2012 International Conference on Future Electrical Power and Energy Systems

Design of Electronic Power Network Frequency Measurement System Based on LabVIEW Virtual Panel *

Wen Xinling, Guo Rongxing

Department of Electronic and Communication Engineering
Zhengzhou Institute of Aeronautical Industry Management
Zhengzhou, Henan 450015, China
wenxinling@zzia.edu.cn

Abstract

Frequency is a standard of electronic power quality, and is important parameter of electronic power system running state. System’s frequency reflects active power supply and demand balance’s basic state of electronic power system. The frequency fluctuation of an electronic power system is mainly affected by 10s~3min pulse sub-component load or continuous sub-component in very slowly changing. So, adopting frequency software tracking method is very necessary. Because virtual instrument technology can largely reduce hardware cost in completing frequency tracking, and add instrument flexibility, This system uses virtual instrument LabVIEW to design a kind of frequency tracking measurement frame diagram procedure, and through system simulation, we prove this method of calculating frequency’s accuracy by using virtual instrument technology.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of [name organizer]

Keywords-frequency measurement; virtual instrument; electronic power quality; system simulation; LabVIEW; electronic power system

I. Introduction

Large-capacity load or generator switching, and imperfect control equipment all can reduce frequency offset. These can affect the stability of power system operation and user equipment normal work. When there is imbalance of power generation and user, and when electric power is more than generator load capacity ability, it will cause electronic network collapse, and seriously threat to the safe operation. When frequency is lower, the generator and the motors’ speed is down, the generator terminal voltage and motor output will decline. This will affect the quality of consumer products and production. And it will lead in increased rejection rate for industrial users of raw materials and energy consumption also will increase. As well as may even lead to power generation equipment and motor burning or other equipment damage. Therefore, there are strict requirements on the frequency of automation equipment malfunction often appear error operation. Such as electric clock error, electrical measuring instruments increasing error, safety devices and automatically

* This work is partially supported by Henan Nature Science Grant #2009A510014
relay malfunction, etc. High frequency running is a kind of abnormal working conditions when power output is higher than the load consumption of a nominal frequency. It is produced because that power unit for various reasons rejects a large number of sudden loads. When the electronic power network is in high frequency, the user and the power system will cause significant hazard, especially in terms of security is more serious. So, by measuring the frequency and frequency changing rate, we can predict whether electronic power system will lose stability, so as to provide a feasible criterion, such as removing the load or cutting machine. This will improve power system stability, security and economy.

There are many factors affecting the frequency. From the power system planning, design up to operation scheduling, there are a number of factors that ultimately may impact the frequency. In the stage of planning and design, power supply and load balance between supply and demand, peaking FM program selection, in which various power plants, hydroelectric plants, allocation ratio is whether configured properly or not, which have a significant impact to the quality of the system frequency quality.\cite{1}

2. Significance of frequency measurement

Electrical signal parameter measurement is foundation of computer monitoring, controlling, and protecting. At present, the electrical signal parameters of computer measurement algorithms, mostly based on synchronous sampling, which is phase-locked loop (PLL) technology, it will realize completely synchronized in a cycle of the signal.

The accuracy of the synchronous sampling to some extent depends on the power system frequency in real time and accurate measurement. In the common protection and security automatic devices, the majority of digital protection algorithm is based on the system design of the rated frequency, when the system frequency changes, these algorithms will produce errors, these errors are usually in the relay, which can not be ignored.\cite{2}

With the application of microelectronics technology in the relay protection, the use of fault component protection method has been implemented very rapidly, such as the direction of ultra-high speed line transient protection, and sformer differential protection. Among this protections, the system frequency changing of the uneven sensitivity of the output will affect the protection. And then often need to use tracking technology to eliminate the frequency effect. With the development of power systems and increasing power generation capacity, voltage level and higher and higher level of automation, network structure and regulation are becoming more complex. At the same time, the national economy increasingly dependent on electricity supply. Power users also pay more and more stringent quality requirements. Thus, electricity production of power system frequency measurement should put forward higher requirements. Therefore, complying with the requirements of modern power production, and studying the power system frequency measurement theory, which will help us to further improvement of the power quality, and help to maintenance of power system security, stability, economic operation.

3. Measurement Method

Frequency measurement algorithms are many more, it not only has a hardware method of frequency measurement, but also wealth of software measurement algorithm.

3.1 Hardware Measurement Method

Hardware frequency measurement method in power system monitoring and protection devices, many of which are set frequency measurement hardware circuit. Hardware frequency measurement will be use a voltage comparator, which will make the sine signal transforme into a square wave signal, from square wave signal rising or falling edge interrupt to the CPU making by measuring the time interval between adjacent break to determine the frequency. To eliminate the impact of harmonics on the measurement results, frequency measurement circuit need low-pass filter to filter harmonic. Hardware frequency measurement method is simple and quick response, but it needs some hardware overhead.

3.2 Software Measurement Method

The software frequency measurement method is getting system frequency for analysis and calculation to sampling data. Frequency measurement does not require dedicated circuits, software frequency measurement algorithm can be summarized as follows:

Cycle method. The original cycle method (Zero Exchange Act) principle is same as hardware frequency measurement method. By measuring the waveform zero crossing time difference to calculate the frequency. The method of physical concept is clear, easy to implement, but the accuracy is low. By the harmonics, noise and the impact of non-periodic
components, real-time is bad. The improved algorithm of method has some level of cross algorithm, such as high-order correction function. Calculation of their volume and complexity of the algorithm will improve the accuracy and the corresponding speed.

Analytical method. Analytical method often used in less demanding speed, precision and non-characteristic components of the signal ignored occasions. The principle is that the signal observation model mathematical transformation measure the value of $f$ is expressed as an explicit function. Analytical method using a simple signal observation model, simple algorithm to calculate the amount of small, more traditional methods has improved the cycle, but it is difficult to adapt to the frequency of non-steady state measurements, even in steady state conditions, there must be a strict pre-filter links, and the algorithm derived a similar process, the overall accuracy is not high. Error minimization algorithm. Using the signal observation model with noise. Algorithm design is to minimize the error as goal Such algorithms includes least squares, least absolute value approximation, Newton type algorithm, the discrete Kalman filter algorithm. Error minimization algorithm principle has advantages is the greatest advantage to better suppress interference with a white noise signal dynamic. With the development of digital signal processing hardware, such algorithms applied gradually from the off-line analysis field into the real-time control. DFT (FFT) algorithm. Such algorithm uses data window before and after the DFT calculation results, and then strike a frequency offset estimation frequency. It can be sampled through the adaptive sampling interval or adaptive data window length, which using to improve the measurement range, accuracy and algorithm stability.

In addition, there are other algorithms such as spectral analysis, quadratic commercial, virtual rotor method, orthogonal signal method.

4. System Software Design Principle

Virtual Instruments [3] is that the computer combines the software modules and hardware devices through the application procedure. User can friendly operate this computer in graphical interface (called virtual front panel) as operating their own definition personal instrument, which to complete the signal collection, analysis, judgments, display, and digital storage. Virtual instrument uses transparent manner, compines software analysis of the data processing, expression, and graphical user’s interface, the computer resources (such as microprocessors, monitors, etc.) and instrument hardware (such as A/D, D/A, digital I/O, timer, signal conditioning, etc.). Virtual instrument break traditional instrument mainly consist of hardware as the main mode. User actually operate with a testing software to measure, like a dummy operation of electronic equipment.

The essence of the virtual instrument technology takes full advantage of the latest computer technology to achieve and extend the functions of traditional instruments. Virtual instrument software is the key, when the basic hardware is determined, using different software to realize different functions. Users design their own instrument system to meet diverse application requirements according to their needs. By using computer software and hardware resources, we can greatly break the traditional instruments of data analysis, processing, expression, transmission, storage and other limitations, and can not compare to the effects of traditional instruments. It not only can be used for electronic measuring, testing, analysis, measurement, and other areas, but also can also be used for equipment monitoring and industrial process automation. Virtual instrument can also be widely used in power engineering, mining exploration properties, medical, vibration analysis, acoustic analysis, fault diagnosis and other aspects of teaching and research. [4]

5. System Software Design

Using VI technology to achieve frequency tracking can greatly reduce hardware costs and increase instrument flexibility. The frequency of the power system is mainly affected by changes in periodic fluctuations in 10s ~ 3min load and changes in the pulse of slow component. Therefore, the software uses the frequency tracking method is feasible. Be achieved in software, real-time character is less than the hardware, but does not increase the hardware, the cost reduced investment and circuit complexity decreased.

Although the sampling frequency of the system can not be predetermined, but the power system has larger inertia, the adjacent two or more cycle of the frequency change is very small. So, the sampling frequency can be adjacent to the former one (or several) frequency of cycle Instead of the sampling frequency of the fundamental frequency. And then to determine the sampling frequency. We use a sample sequence modified method of frequency tracking to complete frequency calculation based on virtual instrument.[5]
Based on software of LabVIEW to track the frequency, which is shown as Fig. 1.

\[
f_0 = \frac{f_s}{N} + f_s \frac{u(N) - \sum_{n=1}^{N} U_{in,n}}{2\pi N} \sum_{n=1}^{N} U_{in,n}
\]

(1)

First, using DAQ-2010 data acquisition card n times to complete data acquisition, each time sampling more than work frequency cycle, and the frequency were calculated. Finally, calculating the average to determine the actual sampling rate. Single channel data acquisition card is from the highest sampling rate 2M/s (2M samples per second spots) for the sampling, the time resolution of up to \( \frac{1}{2 \times 10^6} \)=5\times10^{-7}s. The power system under test signal frequency is 50Hz, a period of 0.02s, and therefore its relative accuracy of the measurement cycle is \( \frac{5 \times 10^{-7}}{0.02} = 0.0025\% \).

Data collection using the AI Waveform Scan.vi, its ability to specify the sampling rate from the specified channel (single channel) designated collection points of data. In the Frequency section, taking into account the harmonics, disturbances, noise and other high frequency components of a cycle will contain more than two zero crossing point, therefore, before the calculation of increase in the frequency of the digital low-pass filter unit, the frequency Calculation process shown in Fig. 2.

![Fig. 1 Frequency tracking procedure front panel.](image)

![Fig. 2 Fixed sequence frequency calculation flow](image)
6. Experiment and Conclusions

Frequency tracking and detection in the frequency calculation process described in LABVIEW and based on modified sequence frequency tracking algorithm. As A-phase voltage detection for example, the frequency tracking frame diagram is shown as Fig. 3.

![Fig. 3 Frequency tracking procedure frame diagram based on fixed sequence.](image)

LABVIEW provides the formula and the script VI, Figure 3 uses frame diagram node, which achieving frequency tracking measurements. Formula Node editing using the formula node editing formula, which greatly simplifies the operation program and part of the preparation.

Electronic power system frequency is the number of periodic motion per unit time, the so-called frequency deviation is the difference between actual value of the power system frequency and the nominal value (frequency 50Hz). The expression is \( \Delta f = f - f_N \), where: \( \Delta f \) - Frequency deviation, \( f \) - the actual value of the frequency, and \( f_N \) - the frequency nominal value.

According to national standard <power quality_ power system frequency tolerance>(GB/T15945-1995) provides:

(1) the normal power system frequency deviation allowed is \( \pm 0.2\text{Hz} \), when the system capacity is small, the deviation values can be relaxed to \( \pm 0.5\text{Hz} \).

(2) Frequency impact load caused by changes in general is no more than \( \pm 0.2\text{Hz} \), according to the nature and size of the shock load conditions, system changes can also be appropriate limits, but should ensure the power network, the generator set, and user’s security, stable operation, as well as the normal power supply. [6]

Procedure frame diagram of the system design using standard (1) of frequency deviation allowed value (\( \pm 0.2\text{Hz} \)) to judge electronic power quality.

![Fig. 4 Frequency tracking front panel.](image)

Front panel result display control file shows that frequency of \( f_N = 50.04\text{Hz} \), and simulation are basically same with fact value 50Hz, which can be seen this frequency measurement method has strong harmonic Inhibition ability.

7. Conclusions

By using VI technology, we simulate three phase voltage, and design software frequency tracking measurement procedure front panel and background frame diagram. Through system simulation, system gets value of frequency, and the simulation result is consistent with fact value.
References


