# Distribution network fault diagnosis recorder

Runsheng Zhang, Jianyang Zhao, Jiahui Zeng, Nan Ma, Shuo Zhang, Jichu Chen
School of Computer and Software Engineering.
Huaiyin Institute of Technology
Huaian,China
*274768001@qq.com*

Jian Chen
State Grid Huaian Power Supply Company.
Huaian,China
*371394237@qq.com*

***Abstract*—This paper describes a fault prediction and detection method of distribution network. It uses the ID3 algorithm in the decision tree to classify the grid parameters in the frequency domain after FFT transformation, and compares parameters with the built-in fault model in the terminal to find the corresponding fault type[1]. The abnormal data needs to be recorded and stored at the same time and uploaded to the information center (cloud platform). The system can predict and monitor the abnormal parameters in a certain line timely, track the occurrence and evolution of the fault in time, and provide enough information to make decisions before the minor fault spreads to the regional grid[2].**

***Keywords- GPS; Distribution network fault; FFT;PMU***

## I. INTRODUCTION

For the problems of distribution network fault prediction and diagnosis, the current methods for predicting grid faults are traditionally single (for example, SCADA), and they are mainly applied to trunk lines and are weak for feeders[3]. The traditional phasor measure unit only obtains the frequency spectrum, instantly determines the power quality, but has no prediction margin, and is not timely in the diagnosis and prediction of the fault[4]. Therefore, the decision tree with fault model is used to analyze the grid parameters in the frequency domain. The terminal simultaneously acquires the grid voltage and current by a 24-bit high-speed AD (AD7767) under the unified timing of the Beidou/GPS PPS signal[5]. Each channel signal collects 1024 points per second (meeting Shannon Sampling Theorem). There are altogether six way signals. Due to the large amount of data, and in order to ease the DSP calculation pressure, the data collected by AD is transferred to the SDRAM cache by the FMC to avoid data calculation conflict. According to the FIFO method, the collected data is calculated by Fourier transforme, and the data is converted from the time domain to the frequency domain for amplitude, phase, and frequency analysis. Converting to the frequency domain is more conducive to discovering fault information that cannot be reflected in the traditional time domain. In the frequency spectrum, it can intuitively discover the changes of fundamental waves and harmonic waves, and can quickly determine the type of failure. The terminal uses a radix-2 FFT calculation, which can reduce the computational complexity by half compared to the DFT. STM32F767 requires 0.5ms to calculate a 1024-point Fourier transform. Each way requires 10 times of calculations. there are 6 ways, a total of 30ms (<1s), so it meets the PPS sampling interval. Calculate the frequency spectrum of the data by FFT transformation, and then send it to the decision tree for machine learning to predict the fault. Compare the signal of the suspected fault with the fault model. Once it is determined to be fault, record the wave of this cycle and the next cycle. At the same time, the fault data is sent to the platform for in-depth analysis (S-transformation).

## II. FFT TRANSFORMATION PRINCIPLE

The collected six-way signal is sent to the second level cache SDRAM to form a ping-pong structure, and the data which is stored in the SDRAM, is sent to the FPU (DSP core) according to the FIFO mode, and the time domain data is converted into frequency domain data by using a discrete fourier transform (DFT). The sampling point must be 2 power of N. 1024 points for a DFT calculation requires 3072 floating-point operations, 10 times for 6-way requires 184,320 operations, and a huge amount of calculation is not conducive to terminal execution. Therefore, using the symmetry of the DFT's rotation factor, the sampling point is 2 power of N. Radix-2 (or radix-4) FFT operations can be used. It can reduce the amount of computation by half. The former N/2 is symmetrical with the latter N/2, and the calculation can only consider the first half of the week.

DFT:

$$X(K) = \sum_{n=0}^{N-1} x(n) W_N^{nk} \tag{1}$$

Radix-2 FFT: $$X(K) = X_1(K) + W_N^{nk} X_2(K) \tag{2}$$

$$X_1(K) = \sum_{r=0}^{\frac{N}{2}-1} X(2r) W_{\frac{N}{2}}^{rk} \tag{3}$$

$$X_2(K) = \sum_{r=0}^{\frac{N}{2}-1} X(2r+1) W_{\frac{N}{2}}^{rk} \tag{4}$$

Using the Radix-2 (or radix-4) FFT operation, MCU can quickly calculate the parameters of the fundamental and harmonic to facilitate the search for the type of fault. Experimental results are shown below in EXCEL

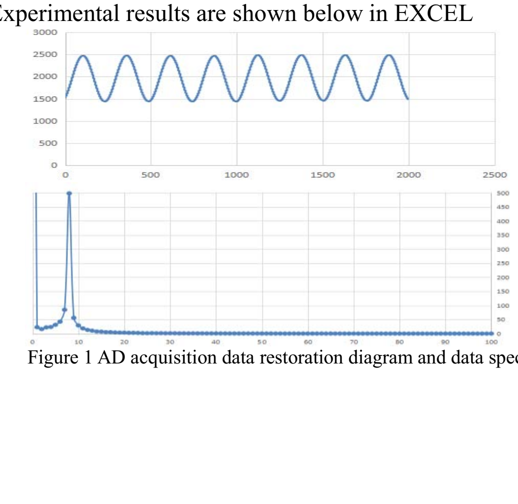

Figure 1 AD acquisition data restoration diagram and data spectrum



978-1-5386-7445-1/18/$31.00 ©2018 IEEE
DOI 10.1109/DCABES.2018.00012

## III. Decision tree prediction principle（ID3）

Build a decision tree (ID3): Step 1: obtain the fault data set of the application grid (as shown in Table 1, marked as training set D) to learn a decision tree that can predict the impending fault. The results of different data set predictions will change. Calculate the root node information entropy of set D.

$$Ent(D) = -\sum_{k=1}^{y} P_k \log_2 P_k \quad (5)$$

Obviously y=2, there are only two situations, Calculate positive case P1= $\frac{1}{10}$ probabilities and counterexamples P2= $\frac{9}{10}$ probability

Step 2: Calculate the information entropy of each attribute in the current attribute set {magnitude deviation ratio, phase difference, frequency deviation ratio, Paswall energy}. Take the deviation of amplitude as an example.Partition D :
$D^1=\{<0.95\}$, $D^2=\{[0.95,1.05]\}$, $D^3=\{>1.05\}$ ,so
$D^1=\{1,6\}$, $D^2=\{2,4,7,8,9,10\}$, $D^3=\{3,5\}$ According to step one, the entropies of three branch nodes can be calculated separately.

Step 3: Calculate the information gain of the attribute in step 2.

$$Gain(D,a) = Ent(D) - \sum_{v=1}^{V} \frac{|D^v|}{|D|} Ent(D^v) \quad (6)$$

V represents the number of branch nodes under this attribute.

Step 4: Repeat steps two and three. Calculate the information gain under each attribute and select the attribute with the largest information gain as the partition attribute.

Step 5: Repeat step 1 to step 4 to select the next division attribute by dividing the attribute branch node selected in step 4.

Step 6: Repeat the above steps until no attributes are assigned to obtain the final decision tree. As shown in Figure 2.

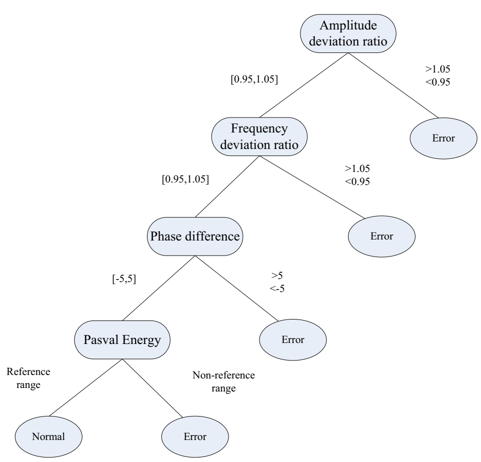


Figure 2. ID3 decision tree under a data set

Table 1 .A regional distribution network fault data set

| Number | Amplitude deviation ratio | Phase difference | Frequency deviation ratio | Pasval Energy | Malfunction |
|---|---|---|---|---|---|
| Formula | $\frac{A_F}{A_{std}}$ | $\phi_F - \phi_{std}$ | $\frac{f_F}{f_{std}}$ | $W_{Pasval}$ | 1：Error 0：Nor |
| 1 | <0.95 | <-5 | <0.95 | $W_{Std}$ | 1 |
| 2 | [0.95,1.05] | [-5,5] | [0.95,1.05] | $W_{Std}$ | 0 |
| 3 | >1.05 | >5 | >1.05 | $W_{Std}$ | 1 |
| 4 | [0.95,1.05] | [-5,5] | <0.95 | $W_{Std}$ | 1 |
| 5 | >1.05 | [-5,5] | [0.95,1.05] | $W_{Std}$ | 1 |
| 6 | <0.95 | [-5,5] | [0.95,1.05] | $W_{Std}$ | 1 |
| 7 | [0.95,1.05] | [-5,5] | >1.05 | $W_{Std}$ | 1 |
| 8 | [0.95,1.05] | >5 | [0.95,1.05] | $W_{Std}$ | 1 |
| 9 | [0.95,1.05] | <-5 | [0.95,1.05] | $W_{Std}$ | 1 |
| 10 | [0.95,1.05] | [-5,5] | [0.95,1.05] | $\neq W_{Std}$ | 1 |

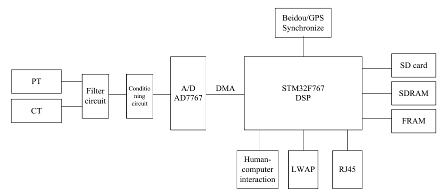


Figure 3. Terminal block diagram

As shown in Figure 3, the terminal needs to convert the high voltage electrical signal of the distribution network into a measurable signal by the transformer, filter circuit, and conditioning circuit. The signal to be measured is the three-phase voltage and current of the power grid (Ua,Ub,Uc,Ia,Ib,Ic). The conditioning circuit uses a differential signal method to prevent the signal from appearing in an oversaturated state. At the same time, a voltage follower is added at the input to ensure that the input voltage does not change and impedance matching is completed, as shown in Figure 4.

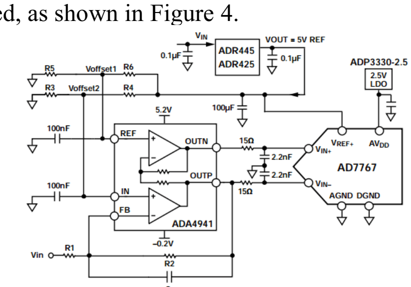


Figure 4 conditioning circuit (differential signal)

## IV. Hardware circuit introduction

The resulting differential signal is sent to a 24-bit ADC for high-speed sampling and transmitted to the the SDRAM via FMC. The 6-channel signal is sampled according to the PPS pulse at the same time, so that all signals are synchronized. Because the distribution network is scattered all over the world, it is necessary to obtain synchronization signals for spectrum analysis, and phasors under the reference point at the same time can be analyzed in the entire network. The terminal sampling synchronization clock is derived from the Beidou/GPS PPS signal with an accuracy better than 1us. At the same time, the UTC time of Beidou/GPS is used to time-stamp the collected data to facilitate synchronization of the entire network data. Connect the PPS signal as an external pulse to the external interrupt. Use the PPS pulse to trigger the interrupt. Start the AD acquisition and read the UTC time in the interrupt to synchronize the sampling and marking, and record the number of interrupts. In order to prevent the loss of star condition and cause the PPS pulse to be lost, the MCU needs to start an additional 500ms timer. Counting the number of timer interrupt, every two times compared with the number of external interrupts, Once the difference reaches a certain threshold, the system will forcibly enter the external interrupt. The first start of the timer is done in the external interrupt. The PPS timing helps the accuracy of the sampling time scale and prevents the equipment from starving.

The AD sampled data is first stored in the SDRAM and then subjected to FFT transformation. Send the frequency domain data to the decision tree for pre-failure. If there is a fault, store the collected data in the SD card and save the data of each sampling cycle before and after the fault. Then compare it with the built-in fault model by the three-way voltage and the three-way current at the same time. Once any channel abnormally, the fault prediction property is transformed into a fault determination, and the type of the fault (short circuit, open circuit, and phase loss) is also determined. Otherwise, the nature of the fault is still predicted. The fault model stored in memory is:

$$\text{short circuit: (circuit } \frac{A_F}{A_{std}} >> 1\text{)},$$

$$\text{open circuit: (circuit } \frac{A_F}{A_{std}} << 1\text{)},$$

$$\text{phase loss: (voltage } \frac{A_F}{A_{std}} << 1\text{)}.$$

Under the condition of judging the occurrence of a fault, using the principle of traveling wave distance measurement (recording the time when the two ends receive the wave surge for the first time),coarse positioning is performed, and the error is in the range of 200-3000 meters. At the same time, the terminal has an Ethernet module, which can send the recorded wave data to the cloud platform according to the 104 protocol of the State Grid for S-transformation, and in-depth analysis of each parameter.

## V.Conclusion

The power grid fault diagnosis system designed in this paper uses Beidou/GPS to obtain synchronized phasors, and the data is analyzed in the frequency domain to analyze power grid quality through FFT. The decision tree (ID3) and the fault model are used to determine the fault. At the same time, the coarse fault location is located using the principle of traveling wave distance measurement. The network port reserved by the system facilitates deep learning.

## Acknowledgments

This paper is supported by Huaiyin Institute of Technology and State Grid Huaian Power Supply Company.

## References

[1] H. Maass et al., “First evaluation results using the new electrical data recorder for power grid analysis,” IEEE Trans. Instrum. Meas., vol. 62,
no. 9, pp. 2384–2390, Sep. 2013.

[2] H. Maaß et al., “Data processing of high-rate low-voltage distributiongrid recordings for smart grid monitoring and analysis,” EURASIP J. Adv.Signal Process., vol. 2015, no. 1, pp. 1–21, 2015.

[3] Y. Yang and M. H. Bollen, Power Quality and Reliability in Distribution Networks With Increased Levels of Distributed Generation, Stockholm,Sweden: Elforsk, 2008.

[4] E. Y. Hamid and Z.-I. Kawasaki, “Wavelet-based data compression of power system disturbances using the minimum description length criterion,” *IEEE Trans. Power Del.*, vol. 17, no. 2, pp. 460–466, Apr.2002.

[5] H. Azami, H. Hassanpour, J. Escudero, and S. Sanei, “An intelligent approach for variable size segmentation of non-stationary signals,” *J. Adv.Res.*, 2014.