

An Inverter Testing System For CRAC

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Abstract—This paper aimed at functional requirements with CRAC (computer room air conditioning) inverter test system, and realized the test system hardware platform design, while completing the software functional design and programming algorithm. For example in Self-Made 10Kw inverter and Schneider ATV31H 2.2Kw inverter, we research on its output three-phase voltage, three-phase current for balance analysis and harmonic calculations. Practical application shows that the system can achieve efficient automated test process, and the measurement results with manual measurement are the same.

Keywords—Air Conditioner Inverter; variable frequency drives (VFD); Harmonic Analysis; Balance Analysis.

I. INTRODUCTION

With the rapid development of communication technology, communications equipment and ancillary equipment energy consumption increases every year. Communication operators and manufacturers pay more and more attention on this issue. It is effectively guarantee the normal operation of communications equipment that extensive use of air-conditioning equipment. Meanwhile it brought great energy issues. Data show that: 73% of the energy consumption of China Mobile is base station energy consume, And the energy consumption rate of 15% for the communications room. The base station with a room which has 46% of energy is generated by the air-conditioning, and in the communications room, the air conditioning power consumption accounted for 34% [1]. The computer room precision air-conditioning power consumption accounts for about 50% of total consumption, the data room is as high as 60% [2].

Frequency conversion is currently one of the most suitable energy-saving technologies for air-conditioning [3, 4]. This technology aimed to achieve energy-saving by adjustment the conditioning compressor speed, by adjustment of the cooling water pump speed, and by adjustment the speed of the ventilation equipment [5-7]. Therefore promotion CRAC frequency conversion energy-saving and performance assessment has great significance for the efficiently operation of the computer room. However there exists no perfect performance test system for inverter. The test systems in article [8, 9] do not analyze the inverter output voltage, output current, harmonic and balancing.

The research goal in this paper is the performance of inverter for CRAC and the corresponding testing system; it will

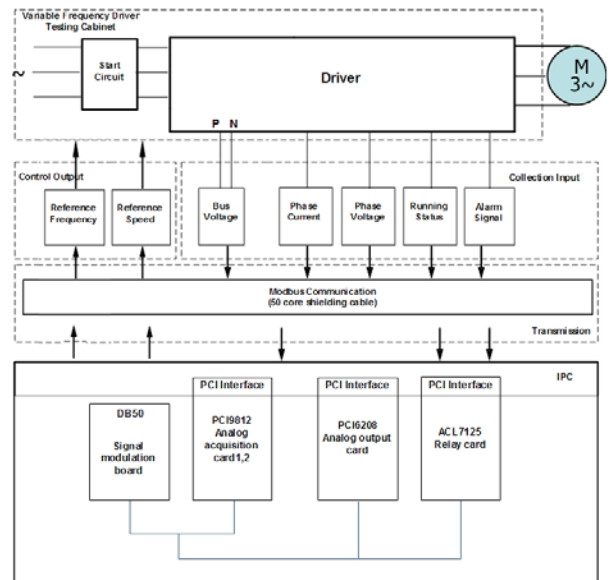


Fig. 1. Structure of System Hardware

be introduced in the second part. The inverter in CRAC than conventional inverter should have a higher frequency stability and harmonic suppression performance, so it is necessary to evaluate the inverter' performance: balancing test method and harmonic test algorithm for inverter testing system will be discussed in Part III. Two Type of motor participate in the experiment. One is the AC asynchronous machine which is used often in traditional CRAC compressor, and the other is AC permanent magnet synchronous motor which is use for next generation CRAC compressor. The experimental results analysis carried out in the fourth part.

II. HARDWARE REALIZATION

The CARC inverter test system hardware structure diagram is showing in Fig.1. It is composed of portable computer and inverter testing cabinet. In the side of portable computer, the portable computer is plugged with PCI19812 acquisition card, ACL7125 relay board, PCI6208 analog output board and Self-Made signal modulation board. Portable computer are used to collecting and analyzing the test signal, meanwhile controlling the inverter.

In the side of the testing cabinet, the signal collection board and the inverter to be measured are installed in inverter testing cabinet. LEM LV-25-P voltage sensor, LEM LA-100-P current

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sensor and sampling resistance are set onto the signal collection card. The measurement range of voltage sensor is $0 \sim \pm 14mA(10 \sim 500V)$, and range of the current sensor is $0 \sim \pm 150A$. Then the collection signals which are amplified and isolated will be transmitted to the Self-Made signal modulation board in computer side. The output of the inverter connects on the motor through cables in the cabinet backplane.

The 50 core shielding cable connected on both two sides of computer and the cabinet. All of the collection signals and the control signals joint to Self-Made 50 core duplex cable in backplane of inverter testing cabinet.

The testing system provides eight A/D inputs which are used by three-phase voltage, three-phase current, DC-bus voltage and speed acquisition. The A/D sampling precision is 12 bits, sampling velocity is 20MHz. The analog output card also provides four output channels which are 16 bits analog signals and can output continuous waveform to be used by velocity setting. Meanwhile the analog output card provides four digital input channels and four digital output channels. The digital inputs can be used for servo and overheating alarm signals. The relay card has 12 relay outputs used for enable signal. The Physical Self-Made inverter as well as test systems is shown in Fig.2.



Fig. 2. Physical Self-Made inverter and Test Systems

III. TESTING SYSTEM SOFTWARE DESIGN AND DATA ANALYSIS ALGORITHM REALIZATION

A. System Software design

Air conditioner inverter testing system has the following feather:

- This system can not only automatically measuring the frequency, rotate speed, voltage, current of the inverter output, but also analyzing voltage, current harmonic and balance.
- In the process of testing, the measured data can realize real time numerical and graphic display.
- When the measurement is finished, the analysis reports and characteristic curves of experiments are memorized and output.
- It also supports the inquiry of historical data.
- Performance testing, including sinusoidal tracking test, step response test and etc.

B. Balance Analysis

The degree of balance of three-phase voltage is as follows.

$$\varepsilon = \frac{\sqrt{1 - \sqrt{3 - 6 \times L}}}{\sqrt{1 + \sqrt{3 - 6 \times L}}} \times 100\% \quad (1)$$

Where $L = (a^4 + b^4 + c^4) / (a^2 + b^2 + c^2)^2$. Here a, b, c is RMS of three-phase voltage.

The balance of three-phase current is similar to the calculation of voltage.

From Fig.3, we can see the inverter has good low speed performance in 10 Hz. And that three-phase current and voltage fastly step into balance state after approximately the 20th sampling point (sampling rates is 1 MHz).

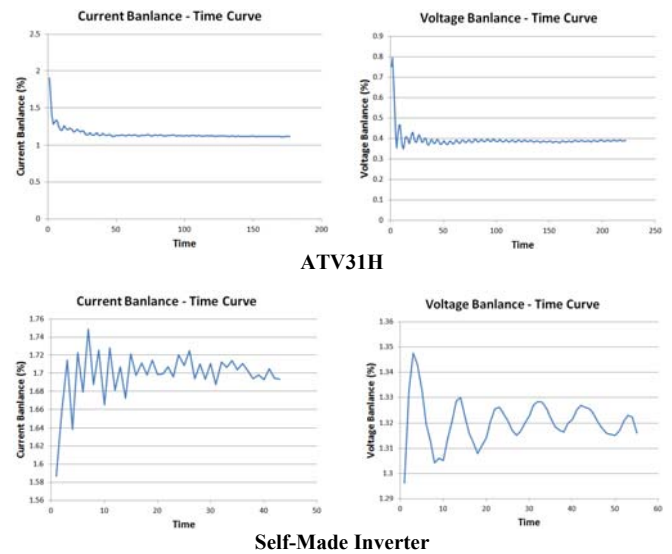


Fig. 3. Balance Analysis with ATV31H and Self-Made Inverter at 10Hz

C. Harmonic Analysis

1) Calculation of harmonic

The harmonic calculation is based on the analysis of current and voltage data of each period. Therefore, it needs to detect whether the collections of collector are in the same period firstly. We use zero-crossing detecting method here. The numerical value of the n th point multiplied by that of the $(n+1)$ th point. If the product is equal or lesser than zero, the

(n+1)th point is zero-crossing point, marked by C(n). If this point is set the starting point for the next period, the cutoff of next period is the second zero-crossing point after n+1 point, marked by C(n+1). The points between C(n) and C(n+1) constitute a cycle.

After the cycle is confirmed, we calculate the voltage, current and harmonic as below^[10].

$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos(n\omega t + \varphi_n) \quad (2)$$

A_0 is DC component, $A_n \cos(n\omega t + \varphi_n)$ is nth harmonic component.

The equation above can be deformed as follows.

$$f(t) = a_0 + \sum_{n=1}^{\infty} (a_n \cos n\omega t + b_n \sin n\omega t) \quad (3)$$

where

$$\begin{aligned} A_0 &= a_0 \\ a_n &= A_n \cos \varphi_n \\ b_n &= -A_n \sin \varphi_n \\ \varphi_n &= -\arctan \frac{b_n}{a_n} \end{aligned}$$

Here

$$\begin{aligned} a_0 &= \frac{1}{2\pi} \int_{-\pi}^{\pi} f(t) dt \\ a_n &= \frac{1}{2\pi} \int_{-\pi}^{\pi} f(t) \cos n\omega t dt \\ b_n &= \frac{1}{2\pi} \int_{-\pi}^{\pi} f(t) \sin n\omega t dt \end{aligned}$$

From formula (3) we can calculate the measured current and the nth harmonic component of voltage.

2) Calculation of harmonic ratio and harmonic distortion

We use the root mean square value (RMS) of voltage and current to compute the harmonic ratio and harmonic distortion. By the following formula, the voltage harmonic can be gained.

The h-th harmonic voltage ratio is HRU_h .

$$HRU_h = \frac{U_h}{U_1} \times 100\% \quad (4)$$

Here U_h hth harmonic voltage (root mean square value), U_1 is fundamental voltage (RMS).

Harmonic voltage ratio U_H is

$$U_H = \sqrt{\sum_{h=2}^{\infty} (U_h)^2} \quad (5)$$

Total voltage harmonic distortion THD_u is

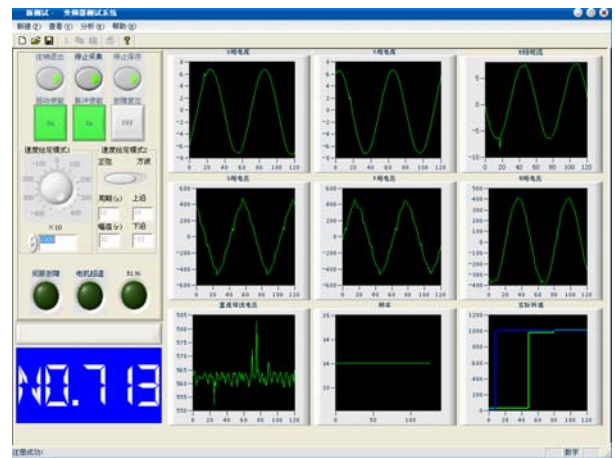
$$THD_u = \frac{U_H}{U_1} \times 100\% \quad (6)$$

The calculation of current harmonic is as same as that of the voltage.

IV. RESULT ANALYSIS

In the hardware platform of above testing system, we use hybrid programming technique of VC++6.0 and NI control to implement the testing system software. The inverter testing system software human-machine interface and the example style of report form are shown in Fig.4.

On condition that the Schneider ATV31H 2.2Kw inverter control 2.2Kw asynchronous AC motor-SIMO YJ TG132S-8A with no load, the full range calculations of voltage harmonic, current harmonic and balance are fulfilled. The part of testing results is shown in Fig.3, TABLE I and TABLE II. The



Inverter Performance Test System			
Analysis Report			
Data No.:	Experiment Time :		
Operator No.:	Operator :		
Inverter Parameter			
Motor Parameter			
Testing results analysis			
Harmonic component analysis			
Harmonic Content			
	Current	Voltage	Common DC bus Voltage
nth harmonic ratio (HR)	<0.00%	<0.00%	<0.00%
	Current	Voltage	Common DC bus Voltage
3th	<0.00%	<0.00%	<0.00%
5th	<0.00%	<0.00%	<0.00%
7th	<0.00%	<0.00%	<0.00%
Total distortion ratio of voltage harmonic (THD)			
	Current	Voltage	Common DC bus Voltage
	<0.00%	<0.00%	<0.00%
Balance Analysis			
Voltage Unbalance			<0.00%
Current Unbalance			<0.00%
SIGNAL CHART---			

Fig. 4. We completed the testing system software too.

Testing system software interface and the style of report forms are showing here.

parallelism test results on Self-Made 10Kw inverter with 9.5Kw PMSM-SIEMENS 1FT6-084-8SH71-3AE3 (no load) are contrasting with ATV31H in the corresponding position.

In Fig.3, when the system runs at 10 Hz, it shows that the balance of voltage and current at start-up stage are worse than the balance at stable operation. With the increasing of time, the system balance gradually tends to a constant (which is consistent with the manual measurement). A large number of tests show that within the range of speed regulation, the balance calculations on different frequencies have the analogous results with Fig.3. Self-Made inverter has the similar performance in output balancing with ATV31H.

From TABLE I and TABLE II, it shows that the 3th to 7th

harmonic of this inverter are more worthy of attention than the higher times harmonic within the range of speed regulation. The total harmonic distortion ratio of current is within 2% and that value of the voltage is within 7% for ATV31H, which is also consistent with the actual situation. As can be seen from the comparison in TABLE I and II, Self-Made inverter have better harmonic suppression performance. The total harmonic distortion ratio of current is nearly 1%, meanwhile the total harmonic distortion ratio of voltage is within 3%.

V. CONCLUSIONS

The system hardware and software implemented the collection and storage of real time data of CRAC inverter

TABLE I. HARMONICS OF A-PHASE VOLTAGE ON DIFFERENT FREQUENCIES

	Frequency	fundamental content	3th harmonic content	3th harmonic ratio (%)	5th harmonic content	5th harmonic ratio (%)	7th harmonic content	7th harmonic ratio (%)	voltage harmonic content	Total distortion ratio of voltage harmonic (%)
SCHNEIDER RATV31H INVERTER	2Hz	28.1000	0.6900	2.4555	0.2940	1.0463	0.2050	0.7295	0.7775	2.7670
	10Hz	125.0000	0.3350	0.2680	0.5330	0.4264	1.0400	0.8320	1.2157	0.9726
	20Hz	240.0000	2.3900	0.9958	0.8600	0.3583	0.1630	0.0679	2.5452	1.0605
	30Hz	324.0000	20.9000	6.4506	0.5920	0.1827	0.6300	0.1944	20.9179	6.4561
	40Hz	422.0000	7.4100	1.7559	0.7900	0.1872	0.2663	0.0631	7.4567	1.7670
	50Hz	480.0000	2.1500	0.4479	0.7060	0.1471	1.4900	0.3104	2.7094	0.5645
SELF-MADE 10KW INVERTER	2Hz	25.0000	0.5021	2.0084	0.4541	1.8164	0.1223	0.4892	0.6879	2.7517
	10Hz	110.0000	0.6170	0.5609	0.3015	0.2740	0.1201	0.1091	0.6971	0.6337
	20Hz	210.0000	2.0314	0.9673	0.5251	0.2500	0.3125	0.1488	2.1213	1.0101
	30Hz	302.0000	5.2146	1.7266	1.2568	0.4161	0.2510	0.0831	5.3697	1.7780
	40Hz	390.0000	4.2145	1.0806	0.6849	0.1756	0.0457	0.0117	4.2700	1.0940
	50Hz	480.0000	2.1549	0.4489	1.0256	0.2136	0.6987	0.1455	2.4866	0.5180

TABLE II. HARMONICS OF A-PHASE CURRENT ON DIFFERENT FREQUENCIES

	Frequency	fundamental content	3th harmonic content	3th harmonic ratio (%)	5th harmonic content	5th harmonic ratio (%)	7th harmonic content	7th harmonic ratio (%)	Current harmonic content	Total distortion ratio of current harmonic (%)
SCHNEIDER RATV31H INVERTER	2Hz	4.3200	0.0744	1.7222	0.0416	0.9630	0.0092	0.2125	0.0857	1.9846
	10Hz	6.6800	0.0269	0.4027	0.0581	0.8698	0.0526	0.7874	0.0829	1.2404
	20Hz	4.6500	0.0348	0.7484	0.0083	0.1785	0.0119	0.2559	0.0377	0.8108
	30Hz	6.6000	0.0281	0.4258	0.0049	0.0736	0.0042	0.0638	0.0288	0.4368
	40Hz	6.5700	0.0243	0.3699	0.0120	0.1826	0.0030	0.0461	0.0273	0.4151
	50Hz	5.5400	0.0188	0.3394	0.0257	0.4639	0.0154	0.2780	0.0354	0.6385
SELF-MADE 10KW INVERTER	2Hz	5.0200	0.0424	0.8446	0.0254	0.5059	0.0145	0.2888	0.0515	1.0260
	10Hz	5.0000	0.0315	0.63	0.0115	0.23	0.0014	0.028	0.0335	0.6712
	20Hz	5.1100	0.0359	0.7025	0.0154	0.3013	0.0022	0.0430	0.0391	0.7656
	30Hz	4.9300	0.0321	0.6511	0.0164	0.3326	0.0047	0.0953	0.0363	0.7373
	40Hz	4.8800	0.0219	0.4487	0.0047	0.0963	0.0142	0.2909	0.0265	0.5434
	50Hz	5.0000	0.0203	0.406	0.0021	0.042	0.0002	0.004	0.0204	0.4081

testing system. The data are well verified by Fluke Power Quality Analyzer. Meantime the curves of three-phase voltage and current, DC bus voltage, frequency, rotate speed are drawn. We also output report and analyze the balances of three-phase voltage and current, harmonic content. Additionally, we integrated some customised function such as: servo ready, error state report(motor overheat, servo error etc), and some typical running control(sine evaluation, sudden stop, etc). The actual use of that system is running well automatically.

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