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Improved power quality for renewable power generation systems presence of non linear loads

K Swathi Priya and Davu Srinivasa Rao
Dept. of Electrical & Electronics Engineering
Malla Reddy Institute of Engineering & Technology
Hyderabad, India
swathipriya.kurikala@gmail.com and sri.davu@gmail.com

Abstract— **An active power filter implemented with a four-leg voltage-source inverter using a predictive control scheme is presented. The use of a four-leg voltage-source inverter allows the compensation of current harmonic components, as well as unbalanced current generated by single-phase nonlinear loads. The compensation performance of the proposed active power filters.**

***Keywords-** Active power filter, Current control, Predictive control, Four-leg converters*

I. 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 volt-age 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 technical literature [2]– [6], the primary con tribution 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 [7], [8]. PI controllers must be designed based on the equivalent linear model, while predictive controllers use the non-linear 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.

II. FOUR-LEG CONVERTER MODEL

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 behaviour is random and unpredictable.

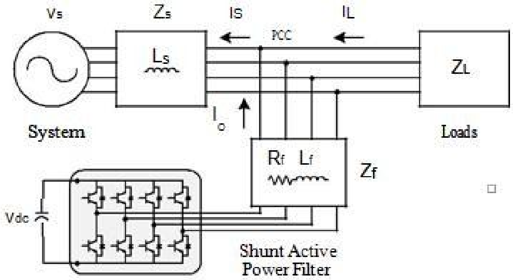

Fig. 1: Three-phase equivalent circuit of the proposed shunt active power filter

The voltage in any leg x of the converter, measured from the negative point of the dc-voltage (N), can be expressed in terms of switching states, as follows

$$v_{xN} = S_x\, v_{dc}, \quad x = u,\ v,\ w,\ n. \tag{1}$$

equivalent circuit shown in fig 1 is,

$$\mathbf{v_o} = v_{xN} - R_{eq}\,\mathbf{i_o} - L_{eq}\frac{d\,\mathbf{i_o}}{dt}, \tag{2}$$

It is composed by an electrolytic capacitor, a four-leg PWM converter, and a first-order output ripple filter, as shown in Fig.1.

Furthermore, the coordination packet is assumed to be small enough to be transmitted within slot duration. Instead of a common control channel, FHS provides a diversity to be able to find a vacant channel that can be used to transmit and receive the coordination packet. If a hop of FHS, i.e., a channel, is used by the primary system, the other hops of FHS can be tried to be used to coordinate. This can allow the nodes to use K channels to coordinate with each other rather than a single control channel.

Whenever any two nodes are within their communication radius, they are assumed to meet with each other and they are called as contacted. In order to announce its existence, each node periodically broadcasts a beacon message to its contacts using FHS. Whenever a hop of FHS, i.e., a channel, is vacant, each node is assumed to receive the beacon messages from their contacts that are transiently in its communication radius

III. DIGITAL PREDICTIVE CURRENT CONTROL

The block diagram of the proposed digital predictive current control scheme is shown in Fig. 2.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. The main characteristic of predictive control is the use of the system model to predict the future behaviour of the variables to be controlled.

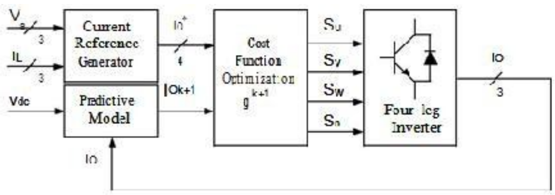

Fig. 2: Proposed predictive digital current control block diagram

A) 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.

B) 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 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 $[k + 1]T_S$.

$$\mathbf{i_o}[k+1] = \frac{T_s}{L_{eq}}\left(v_{xN}[k] - \mathbf{v_o}[k]\right) + \left(1 - \frac{R_{eq}T_s}{L_{eq}}\right)\mathbf{i_o}[k].$$

in order to predict the output current io at the instant (k+1), the input voltage value vo and the converter output voltage vxN, are required.

The algorithm calculates all 16 values associated with the possible combinations that the state variables can achieve.

C) Cost Function Optimization : In order to select optimal switching state that must be applied to the power converter.

$$\begin{aligned} g[k+1] = &\left(i_{ou}^*[k+1] - i_{ou}[k+1]\right)^2 \\ &+ \left(i_{ov}^*[k+1] - i_{ov}[k+1]\right)^2 \\ &+ \left(i_{ow}^*[k+1] - i_{ow}[k+1]\right)^2 \\ &+ \left(i_{on}^*[k+1] - i_{on}[k+1]\right)^2 \end{aligned}$$

IV. CURRENT REFERENCE GENERATOR

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

The dq-based scheme operates in a rotating reference frame; therefore, the measured currents must be multiplied by the sin(wt) and cos(wt) signals. By using dq-transformation, the current component is synchronized with the corresponding phase-to-neutral system voltage and the q current component is phase-shifted by 90°. The sin(wt) and cos(wt) synchronized reference signals are obtained from a Synchronous Reference Frame (SRF) PLL.

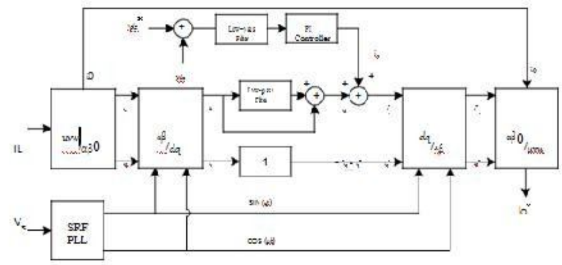

Fig 3.. dq-based Current Reference Generator Block Diagram.

A) DC Voltage Control : The dc-voltage converter is controlled with a traditional PI controller.

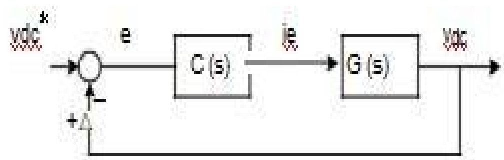

Fig. 4: DC-Voltage control block diagram

V. 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 simplicity, 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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