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

http://dx.doi.org/10.3991/ijoe.v11i7.4756

Xijuan Wang[1], Tao Zhou[1], Yang Zhao[2], Jingxiao Feng[3], Jialun Zhang[3] and Hongjun Zhang[3]
[1]Luoyang Normal University, Luoyang, Henan, China
[2]Jiangmen Polytechnic, Jiangmen, Guangdong,China
[3]Luoyang Mining Machinery Research Institute, Luoyang, Henan, China

***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 $\alpha\beta$ 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 $\alpha\beta$ 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 $\alpha$ plane and the delayed current and voltage in $\beta$ 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 0.005s, which is precisely one quarter of the total period. Thus the 90 degrees angle shift in $\alpha\beta$ 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.

$$\begin{bmatrix} p(t) \\ q(t) \end{bmatrix} = \begin{bmatrix} v_\alpha(t) & v_\beta(t) \\ -v_\beta(t) & v_\alpha(t) \end{bmatrix} \begin{bmatrix} i_\alpha(t) \\ i_\beta(t) \end{bmatrix}$$

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.

$$\begin{bmatrix} i_{comp\alpha}(t) \\ i_{comp\beta}(t) \end{bmatrix} = \begin{bmatrix} v_\alpha(t) & v_\beta(t) \\ -v_\beta(t) & v_\alpha(t) \end{bmatrix} \begin{bmatrix} -P_{ac}(t) \\ -q(t) \end{bmatrix}$$

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.

$$\begin{bmatrix} i_{compa}(t) \\ i_{compb}(t) \\ i_{compc}(t) \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -0.5 & \sqrt{3}/2 \\ -0.5 & -\sqrt{3}/2 \end{bmatrix}$$

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 necessary to consider the current in phase a.

$$i_{compa}(t) = \sqrt{\frac{2}{3}} \bullet i_{comp\alpha}(t) = -\sqrt{\frac{2}{3}}\left[v_{\alpha}(t)p_{ac}(t) + v_{\beta}q(t)\right]$$ Thus

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.

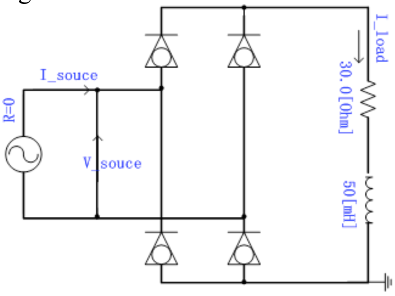


Figure 1. The single phase loading circuit

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]

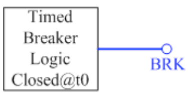


Figure 2. The breaking signal

### *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.

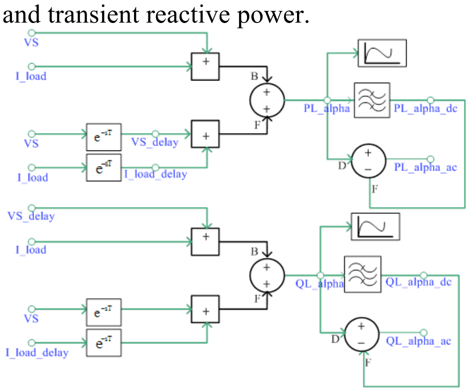


Figure 3. The PQ calculation in PSCAD

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 αβ coordinate. [6]

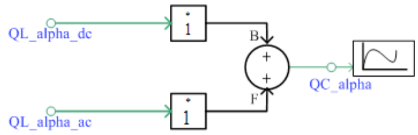


Figure 4. The reactive compensation power calculation

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

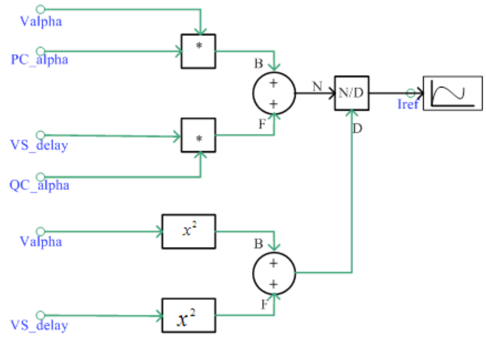


Figure5. The compensation current calculation

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.

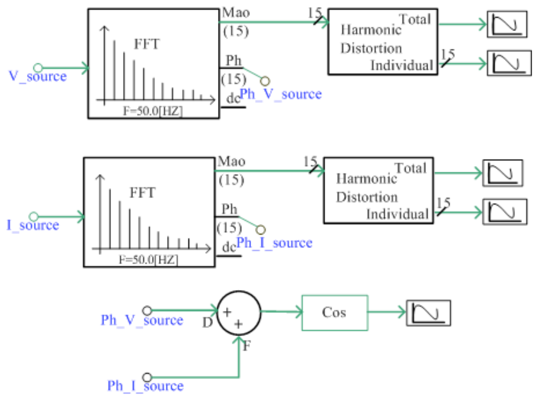


Figure6. The power quality calculation

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

### *D. Simulation Result*

By the calculation, the compensation current is deduced:

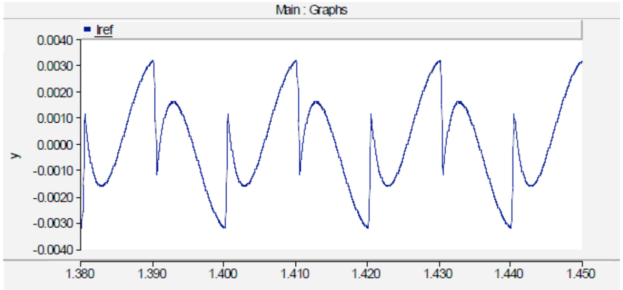


Figure7. The calculated reference current

The reference compensation current shall be used and then the result derived.

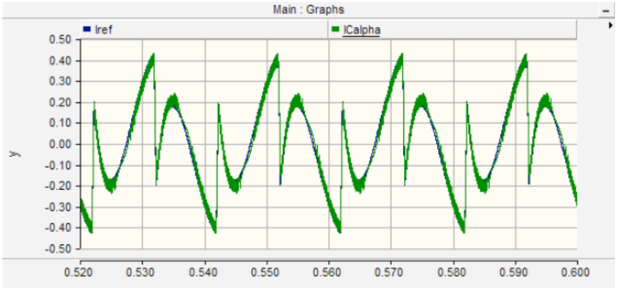


Figure8. The reference current and output current of the compensator

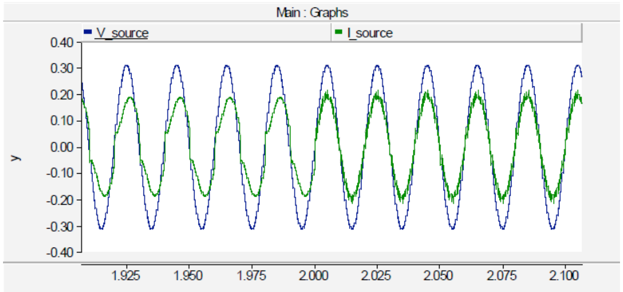


Figure9. The source voltage and current comparison before and after the compensation

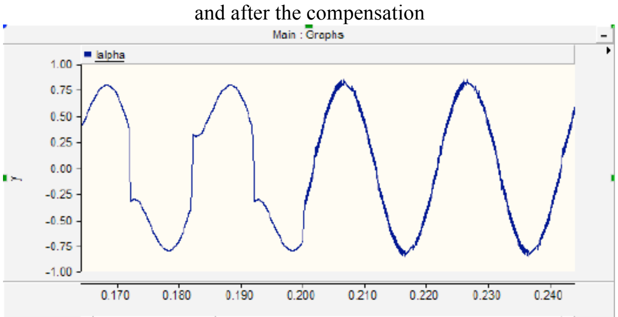


Figure10. The optimization of the source current

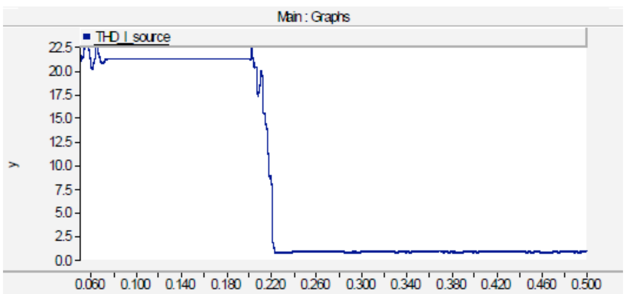


Figure11. The decrease of the current THD

It is very obvious that a clear phenomenon of compensation occurs. Before the compensation, a 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.

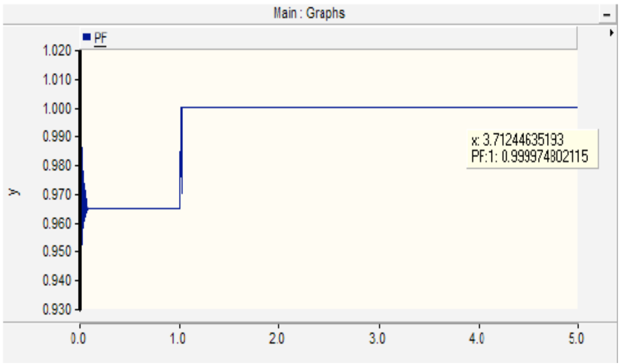


Figure12. The power factor

It is clear that after the simulation starting, the power factor is relatively low (about 96%), which is caused by the converter and the inductive load. After 2 seconds, the breaker is trigged. The compensator is connected into the system. Then the power factor is increased up to 99.99%. It is clear that the power factor is almost reached to 1. So, this simulation of active compensator is good.

## REFERENCES

[1] Akagi. H, Kanazawa Y., and A. Nabae, "Generalized Theory of the Instantaneous Reactive Power in Three-phase Circuits," *Proc. of IEEJ International Power Electronics*. Vol. 58, pp 1375-1386, May 1983.

[2] Xin Jing, Jing Zhang, and Yang Zhao, "An efficient complex event processing system having the ability of parallel processing and multi event pattern sharing," *Journal of Intelligent and Fuzzy Systems*, Vol. 28, pp. 885-896, February 2015.

[3] Haque,M. T.& Ise,T., *Power Conversion Conference*, Vol. 2. PCC Osaka, 2002, pp.761-765.

[4] Shuo Xiao, Yang Zhao, Yuan Cao, Haifeng Jiang, and Wenliang Zhu,"Computing method of thermal conductivity of heat dissipation vias in printed circuit board and its optimization,"*Circuit World*,vol. 41, pp. 14–19, February 2015. http://dx.doi.org/10.1108/CW-10-2014-0043

[5] Bo Baozhong,*Research on PWM Control Technique of Multilevel Inverters*. Xi'an ,Xi'an Jiaotong University, 2002.

[6] Yang Zhao, Chi Zhang, "A RBF network direct generalized predictive control based on tracking error adjustment,"*International Journal of Applied Mathematics and Statistics*, vol. 43, pp.126–133, November 2013.

[7] Yanqing Peng, Ji Zhang, "The Research of PWM Rectifier Unbalanced Power Supply and DSP Implementation" . *Journal of Convergence Information Technology*, vol. 6, pp.126-132, , July 2011. http://dx.doi.org/10.4156/jcit.vol6.issue7.16

[8] SBuso,S Fasolo,"Uninterruptale power supply multiloop control employing digital predictive voltage and current regulators,"*IEEE Trans. On Power Electronics*, vol.37, pp.1846-1854, May 2001.

## AUTHORS

**Xijuan Wang** is now with the School of Physical and Electrical Information, Luoyang Normal University, Luoyang, 471022, Henan, China (e-mail: fjxwxj@126.com).

**Tao Zhou wa**s Tongji university, Shanghai, China. He is now with the School of Physical and Electrical Information, Luoyang Normal University, Luoyang, 471022, Henan, China (e-mail: zhoutao041@163.com).

**Yang Zhao** is now with Department of Electronic and Information Technology, Jiangmen Polytechnic,Jiangmen 529090, Guangdong,China (e-mail: zhaoyang19781023@gmail.com).

**Jingxiao Feng** is now with Luoyang Mining Machinery Research Institute, Luoyang 471039, Henan, China(e-mail: fjxwxj@163.com).

**Jialun Zhang** is now with Luoyang Mining Machinery Research Institute, Luoyang 471039, Henan,China(e-mail:1043226991@qq.com).

**Hongjun Zhang** is now with Luoyang Mining Machinery Research Institute, Luoyang 471039, Henan, China(e-mail: 992083321@qq.com)

This study is supported by Science and Technology Research Projects in Henan Province of China (142102210474) and Key Education Department Science and Technology Research Project in Henan Province of China (14A413007).
Submitted, January, 10, 2015. Published as resubmitted by the authors on July, 16, 2015