Research of Harmonic Index and Testing Method Based on Virtual Instrument

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Abstract. In view of the practical problems such as the imperfect harmonic testing and evaluation methods of the variable frequency speed regulation system and the high operating cost, a harmonic evaluation index system including 9 indexes is established, and the calculation method of each index is clarified. At the same time, the harmonic testing and analysis method of the variable frequency speed regulation system based on virtual instruments is proposed. The Labview software platform is combined with an external data acquisition module to replace the traditional testing instruments for harmonic testing and signal acquisition, processing and analysis. On the basis of theoretical research, an experimental platform was built to conduct verification experiments, and then the application experiments of 2 working conditions were carried out. The results show that the test method was correct and feasible. Based on the experimental results, further analysis of the impact of harmonics on the performance of the variable frequency speed control system, and the corresponding law of influence will be obtained, which will provide guidance for the subsequent development of harmonic prevention and other related work.

1 Introduction

Frequency conversion speed regulation technology is a mature power-saving technology. Its related technologies and products have been widely used in key energy-consuming fields such as electricity, machinery, petrochemicals, etc., and have achieved good results in energy saving, production automation adjustment, etc. However, according to the structural principle of the frequency converter and related theoretical analysis of frequency conversion speed regulation technology, it can be seen that the frequency converter will generate harmonics during the work process. Meanwhile, practical engineering applications also show that harmonics will not only reduce the power transmission quality and utilization efficiency of the system, but also interfere with communication and electronic equipment outside the power system, seriously affecting the normal operation of the system\[1\]. Therefore, the corresponding harmonic testing and evaluation for variable frequency control system has been included in the normal work schedule of various industries and related companies.

At present, the domestic harmonic testing and evaluation of frequency control system is mainly based on GB/T 14549, SY/T 6834-2017\[2,3\] and other standard. However, with the continuous development and promotion of frequency conversion technology, the problems in practical application indicate that the harmonic testing, calculation and evaluation
methods in the current standard are not fully applicable. Therefore, it is necessary to improve and perfect the existing harmonic evaluation indexes and corresponding analysis methods according to the actual working conditions and other requirements of the oil-gas field site. On this basis, it is necessary to further consider upgrading the existing harmonic testing instruments to effectively solve the problems that commonly exist in the current application on-site, such as high harmonic testing cost, complicated operation, low efficiency, and inaccurate test analysis results.

2 Analysis of inverter harmonics index

2.1 Harmonic evaluation index status

At present, the testing and evaluation of harmonics at home and abroad are mainly according to the corresponding domestic or international standards. Among them, the international aspect is mainly refer to the regulations of IEC 61000, IEEE 519[4,5] and other related standards in Europe and Norway, Domestically mainly based on GB/T 14549, GB/T 17626 and other standards. In addition, petroleum enterprises are mainly according to SY/T 6834. In the standard, the inverter, motor and its drag load is regarded as a whole system, and 7 energy-saving evaluation indexes with their calculation methods are also clarified. There are 4 indicators related to the inverter and harmonics, which consist of harmonic voltage limit, harmonic current allowable value, inverter input side power factor, inverter efficiency.

Practical application shows that the harmonic testing, calculation and evaluation methods given in the current standards are not fully applicable in view of the actual operating conditions and working conditions on site. The main reason is: SY/T 6834-2017 is mainly suitable for harmonics on the input side of the inverter. However, in essence, the harmonics generated by the inverter not only affect the input side, but also the output side, which contains actuators connected to motors, loads, etc. Therefore, in order to fully understand the impact of harmonics on the variable frequency drive system, it is necessary to clarify the harmonic test and analysis method on the input side of the inverter, and research on the output side harmonic testing and analysis methods meanwhile based on the comprehensive consideration of the output side.

2.2 Index system for inverter harmonics evaluation

Based on the above analysis of the current frequency converter harmonic testing and evaluation status, a harmonic evaluation index system was established with the comprehensive consideration of factors such as the requirements of field test conditions in practical engineering applications. The indicator system includes a total of 9 indicators in 2 categories, among them, 3 items on the input side of the inverter and 6 items on the output side. The definition of each index is shown in Table 1.

| Category       | Indicators                  | Symbol | SI | Index definition                                                                 | Remarks       |
|----------------|-----------------------------|--------|----|----------------------------------------------------------------------------------|---------------|
| Inverter input- side | Harmonic voltage total distortion rate | $V_{\text{THDI}}$ | %  | The ratio of the RMS value of the 2nd to 40th harmonic content to the RMS value of the fundamental wave | RMS voltage   |
| Harmonic current total distortion rate | $I_{\text{THDI}}$ | %  | The ratio of the RMS value of the 2nd to 40th harmonic content to the RMS value of the fundamental wave | RMS current   |
| Three-phase voltage unbalance | $V_{\text{unhl}}$ | %  | | | |
It should be noted that the various indicators in the system can reflect the influence of harmonics on the variable frequency control system from different angles and levels, which are not completely independent, but complement each other.

3 Harmonic testing method based on virtual instrument

3.1 Harmonic test instrument application status

Harmonic testing belongs to the category of power quality testing. Commonly used electrical energy testing instruments are HIOKI 3169, Kyoritsu 6310, power quality testing instruments mainly include FLUKE F430, HIOKI 3196, power analysis instruments mainly include HIOKI 3390, Fluke Norma 4000/5000, etc.\[6\].

In the current engineering application, HIOKI3390 and Fluke Norma5000 are mainly used for the on-site harmonic and power quality testing work of the variable frequency control system. The application results show that both instruments can meet the testing and analysis requirements. Norma5000 has higher accuracy and better performance, but the cost is relatively higher. In addition, the requirements for on-site test conditions are more stringent, and the operation is complicated, which is not convenient for on-site testers.

3.2 Virtual instrument for harmonic testing based on Labview

A complete set of harmonic testing virtual instrument mainly includes 2 parts: Labview software program and external data acquisition card. The signal processing and harmonic analysis module and related algorithms of traditional harmonic testing instruments(such as Norma 5000) are implemented by Labview software program, and the external data acquisition card can realize the collection and transmission of the electrical signal data of the test front end, therefore, a set of complete harmonic testing virtual instrument is constructed to replace traditional testing instruments.

The comparison of harmonic testing and analysis results between traditional instruments and virtual instrument proposed in this paper is shown in Table 2.

| Category       | Test instrument | Testing parameters | Analysis of harmonic index | Accuracy of results | Operational complexity | Testing cost |
|----------------|-----------------|--------------------|---------------------------|---------------------|------------------------|-------------|
| Traditional method | HIOKI 3169, 3390 | Voltage Current | unable to analyze | low                | low                    | low         |
| Traditional method | Norma5000       |                    | 8 indicators on the input/output side | high               | high                   | high        |
| This paper method  | Virtual instrument | Test instrument | 8 indicators on the input/output side | high               | low                    | low         |

Table 2. Comparison of harmonic testing instruments.
On this basis, a set of harmonic testing and analysis simulation system for variable frequency control system based on virtual instrument is established, which can realize the collection of test data, harmonic signal processing and analysis of harmonic indicators by nesting the harmonic evaluation indicators and calculation methods proposed in this paper into the corresponding harmonic testing and analysis module of Labview.

3.3 Testing method

For a specific type of variable frequency control system, the corresponding harmonic testing and evaluation can be carried out as follows:

— Measuring point arrangement: determine the test parameters according to the actual load type, and arrange the measuring points for each parameter according to Figure 1;
— Basic parameter test: Under the conditions of stable system operation, all parameters are tested simultaneously;
— Virtual instrument data acquisition and processing: Through the external data acquisition card, complete the communication and transmission of the front-end test data signal. On the basis of ensuring the real-time acquisition and transmission of all signals, using the built-in signal processing and analysis program module developed by Labview in virtual instrument to extract the harmonic components;
— Calculation and evaluation of harmonic index: Basing on the extraction results of harmonic components, applying the harmonic index and Labview program module proposed in this paper, the corresponding index results can be obtained, which provides a data basis for a series of subsequent analysis such as the relevant impact of harmonics.

![Figure 1](image1.png)

**Figure 1.** The arrangement of the measuring points for variable frequency speed control system.

4 Application experiment

On the basis of the above theoretical research, an experimental platform of variable-frequency speed-regulating and dragging system based on virtual instruments was built, and the motor was used as the simulated load, correspondingly configure PWM type inverter commonly used in oil-gas fields. The physical picture is shown in Figure 2.

![Figure 2](image2.png)

**Figure 2.** Experiment platform of variable frequency speed control system based on virtual instrument.

The relevant basic parameter settings of the experiment as follows:
— Inverter: SB70, 37kW
— Motor: Three-phase asynchronous motor, Y-2809-8, 37kW, Δ, 740r/min
Simulated load: Siemens DC motor
Virtual instrument: PC + Data acquisition card (NI-9215)
Condition settings: conditions 1: 50Hz, 300N-m; conditions 2: 40Hz, 250N-m

4.1 Feasibility verification

Firstly, the feasibility verification experiment was carried out. The comparison of electrical parameter test results between the virtual instrument test method and Norma5000 is shown in Table 3.

| No. | Testing parameters | SI | Virtual instrument test results | Norma5000 test results | Average error |
|-----|--------------------|----|---------------------------------|------------------------|--------------|
|     |                    |    | conditions 1 | conditions 2 | conditions 1 | conditions 2 |                    |
| 1   | UV                 |    | 224.69       | 224.74       | 225.14       | 224.97       | -0.68             |
| 2   | I                  |    | 50.63        | 36.41        | 50.09        | 36.81        | 1.14              |
| 3   | P                  |    | 26.31        | 18.06        | 26.11        | 17.85        | 0.41              |
| 4   | λ                  |    | 0.7709       | 0.7358       | 0.7719       | 0.7388       | -0.004            |

The comparison results in the table shows that the test result of the virtual instrument proposed in this paper is basically consistent with Norma5000, and the average absolute error is 0.51, the overall error is small. On this basis, the electrical signal waveforms and harmonic component extraction results on the input and output sides of the inverter are further analyzed, which is shown in Figure 3.

From the analysis of the above figure, we can see that display range of the main harmonic order is from 2 to 40 times, which all distributed nearby the power frequency and its multiple etc. The results verify the effectiveness and accuracy of the harmonic component extraction.

![Figure 3 Electrical signal waveform and harmonic component extraction of the inverter (input/output).](image)

On the basis of ensuring real-time and effective signal acquisition, data processing and analysis of test signals such as electrical parameters, application experiments are carried out. According to the experimental results, further analysis of the harmonics influence on
the performance for variable frequency control system and other related equipment can be carried out.

4.2 Test and calculation of harmonic index

On the basis of verifying the feasibility of the test method proposed in this paper, the harmonic index calculation results under 2 different working conditions are obtained through the corresponding index analysis and calculation module of Labview, which nested in the virtual instrument. The calculation results of 8 harmonic evaluation indexes on the input and output sides of the inverter obtained from the experiment are shown in Table 4.

Table 4. Results of harmonic index for inverter input/output.

| No. | Frequency Hz | Load N·m | Input side | Output side |
|-----|--------------|----------|------------|-------------|
|     |              |          | $V_{THDI}$ % | $I_{THDI}$ % | $V_{unbI}$ % | $V_{THDII}$ % | $I_{THDII}$ % | $V_{unbO}$ % | HVF | HCF   |
| 1   | 50           | 300      | 3.91       | 77.74       | 0.17        | 0.69          | 1.25          | 0.20        | 0.0023 | 0.0087 |
| 2   | 40           | 250      | 3.31       | 87.03       | 0.28        | 1.84          | 1.52          | 3.28        | 0.0016  | 0.0085 |

Using the harmonic index and the corresponding virtual instrument test method proposed in this paper, the results of the 8 harmonic indexes on the input and output sides of the inverter can be calculated. On the basis of theoretical research and preliminary experiments results, a large number of related experiments can be carried out. Through the summary analysis of experimental data, the trend of the harmonics influences on the performances of frequency control system and other related equipments such as inverter and motor will be obtained, which can put forward effective measures and suggestions for the prevention and control of system harmonic pollution.

5 Conclusion

Through the analysis of the current harmonic testing and evaluation situation, a set of evaluation index system that can reasonably characterize the effect of harmonic influence is established, and a method of harmonic testing and analysis based on virtual instruments is proposed. The research results can be used as the guidelines for the relevant industry to carry out the harmonic testing and evaluation more standardized and efficiently. In addition, the effective promotion of the virtual instruments and test methods can reduce amount of manpower, material resources and cost investment in the existing test work, which also can provide theoretical guidance for subsequent harmonic prevention and system improvement, in order to effectively promote the energy-saving and efficient operation of the frequency control system, besides the green sustainable development for enterprise.

References

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