

Simulation of an Improved Active Power Filter Performance for Renewable Power Generation systems

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Abstract-This paper represents an active power filter implemented with a four-leg voltage-source inverter using a predictive control scheme is presented. Here the active power filter is used to reduce the current harmonics. Generated from the load. The load nothing but non-linear load. So we are eliminating the current harmonics generated from the load. The effective solution to eliminating the current harmonics are the active power filters is derived and used to design the predictive control algorithm. The compensation performance of the proposed active power filter and the associated control scheme under steady state and transient operating conditions is demonstrated through simulations and experimental results.

I. INTRODUCTION

The increasing energy demand, increasing costs and exhaustible nature of fossil fuels, and global environment pollution have generated huge interest in renewable energy resources. Other than hydroelectric power, wind and solar are the most useful energy sources to satisfy our power requirements. Wind energy is capable of producing huge amounts of power, but its availability can't be predicted. Solar power is available during the whole day but the solar irradiance levels change because of the changes in the sun's intensity and shadows caused by many reasons. Generally solar and wind powers are complementary in nature. Therefore the hybrid photovoltaic and wind energy system has higher dependability to give steady power than each of them operating individually. Other benefit of the hybrid system is that the amount of the battery storage can be decreased as hybrid system is more reliable compared to their independent operation. Although active power filters implemented with three-phase four-leg voltage-source inverters (4L-VSI) have already been presented in the technical literature, 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.

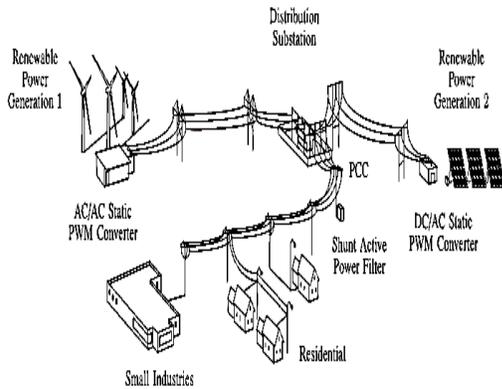


Fig 1. Stand-alone hybrid power generation system with a shunt active power filter

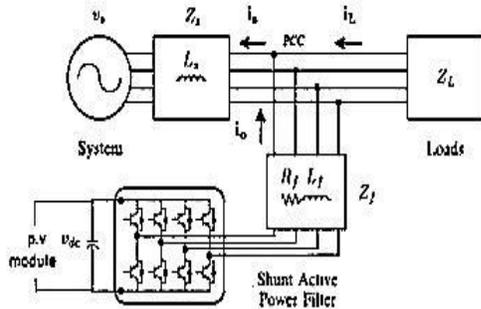


Fig.2. Three-phase equivalent circuit of the proposed shunt active power filter

Control scheme compensation are demonstrated through simulation and validated with experimental results obtained in a 2 KVA laboratory prototype.

II. FOUR-LEG INVERTER 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 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, improving control flexibility and output voltage quality, and is suitable for current unbalanced compensation.

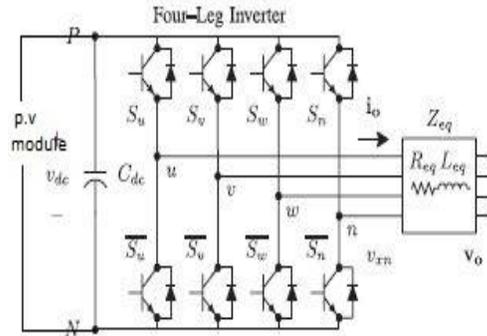


Fig. 2.1. Two-level four-leg PWM-VSI topology

III. DIGITAL PREDICTIVE CURRENT CONTROL

The block diagram of the proposed digital predictive current control scheme is shown in Fig. 3.1. This control scheme is basically an optimization algorithm and, therefore, it has to be implemented in a microprocessor. Consequently, the analysis has to be developed using discrete mathematics in order to consider additional restrictions such as time delays and approximations

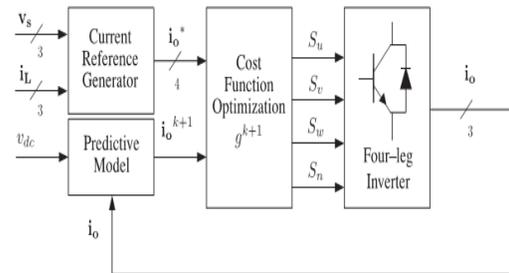


Fig. 3.1. Proposed predictive digital current control block diagram.

The main characteristic of predictive control is the use of the system model to predict the future behavior of the variables to be controlled. The controller uses this information to select the optimum switching state that will be applied to the power converter, according to predefined optimization criteria. The predictive control algorithm is easy to implement and to understand, and it can be implemented with three main blocks, as shown in Fig.

1) CURRENT REFERENCE GENERATOR

This unit is designed to generate the required current reference that is used to compensate the undesirable load current components. In this case, the system voltages, the load currents, and the dc-voltage converter are measured, while the neutral output current and neutral load current are generated directly from these signals (IV).

2) PREDICTION MODEL

The converter model is used to predict the output converter current. Since the controller operates in discrete time, both the controller and the system model must be represented in a discrete time domain. The discrete time model consists of a recursive matrix equation that represents this prediction system. This means that for a given sampling time T_s , knowing the converter switching states and control variables at Instant kT_s , it is possible to predict the next states at any instant $[k+1]T_s$. Due to the first-order nature of the state equations that describe the model in (1)–(2), a sufficiently accurate first-order approximation of the derivative is considered in this paper

$$\frac{dx}{dt} \approx \frac{x[k+1] - x[k]}{T_s} \tag{1}$$

The 16 possible output current predicted values can be obtained from (2) and (4) as

$$i_o[k+1] = \frac{T_s}{L_{cq}}(v_{xn}[k] - v_o[k]) + \left(1 - \frac{R_{cq} T_s}{L_{cq}}\right) i_o[k] \tag{2}$$

As shown in (5), in order to predict the output current i at the instant $(k+1)$, the input voltage value v_o and the converter output voltage v_{xn} , are required. The algorithm calculates all 16 values associated with the possible combinations that the state variables can achieve.

3) COST FUNCTION OPTIMIZATION

In order to select the optimal switching state that must be applied to the power converter, the 16 predicted values obtained for $i_o[k+1]$ are compared with the reference using a cost function, as follows:

$$g[k+1] = (i_{ou}^*[k+1] - i_{ou}[k+1])^2 + (i_{ov}^*[k+1] - i_{ov}[k+1])^2 + (i_{ow}^*[k+1] - i_{ow}[k+1])^2 + (i_{on}^*[k+1] - i_{on}[k+1])^2$$

4). 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. 3.2. This module calculates the reference signal currents required by the converter to compensate reactive power, current harmonic and current imbalance. The displacement power factor ($\sin\phi$ (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.

The dq-based scheme operates in a rotating reference frame; therefore, the measured currents must be multiplied by the $\sin(\omega t)$ and $\cos(\omega t)$ signals. By using dq-transformation, the d current component is synchronized with the corresponding phase-to-neutral system voltage, and the q current component is phase-shifted by 90° . The $\sin(\omega t)$ and $\cos(\omega t)$ synchronized reference signals are obtained from a synchronous reference frame (SRF) PLL [29]. The SRF-PLL generates a pure sinusoidal waveform even when the system voltage is severely distorted.

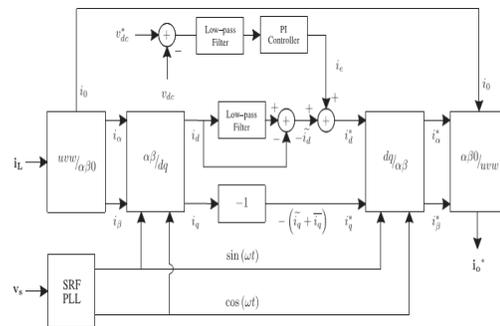


Fig. 3.2 D q-based current reference generator block diagram

Tracking errors are eliminated, since SRF-PLLs are designed to avoid phase voltage unbalancing, harmonics (i.e., less than 5% and 3% in fifth and seventh, respectively), and offset caused by the nonlinear load conditions and measurement errors [30]. Equation (8) shows the relationship between the real currents $i_{Lx}(t)$ ($x=u, v, w$) and the associated dq

components (i_d and i_q). One of the major advantages of the dq -based current reference generator scheme is that it allows the implementation of a linear controller in the dc-voltage control loop. However, one important disadvantage of the dq -based current reference frame algorithm used to generate the current reference is that a second order harmonic component is generated in i_d and i_q under unbalanced operating conditions. The amplitude of this harmonic depends on the percent of unbalanced load current (expressed as the relationship between the negative sequence current $i_{L,2}$ and the positive sequence current $i_{L,1}$). The second-order harmonic cannot be removed from i_d and i_q , and therefore generated.

IV. EXISTING MATLAB/SIMULINK MODEL

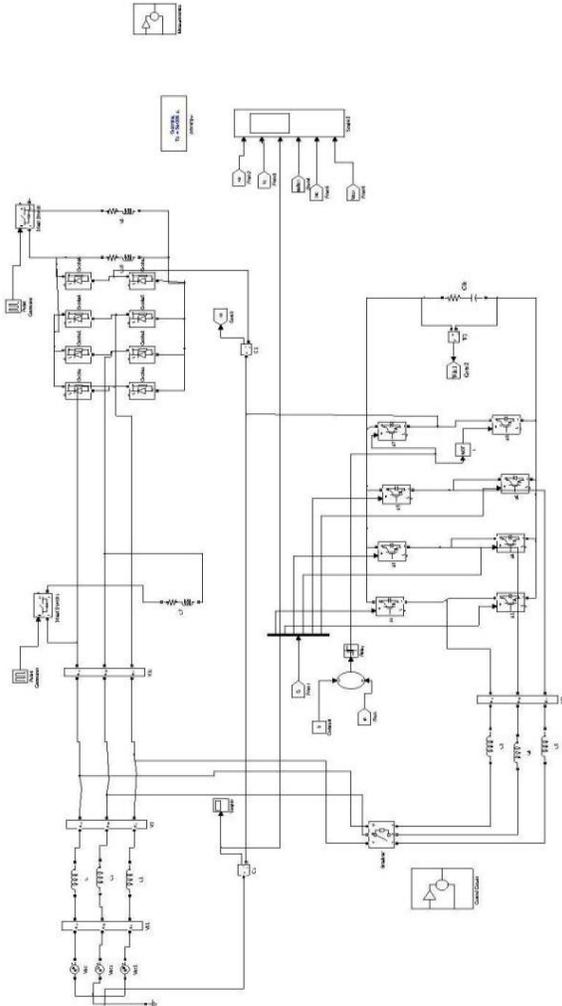


Fig 4.1 Existing Mat lab/Simulink Model

MATLAB/SIMULINK OUTPUT

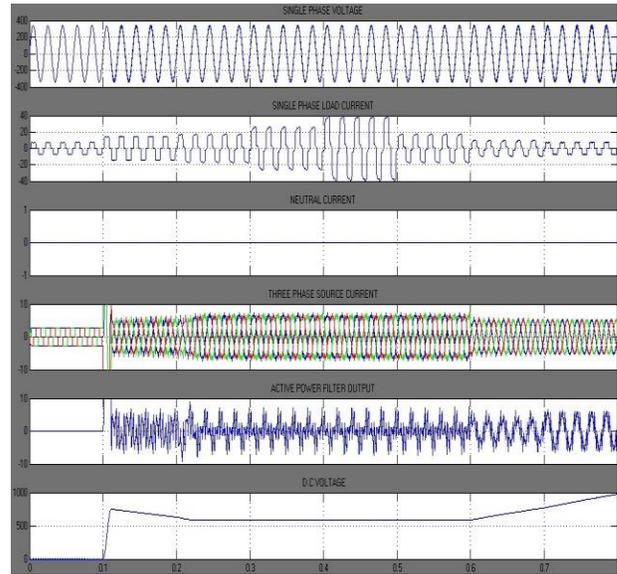


Fig 4.2 Existing Mat lab/Simulink Output

V.CONCLUSION

Improved system performance is observed after the introduction of P.V module as an input to active power filter which includes the compensation of reactive power, and current harmonics by numerically reducing the total harmonic distortion of the source current from 30% to 6% on average. Resulting in surge of the quality of power in distribution system to a good extent. The predictive algorithm is proved a better alternate to conventional converters in handling non linear and unbalanced load because of its simplicity.

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