**Multilevel Inverter Compensation System of the Single-phase Based on Instantaneous P-instantaneous Real Power and Q-instantaneous Virtual Power Theory**

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**Abstract**—This paper gives an introduction to the single-phase instantaneous PQ (P-instantaneous real power and Q-instantaneous virtual power) theory and carries out the calculation and simulation analysis on reactive power, active power, instantaneous reactive power and instantaneous active power for the single system before and after the compensation of the multilevel inverter. By analyzing the experimental results, it can be seen that harmonic current of the single phase system decreased significantly after using multilevel inverter, while the power factor improved obviously.

**Index Terms**—The harmonic current, The instantaneous PQ theory, The multilevel Inverter, The power factor

I. INTRODUCTION

When it comes to the field of power quality and compensation, one of the most important theories is the instantaneous PQ theory which is put forward by Hirofumi Akagi Y. Kanazawa, A. Nabae in 1983. [1] This theory provides a very good way to measure and calculate the three phase instantaneous active power and reactive power. It regards the power as the average active power, transient active power, average reactive power and transient reactive power. The important thing is the average active power, so that the power quality of the system is good. [2] The transient active power, average reactive power and transient reactive power are the power that causes the contamination of the power grid, which are the power that need to be compensated.

II. THE SINGLE-PHASE INSTANTANEOUS PQ THEORY

Since in the Clarke Transformation the αβ plane is an orthogonally coordinate system. So when it comes to the usage of PQ theory in single phase, it is not necessary to transfer them into αβ plane. It is only necessary to directly make a delay on the single phase current voltage so that it is ok to regard the original current and voltage as the current and voltage in αβ plane and the delayed current and voltage in β plane. Then it shall use the calculation method that mentioned previously and get the compensation current.

Since it is in the single phase case, only the current and voltage in phase A are considered. As for phase b and phase c, they can be considered that the currents and voltages in them are zero.

Firstly, it shall identify the single phase voltage and current (which are V_source and I_source in this project) as the voltage and current in alpha plane. Then applying a delay function to them and the delayed value of them (indicated as “V_source_delay” and “I_source_delay”). The delay that used is one quarter of the total period. In this project the frequency is 50 Hz. So that the period is 0.02 s. The delay that used is 0.005 s, which is precisely one quarter of the total period. Thus the 90 degrees angle shift in αβ plane can be simulated. Thereby, the voltage on alpha plane and beta plane can be got.

Then the following calculation can be deduced. Firstly, the single phase active power and reactive power shall be calculated.

\[
\begin{bmatrix}
    p(t) \\
    q(t)
\end{bmatrix} =
\begin{bmatrix}
    v_a(t) & v_b(t) & i_a(t) \\
    -v_b(t) & v_a(t) & i_b(t)
\end{bmatrix}
\]

Then a low pass filter shall be used to filter the signal of the active power. After filtering the transient active power and the constant real power can be deduced. In the compensation, the goal is to compensate the transient real power and the reactive power. Only the constant real power is left. So, based on the transient active power and the total reactive power and it steps into the further calculation.

The matrix is listed for calculating the compensation current on the alpha plane and the beta plane.

\[
\begin{bmatrix}
    i_{comp}(t) \\
    i_{comp}(t)
\end{bmatrix} =
\begin{bmatrix}
    v_a(t) & v_b(t) & -p(t) \\
    -v_b(t) & v_a(t) & -q(t)
\end{bmatrix}
\]

The compensation current on alpha plane and beta plane can be deduced. Then the matrix shall be used that can convert the current into the normal three phase system.

\[
\begin{bmatrix}
    i_{comp}(t) \\
    i_{comp}(t)
\end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \sqrt{3}/2 & -0.5 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -0.5 & \sqrt{3}/2 \end{bmatrix}
\]

Since it is applying the instantaneous pq theory in single phase case, it can be considered that the compensation current in phase b and phase c is zero. So it is only neces-
necessary to consider the current in phase a.

\[i_{\text{comp}}(t) = \frac{2}{3} \cdot i_{\text{comp}}(t) = -\frac{2}{3} \cdot \left[ e_{\text{a}}(t)\cdot p_{\text{ac}}(t) + v_{\text{b}}\cdot q_{\text{ac}}(t)\right]\]

the compensation current is generated.[3]

III. SINGLE PHASE COMPENSATION SIMULATION

A. Build up the loading circuit

It shall be built for the single phase DC inductive loading circuit with AC source and a converter.

![Figure 1. The single phase loading circuit](image)

Measuring the V_source and I_source to be used in the future calculation.

B. The Multilevel Inverter

The 5-level multilevel inverter with Hysteresis technology shall be used that was built in the previous section as the provider of the compensation current. Notice should be paid that the reference current now is no longer the sinusoidal current. Now it is the calculated signal that generated by the compensation part. [4]

Besides, it is necessary to add a breaker at the output of the inverter. Moreover, the breaking function shall be applied to let the inverter to be connected with the circuit two seconds after the simulation starting. Then the output result can be observed and judged whether it meets the requirement.[5]

![Figure 2. The breaking signal](image)

C. The Compensation Calculation

In this part, it shall firstly calculate the average active power, transient active power, average reactive power and transient reactive power.

![Figure 3. The PQ calculation in PSCAD](image)

Notice should be paid that the delay in the circuit is to generate a 0.005 s delay for the voltage and current. Since the frequency of 50Hz is used, the 0.005s delay means that there is 90 degree phase shift on the \(a\beta\) coordinate. [6]

![Figure 4. The reactive compensation power calculation](image)

Then the dc and ac reactive power are combined together as the reactive power to be compensated.

![Figure 5. The compensation current calculation](image)

Then the calculation of the current will be injected into the circuit which can be deduced. Consequently, let the 5-level Hysteresis inverter to generate the compensation current. [7]

This part shall be used to calculate the power factor of the system.

![Figure 6. The power quality calculation](image)

This part shall be used to calculate the power factor of the system.

D. Simulation Result

By the calculation, the compensation current is deduced:
It is very obvious that a clear phenomenon of compensation occurs. Before the compensation, the source current lags the source voltage due to the inductive load that used, and harmonic component currents are very significant in the source current because of the rectifier. These harmonic currents will contaminate the source current and cause damage to the AC source. [8]

After the compensation current is injected into the current when the time is 2s, the source current becomes in phase with the source voltage and the harmonic currents are compensated and eliminated.

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