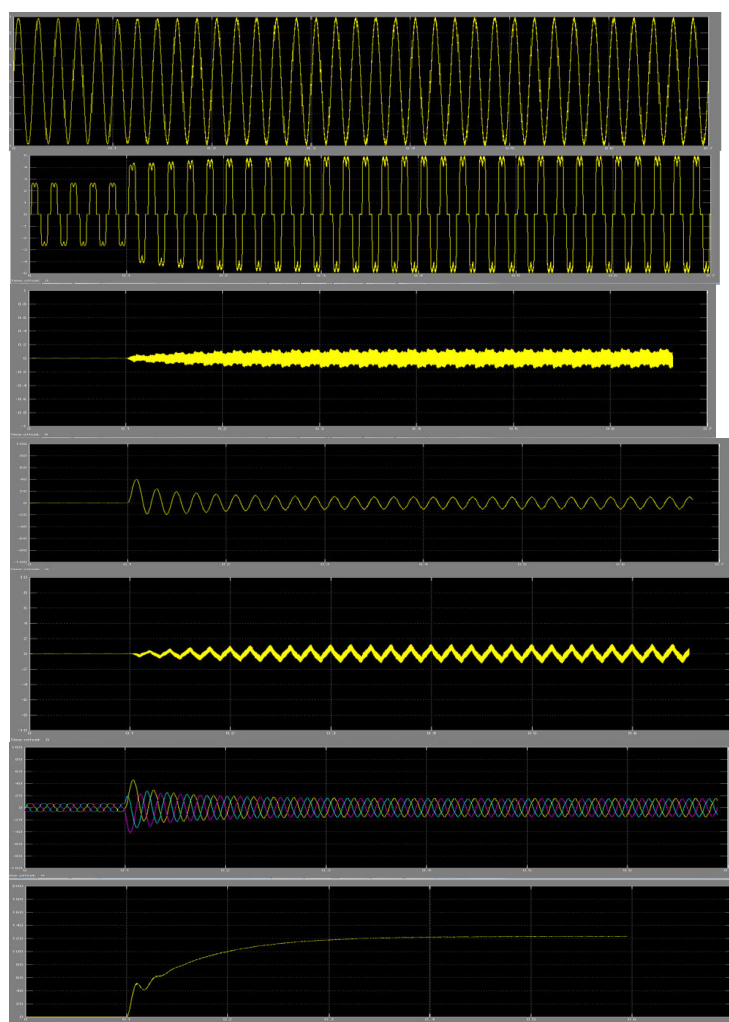


Fig. 3. Simulated waveforms of the proposed control scheme. (a) Phase to neutral source voltage. (b) Load Current. (c) Active power filter output current. (d) Load neutral current. (e) System neutral current. (f) System currents. (g) DC voltage converter.

6. CONCLUSION

Improved dynamic current harmonics and a reactive power compensation scheme for power distribution systems with generation from renewable sources has been proposed to improve the current quality of the distribution system. Advantages of the proposed scheme are related to its modeling, and implementation. The use of a predictive control algorithm for the converter current loop proved to be an effective solution for active power filter applications, improving current tracking capability, and transient response. Simulated and experimental results have proved that the proposed predictive control algorithm is a good alternative to classical linear control methods. The predictive current control algorithm is a stable and robust solution. Simulated and experimental results have shown the compensation effectiveness of the proposed active power filter.

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