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A Development of Real-Time-Piecewise Meter for Three-Phase Power

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Abstract

Aiming at realising a whole range precision metering for both ultra-lower load power circumstance and normal one, this paper proposed a device for the piecewise real-time metering in terms of load power. The design, at the measuring entrance, took a piecewise inputting real-time load signal from the entrance according to the ratio of its three-phase power; through controlled switching, the load signal measured under different ratio was processed by ATT7022B-type metering chip, and calculated by AT89S52-type MCU under different range; and then was processed to satisfy the output required for the multi-function electrical power metering device. The result of the experiments has demonstrated that the design has realized an error equilibrium over whole range, precise metering and other functions.

Keywords: Load power, ATT7022B, Error, Piecewise real-time, Switching, Power-metering

1. Introduction

The device of electric kilowaterhour metering is developing into piecewise fee-ratio, multi-function and network at the present. Current three-phase electric kilowaterhour meter has had several functions such as positive and negative direction active power, reactive power metering and frequency, current, power factor measuring etc. some meters has increased complicated data analysis function. Under this development trend, many related scholars are researching in this field and at the same time the research is promoting the trend. J. Chen etc.(Jianguo Chen, Guowei Di and Fuyuan Wang, 2006) proposed a design of broad range electric kilowaterhour meter, based on an ATT7022A-type electric power load metering processing chip (LMP), and gave a realizing plan. T. Chen etc.(Tao Chen, Chunjie Zhang and Wenxu Zhang, 2006,) suggested a design plan of electric power monitoring terminal based on ATT7022A, and developed a hardware system for high-voltage power lines monitoring terminal which can exactly measures electric power parameters in time and has a function of flexible calibration through long-distance software. J. Zhang etc.(Jianxiong Zhang, Hongying Su and Wenzheng Zheng, 2006),applying the active energy and apparent energy measuring function of ADE7763-type LMP, designed a power factor meter which can adapt interfere environment, arrived the precision of the requirement designed. These literatures, from different sides, indicated the developing direction of electric load metering technique. As summarizing up, however, the researches on the combined electric energy metering devices, adopting new materials and having variety of functions, have been found out. The piecewise and combined-type meter, with multi-function include electric-steal against etc., has not been found out. And there have not been the research literatures on both real-time-piecewise measuring and metering at the ratio of load yet. Especially, the problem on high precision equilibrium metering for 10~35kV transmit and distribution electric power grids, has not been researched up to now, and has not involved with piecewise metering. Although there are some piecewise metering as above mentioned, the piecewise, so called peak and valley, is fixed at regulated time, is not essential peak and valley piecewise, the real-time peak and valley piecewise. In the mean time, the roughness of metering in light load range is still not revised. It is just for solving this problem that this paper proposes a design plan of a whole range precision equilibrium metering device for 10~35kV transmit and distribution electric power grid load.

The load signal is educed into the metering part of the device from the second terminals of combined sensor, the measuring part of the device, through the load ratio judging and switching control, high and low load metering channels are automatically switched at real load ratio, for guaranteeing the whole range metering precision balance between high and low load and reducing metering line loss and error from increased measuring error produced by ultra-high and low load run of sensors.

The general scheme is that: at the measuring part, the current sensor (CT) with high and low ratio are adopted to reflect high and low load ratio, and run in the period of high load power and that of lower, respectively. that is piecewise measuring mode, by which whole range error balance is realized and metering, displaying precision is improved. in the mean time, the device should piecewise and circularly display active, reactive energy, active, reactive power and power factor, according to load power ratio, circularly display records of abnormal records such as high power humorous waves, negative powers, voltage-losses, phase exchanges, power-cuts etc.

2. Foundation and Principle of Load Ratio Piecewise Metering

Many researches (Conai Liu,1991; Yan Huang and Dingbai Li, 2006; Hui Hu, 2005) have indicated that according to the phasic vector graph of the equivalent circuit of CT, $I_1^{'}$, the equivalent primary side load current converted to secondary side, ($I_1^{'}=I_1/n$, I_1 is the primary side load current, $n=I_{1e}/I_{2e}$ is the ratio of CT, I_{1e} and I_{2e} is the rated load current of the primary side and the rated current of the secondary side, respectively)can be approximately expressed as

$$I_1^{'}=I_2+I_{1M}^{'}\cos\beta\ ,$$

Where, I_2 is the current of the secondary side of CT, $I_{1M}^{'}$ is the excitation current of CT, β is the leading angle of phasic vector I_2 with respect to phasic vector $I_1^{'}$. And the current' error of CT is expressed as

$$f_i=\frac{I_2-I_1^{'}}{I_1^{'}}\times 100\%\cdot$$

While CT runs such that primary side load current I_1 goes within a vicinity of rated current I_{1e}, error f_i is minimum. otherwise, the greater the discrepancy that load current departs from the rated value is, the more the error is. An error circumstance of a typical ratio CT, under secondary impedance Z_2=1Ω, leading angle β=0.8, is in Fig.1. If load current is in 120% of the rated, from the Fig., the grater the load is, the smaller the error; while load is light, real load current is lower than 30% of the primary rated current of CT, esp., while load current goes at 20% of the rated and lowers, negative ratio difference f_i goes at allowance $\underline{f_i}$ and rapidly increase along with load current's lowering. The circumstance has been demonstrated by the data of experiment measures.

Fig.2 is the error circumstance of several CTs with different ratios under the same second load. Where, AB is a CT's error curve with ratio n_1 and primary side rated load current I_{1en1}; CD is another CT's error curve with ratio n_2 and rated current I_{1en2}; EF is the curve with ratio n_3 and primary rated load current I_{1en3};……. From the Fig., it is obvious that with ratio n_1, along with primary side load current I_1's lowering, negative ratio difference f_i gradually greatens along curve AB, such as arriving at B (where I_1=20%I_{1en1}, error arrives at allowance limit $f_i=\underline{f_i}$); If I_1 continuously lowers with the ratio, error would be unacceptable. If ratio is changed into n_2 on point B (corresponded rated load current of the primary side is I_{1en2}), such that the CT is switched to run along curve CD, error f_i will greatly lower. By the same reason, once primary load current I_1 lowers and arrives at point D along curve CD under ratio n_2, (where I_1=20%I_{1en2}, error again gradually increase and arrive at allowance limit $f_i=\underline{f_i}$). If ratio is once more changed into n_3 on point D, such that the CT is switched to run along curve EF, error f_i will greatly lower again;……. Like this, corresponding to the varying of load current (*i. e.*, the ratio of load), the ratio of CT is changed to guarantee that the measuring error of CT is always smaller than the given value. The idea, that the ratio of CT is piecewise switched corresponding to load varying to make error small and even, is proposed just based on this principle.

This paper will, by partitioning two sections corresponding to load, design a three-phase power load metering device. Three-phase power load energy, through being transformed by the combination of a voltage transfer (PT) and a double ratio CT, as the form of analog voltage signals, is fetched out from the second side of the combined sensor (CT+PT). The analog signal corresponding to low ratio current and that to high ratio one, together with the voltage analog signal, is delivered to low ratio signal processing channel and high one, respectively. Two channels are switched by channel switch, one of them is chosen to send its signal to metering management module with an LMP as core. LMP transforms the analogs into corresponded digital signals, through energy metering processing such as calculating, managing, etc., gives out many kind of real-time data, including active energy, reactive one, power factor and so on, to calculation and control module with a micro-program control unit shingle chip (MCU) as core. Than, MCU has the corresponded data been output-processed, by means of memory module, liquid crystal display module (LCD), data communication module (COM) etc., and outputted, such as memory renovating, data displaying, data communicating etc. In the mean time, MCU, through the calculating and judging power data inputted from LMP, produces a control level and delivers it to a multi-way simulation switch (SS), to control SS's switching. SS, through its conversion, chooses on low ratio signal processing channel or high one and sends the corresponded load signals to the input terminals of LMP.

3. General Design Requirement for Multi-function Meter

Multi-function compound electric energy meter needs to realize main functions as follows:

1) While no keystroke, displaying for 4 circles with 5 seconds as a circle: (1) the current active and reactive energy under load≤20% of rated power capacity (current) (≤20%: W, V); (2)the current active and reactive energy under load>20% of rated power capacity (current)(>20%: W, V).

2) After keystroke “dispersion” or during its availability, displaying for 4 circles with 5 seconds as a circle: (1) the active and reactive energy at the end of last time (month) under load≤20% of rated power capacity (current) and the dispersions of the current active and reactive energy minus the active and reactive energy at the end of last time (month) under load≤20% of rated power capacity (current) (≤20%: W_0, V_0,W -W_0, V-V_0); (2) the active and reactive energy at the end of last time (month), under load>20% of rated power capacity (current) and the dispersions of the current active and reactive energy minus the active and reactive energy at the end of last time (month), under load>20% of rated power capacity (current)(>20%: W_0, V_0, W -W_0, V-V_0).

3) After keystroke “instant” or during its availability, displaying for 2 circles with 3 seconds as a circle: (1) the active, reactive power and power factor under load≤20% of rated power capacity (current) (≤20%: P, Q, cos); (2) the active, reactive power and power factor under load>20% of rated power capacity (current)(>20%: P,Q,cos).

4) After keystroke “abnormity” or during its availability, displaying for 3 circles with 6 seconds as a circle: (1) the sequence of last four appearances of harmonic power being larger than set value and each begin-end time of them (*k*st H: yy/mm/dd//hh:mm:ss—yy/mm/dd//hh:mm:ss); (2) the sequence of last four appearances of inverted power and each begin-end time of them (*k*st F: yy/mm/dd//hh:mm:ss—yy/mm/dd//hh:mm:ss); (3) the sequence of last four appearances of voltage-loss phase and each begin-end time of them (*k*st A (B or C): yy/mm/dd//hh:mm:ss—yy/mm/dd// hh:mm:ss); (4) the sequence of last four appearances of phase exchange and each begin-end time of them (*k*st A←→: yy/mm/dd//hh:mm:ss— yy/mm/dd//hh:mm:ss); (5) the sequence of last four appearances of power-cut and each begin-end time of them (*k*st K: yy/mm/dd//hh: mm:ss—yy/mm/dd//hh:mm:ss).

5) Sound and light alarming, once any of the first four abnormities in requirement 4 appearing.

6) While power cut, saving related data.

7) Through communication interface, providing channel for data communication with long-distance terminals.

4. The Circuit Design and Realization of the System

4.1 The overall structure of the combined electric energy metering device

Load power piecewise combined electric energy metering device is composed of measure module, signal processing module, metering and calculation module, data memory, display and output module, power supply unit and so on. Where, measure module, as the measuring part of the device, is mainly combined CT and PT, used to transform load quantity into corresponded current and voltage signals; signal processing, metering and calculation module, data memory, display and output module, power supply unit are combined to meter groupware including a series of software and hardware, they are a system aggregating the functions such as signal processing, switching; data gathering, comparing, processing, analyzing, calculating, saving, renovating, displaying and data communication, etc.

The hardware structure shows in Fig. 3. The CT+PT in the measure module is a dry-type outdoor exact device made from new materials and by new technologies, two current ratios are 150/5A and 30/5A (CT: 150, 30/5A), double level voltage ratio is 10kV/100V/5V (PT: 10kV/100V/5V). The signal processing module is composed of signal compensating, filtering and attenuating resistance-capacitance-networks (F.A.I1 (high ratio current channel), F.A.I2 (low ratio current channel) and F.A.V (voltage channel)) and SS chip CD4053. Such structure order as processing before switching is to consider both that the secondary side of CT does not open and the application of SS and its switch-on-resistances. The metering, calculation and management module includes an electric load metering processing unit which takes ATT7022B-type LMP as core, with the related outer elements, aiming at obtaining several real-data such as active, reactive energy, power factor and so on, and a calculating unit which takes AT89S52-type MCU as core, matched by outer chips such as real-time clock, fail-tolerance circuits etc., aiming at running calculation, control and so on. The memory and renovation module, which takes a FM3116-type ferrous-memory chip (FM) as core, is used to hold current all data and to realize data saving function during power-cut. The display unit, adopting an LCD chip, JHD 204A, is used to display requirement 1 to 4 above mentioned. COM unit, adopting a MAX485 chip and a semiduplex RS485 interface, is to real-time deliver all kinds of related data, programmable parameters, and so on to upper-computer. The power supply unit (PS) adopts double polarity (positive and negative) groups, one of them is a structure that a parallel connection of triple single-phase rectifying bridges links with a voltage regulator, to fit for every run environment.

4.2 A Design Realization of the Signal Processing Circuit and its Work Principle

The feature of the device is mainly embodied in the signal processing module. The signal processing and piecewise switching circuit is given in Fig. 4.

In the Fig., the load current signals of A(B, C) phase come from the corresponded high ratio terminal, AP1 (BP1, CP1), the corresponded low ratio terminal, AP2 (BP2, CP2), and the conjunct terminal, AN (BN, CN), on the secondary side of CT. On each channel, say A phase high ratio signal channel, RC circuit composed of R_1, R_4, C_1, R_8, C_4 is for shunt, compensation of phase order and low-frequency-pass filtering. Its frequency is set at 4.8kHz. CT would generally produce a 0.1°~1° phase angle error, but it would be corrected in the phase correcting register (PhsregA (PhsregB, PhsregC)) in LMP. Two diodes, reverse parallel connected, become a protecting circuit.

Other channels are similar to the above mentioned. The voltage signal channel of every phase is similar to the current signal channel of the conjunct terminal of corresponded phase.

In three phase voltage signals, each, going though processing channel F.A.V, directly input to corresponded voltage-analog input-terminal pair on LMP, ATT7022B. For example, the signal of A phase inputs to terminals V2P-V2N (B to V4P-V4N, C to V6P-V6N (omitted in Fig.4)). In three phase current conjunct signals, each, going though processing channel F.A.I1 and F.A.I2, directly input to corresponded current-analog input-terminal pair on LMP. For example, the signal of A phase inputs (gong through terminal an) to terminal V1N (B (through bn) to V3N, C (through cn) to V5N (omitted in fig.4)).

High ratio three phase current signals, going though processing channel F.A.I1, and low ratio three phase current signals, going though processing channel F.A.I2, are respectively input (going through terminals ap_1, bp_1, cp_1 and ap_2, bp_2, cp_2) to corresponded input terminals ax, bx, cx and ay, by, cy on SS, CD4053. Controlled by the control level on its control terminals A, B, C, SS switches and sends high ratio three phase current signals or low ratio ones (through its output terminals a, b, c) to corresponded three current analog input terminals V1P (A phase), V3P (B), V5P (C) on LMP.

ATT7022B-type LMP has 7 analog input terminals. The first six of them are partitioned into a current channel and a voltage one. The current channel is for the input of 3 pairs of difference voltages and includes terminals V1P-V1N, V3P-V3N and V5P-V5N, standing for A, B and C phase. The bound of the signal voltages of the 3 channels is ±1.5V. the voltage channel includes 3 pairs of difference voltages terminals V2P-V2N, V4P-V4N, V6P-V6N, for A, B, C phase.

While load is not smaller than 20% of the rated capacity (current) of a power system, MCU, going through calculating and judging, by means of its terminal P1.0, gives off a high level to the control terminals A, B, C of SS, controls SS to switch. Thus, the low ratio signals of three phase load currents are sent to 3 pairs of difference voltages input terminals V1P-V1N, V3P-V3N and V5P-V5N of current channel of LMP, going through the input terminals a, b, c of SS and the conjunct terminals an, bn, cn of F.A.I1, F.A.I2. While load is smaller than 20% of the rated capacity (current) , MCU, through calculating and judging, by its terminal P1.0, gives off a low level to the control terminals A, B, C, controls SS to switch. Thus, the high ratio signals of the load currents are sent to 3 pairs of terminals V1P-V1N, V3P-V3N and V5P-V5N, through terminals a, b, c and terminals an, bn, cn. Besides, the load signals of two ratio conditions are processed, managed and metered by LMP, the load data of two conditions are calculated and control by MCU, and so on. Then the data of the two conditions are saved and renovated by FM, displayed by LCD and prepared for communication by COM.

5. Software Design of the System

The software of the multi-functional metering device is mainly for the calculation of real-time data, inner parameters, dispersion, moment value and so on, the accumulation of energy, the management of every modules, the judging disposal of abnormal circumstances such as harmonious waves with power being larger than given value, inverted power, voltage-loss, phase-exchange and power-cut, the disposal of memory and renovation, display, etc. A block chart of the program function flow is shown in Fig. 5. The software fitting for ATT7022B-type LMP is mainly the control programs of AT89S52-type MCU. They execute the configuration to LMP, the disposal of several related data, and at the same time, make use of the data transmitted by SPI to affect the search of outer data, to calibrate the configuration of data.

The frame of the overall program is follows:

```
#include <reg52.h> ……
sbit    qh=P1^0;       ……
float    h=0;          ……
uchar sr(void);       ……
……
main( )
{……
do{if(P3=0xff) {……}
```

```
if(P3=0xfb) {……}
if(P3=0xf7) {……}
if(P3=0xef) {……}
}while(1);
}
void cw(uchar rw,add,length) {……}
uchar sr( )                {…}
void spiw(uchar var) {…}
void iic(uchar rw, dd, addh, addl, length) {……}
uchar iicr( )            {……}
void iicw(uchar var) {…}
void init(void)          {…}
void cmd(void)           {…}
void wdata(void)       {…}
void cb(void)             {…}
void delay(lint nop)    {…}
void zh(uchar com0,com1,com2){……}
void xs(float g)      {……}
void xsr(float g)      {……}
void sj(uchar g)      {……}
void xz(void)          {……}
```

6. Conclusion

This device has taken a measure that piecewise input real-time load signal according to the ratio of tree-phase power. By controlling and switching the ratio of CT, it, within different range, calculates the different ratio load signal measured, on the basis of the metering proposal from LMP, and more, executes every input function required. The device actualized has, by experiments, been proved to be accurate and feasible. The result of experiments has demonstrated all of functions required. The device has realized error balance and precision metering over whole range. It has passed the technological appraisal held by Science and Technology Department of Anhui Province, China, and has applied an invention patent of nation of China. The other problems and the requirements for expanding functions are easier to solve and have had mature techniques to apply, and do not give unnecessary details in this paper.

References

Jianguo Chen, Guowei Di and Fuyuan Wang. (2006). A Design and Realization of On-line Broad Range Electric Energy Meter Based on ATT7022 , *Modern Electronic Technology*, 9, 94-101.

Tao Chen, Chunjie Zhang and Wenxu Zhang. (2006) . Design of Electric Power Monitoring and Controlling Terminal Based on ATT7022A-type Electric Load Metering Chip. *Information Technology*, 9, 40-43.

Jianxiong Zhang, Hongying Su and Wenzheng Zheng. (2006). A Power Factor Meter Based on Electric Load Metering Chip . *Electricity Applications*, 4, 76-78.

Conai Liu. *Inductance Sensor and Phase Order Filter*. (1991). Beijing: China's Water and Electricity Power Pres.

Yan Huang and Dingbai Li. Reasonable Choice of Current Transformer. (2006). *Jiangxi's Power*, 5, 37-40.

Hui Hu. *Singlechip Principle and Application Design*. (2005). Beijing: China's Water and Electricity Power Pres.

Zhuhai Juli Integrate Circuit Design Co. Ltd. ATT7022B *User Manual*. (2005). www.action.com, 2005.

Zhuhai Juli Integrate Circuit Design Co. Ltd. ATT7022B *Applicaion Note*. (2005). www.action.com, 2005.

Lei Yang and Guangming Huang. A Realization of ATT7022B Automatic Calibrator. (2007). *Electic Measure and Meters*, 5, 44-497.

Zaixin Huang and Daliang Zeng. *Program Design Base—C Language*. (2000). Beijing: People posts and telecom. Pres., (2000.12).

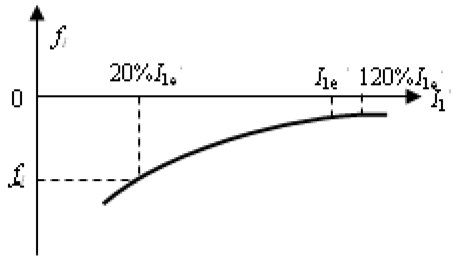

Figure 1. The error of CT' runing

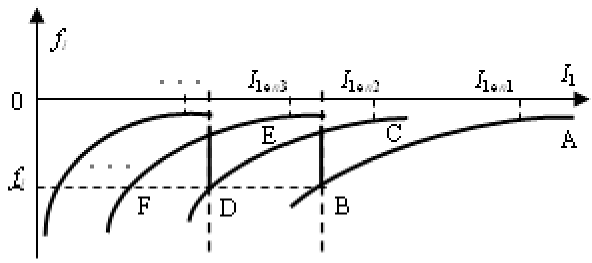

Figure 2. Switching running of multi-ratio

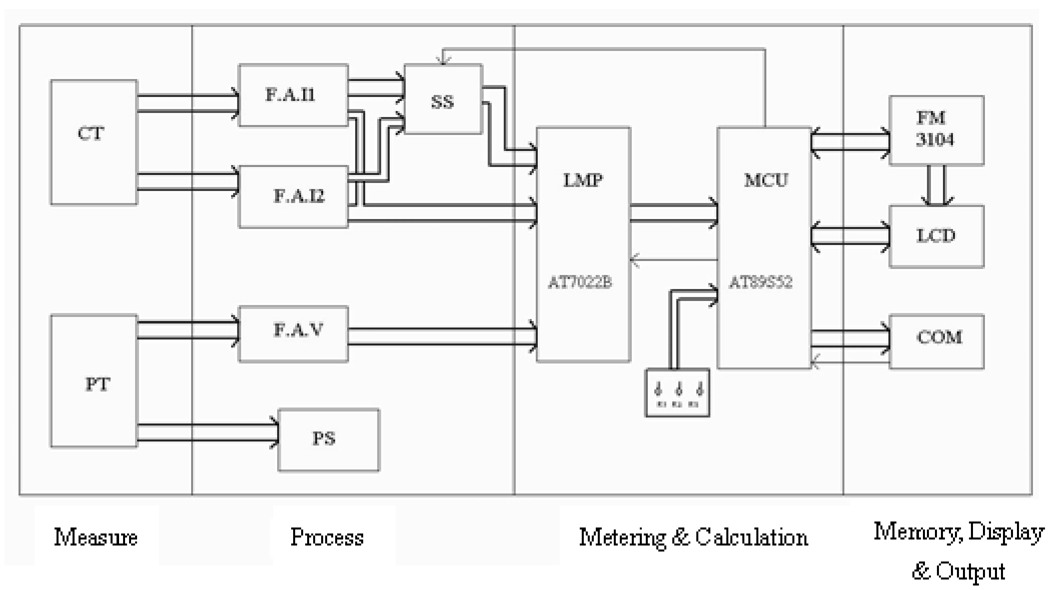

Figure 3. The hardware structure block of the meter

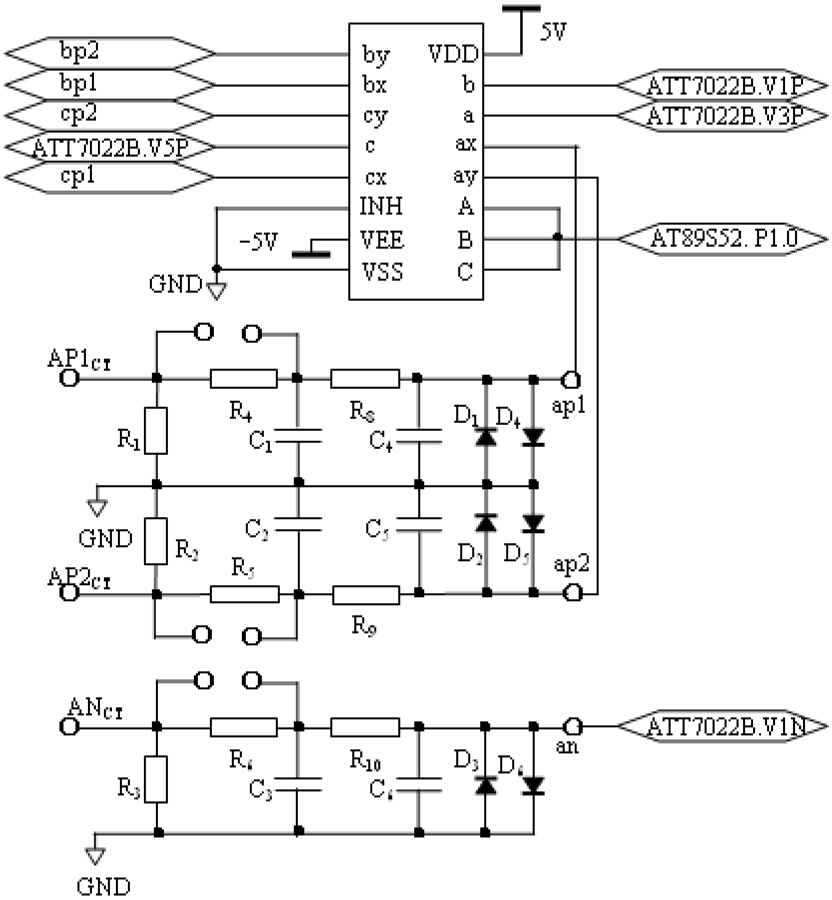

Figure 4. Signal processing and piecewise switching circuit

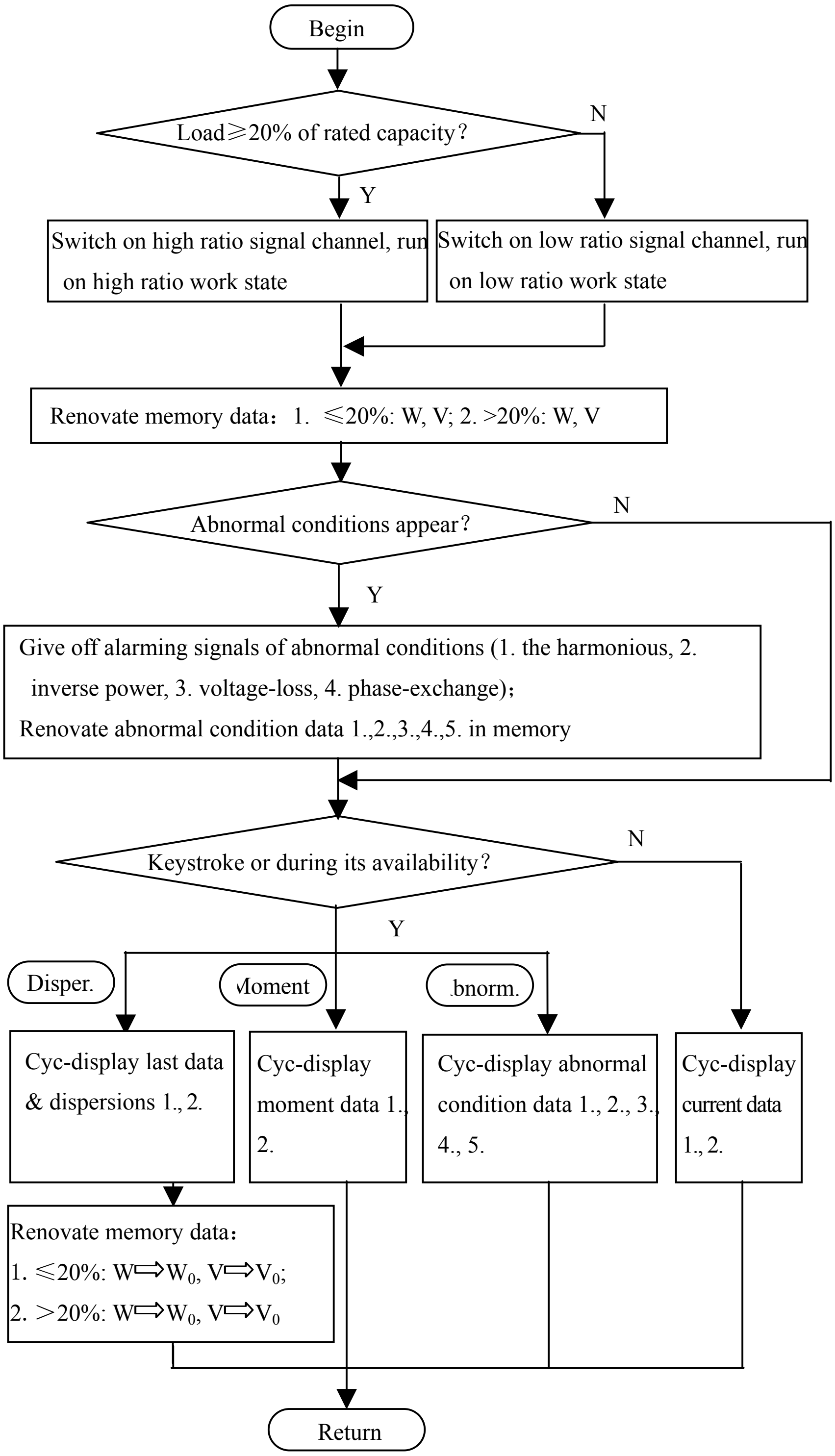

Figure 5. Flow of Program function module