The Burn—in Test of Three—Phase UPS by Energy Feedback Method

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Abstract—In the burn—in test of three—phase on—line uninterruptible power supply(UPS) system, R. L. C. is usually used as a load in conventional method. For saving energy and decreasing the test cost of UPS, the energy feedback method is proposed to apply the test of the on—line UPS. In this method, the utility system is used instead of a load. A voltage regulator is used in parallel operation to turn back the energy, which was dissipated in conventional method, to the utility system. The values of real power and reactive power in the output of UPS can be regulated in the proposed method to imitate various load. From the experimental results, the efficiency of saving energy is more than 85 percent at half—load nearby and will be higher while load increasing.

1. Introduction
To keep the high operating reliability of UPS is the highest priority. Besides all of circuit design[1], the burn—in test of the UPS is very important process for keeping a high reliability before the UPS is taken over to the users. The standard of characteristic test for safety have detailed description in the literatures[2,3]. In conventional method, the resistance load is directly connected in the on-line UPS’s burn-in test. It generally take 24 to 72 hours burn—in test with full or half load. This will cause a large energy loss and the test cost of UPS will increased.

Saving energy is the major purpose for the lack of energy. This paper presents an energy feedback method for testing a 20KVA 208 V three-phase on-line UPS. The principle of parallel operation of transmission is used[4—6], the load is replaced by the utility system. The power flow can be controlled by regulating the voltage magnitude and the phase angle and turned back to the utility system. The devices of the test system include an autotransformer, a transposing transformer, an inductor, and a source of 3 φ 4 w of 208 V. The output of the tested UPS is connected with the utility system through the regulator which regulate the phase angle and voltage magnitude. The utility system is used as a linear load, and the energy that will be wasted in conventional method is turned back to the utility system. Using the proposed method, the process of burn—in test can be performed and the dissipation of energy and cost can be decreased. The power factor from the utility system also can be improved. Finally, from the experimental results, in the burn—in test the energy is saved about 85 percent.
2. Theoretical Analysis

2.1 Conventional Method

In conventional method for burn-in test of UPS is generally connected R. L. C. load to the output of UPS directly. Fig. 1 shows the block diagram of conventional test method of UPS. There are two drawbacks: 1) the cost of test is high, 2) the energy of test is dissipated in the tested load. The wasted energy is expressed by

\[
W_{\text{out}} = |V_{\text{ups}}| |I_{\text{ups}}| \cos \delta \times T
\]

where

\[
\delta = \text{phase angle between } V_{\text{ups}} \text{ and } I_{\text{ups}}
\]

\[
T = \text{testing time}
\]

2.2 Proposed Method

The proposed method for burn-in test of UPS is shown in Fig. 2 [7]. In this basic block diagram, the block H is a regulator for power flow control. The output power of UPS, tested load, is turned back to the utility system. It's easy to know that the total dissipated energy is

\[
W_{\text{total}} = W_{\text{in}} - W'_{\text{out}}
\]

Where \( W_{\text{out}} \) is the energy which is turned back to the utility system. By this energy feedback method, it saves energy and decreases cost brightly lower than those of the conventional method.

The basic regulating circuit diagram of power flow between the output of UPS and utility system is shown in Fig. 3, where \( X_{\ell} \) is a variable inductor used as a reactive coil to limit and control the amplitude of current between UPS and utility system. Where, \( V_{\text{ups}} \) is the output voltage of UPS and \( V_{a'} \) is the regulated voltage of utility system. Assume that

\[
V_{\text{ups}} = |V_a| \angle 0^\circ
\]

\[
V_{a'} = |V_a'| \angle 0^\circ
\]

then

\[
I_a = \frac{|V_a| \angle 0^\circ - |V_{a'}| \angle -\alpha}{jX_{\ell}}
\]

The complex power \( S \) in per phase is

\[
S = P + jQ = V_{\text{ups}} \times I_a
\]

and the well-known output power from UPS to utility system is expressed by

\[
P = \frac{|V_a|}{X_{\ell}} \sin \alpha
\]

\[
Q = \frac{|V_a|}{X_{\ell}} (|V_a| - |V_{a'}| \cos \alpha)
\]

From (5) and (6), \( \alpha \) and \( |V_{a'}| \) are the major factor which control the values of \( P \) and \( Q \).

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**Fig. 1** The conventional test method of UPS.

![Fig. 1](image1.png)

**Fig. 2** The block diagram of the proposed method.

![Fig. 2](image2.png)
Fig. 3 The parallel operation of UPS.

3. The Analysis of the Tested System

The whole test system for energy feedback system is shown in Fig. 4. The output of UPS and regulating transformer are connected together through reactor coils $X_L$. The 3φ regulating transformer was organized with two three-phase transformers: one is an autotransformer, the other is a transposing transformer. The former is used to adjust the magnitude of transposed voltage which derived from other phases; the latter is used to add a little transposed voltage to each phase of utility system in clockwise direction. Because the utility system voltage is connected to the input ports (A, B, C) of regulating transformer and added a transposed voltage, it forms a regulated voltage in the output ports ($a'$, $b'$, $c'$) of regulating transformer.

From the viewpoint of the connection method, there are two kinds of configuration of three-phase regulating transformer: (1) Y-Y connection and (2) Y-Δ connection. The configuration and phasor diagram are shown in Fig. 4-7.

Fig. 4 The regulating transformer with Y-Y connection.

Fig. 5 The regulator phasor diagram of Y-Y connection.
Where the output voltage of regulating transformer can be expressed as

\[ V_{a'} = V_A + V_{V'} \]
\[ V_{b'} = V_B + V_{W'} \]
\[ V_{c'} = V_C + V_{U'} \]

Now, let per phase voltage of UPS as follows:

\[ V_{ups} = |V_{an}| \angle 0^\circ \]  \hspace{1cm} (7)
\[ V_{an} = K |V_{an}| \angle \alpha, \]  \hspace{1cm} (8)

where \( K \) is the voltage ratio and \( \alpha \) is the phase angle between \( V_{ups} \) and \( V_{an} \).

Then, from (5) and (6) the output power can be rewritten as

\[ P = \frac{K|V_{an}|^2}{X_L} \sin \alpha \]  \hspace{1cm} (9)
\[ Q = \frac{|V_{an}|^2}{X_L} (1 - K \cos \alpha). \]  \hspace{1cm} (10)
4. The Experiment Results

A three-phase on-line bidirectional converter with triport transformer UPS (20KVA 208V 60Hz) is used to implement the burn-in test as shown in Fig.9. The tested UPS is connected to the utility system through the regulating transformer and reactor coils as shown in Fig.8. Fig.10 shows the waveform of tested result in normal operation at half load (26 amperes nearby), and the reactive coil $X_L = 0.5 \Omega$. For example, $W_{out} = 7.72$ (KW), $W_{out}' = 6.67$ (KW), $W_{in} = 9.32$ (KW), $W_{total} = 2.56$ (KW), and $\eta = 87.6\%$, where the efficiency $\eta$ is defined as

$$\eta = \frac{W_{out}'}{W_{out}}$$

The power of utility system provide is smaller than that of the UPS output. It means that when UPS operates in the burn-in test, it only takes little power which supplied from utility system, because most of the output energy are turned back to utility system.

Fig.9 The system block diagram of tested UPS.

Fig.10 (a) the voltage and current waveform of utility system, (b) the output voltage and current waveform of UPS.
5. Conclusions

For saving energy and decreasing the test cost, the method is proposed to improve the shorting in the conventional method. The regulator is adopted to adjust the voltage of utility system and control the output power (tested load). The power flow is controlled by means of the principle of parallel transmission. The energy that will be dissipated is turned back to the utility system in the burn-in test. In other words, by proposed method, there are only little energy is needed to supply the test energy. From the experimental results, the efficiency of saving energy is more than 85 percent, and the regulating devices is easy to construct.

References: