A Wireless Transmission Technique for Remote Monitoring and Recording System on Power Devices by GPRS Network

Cheng-Chien Kuo *Hong-Chan Chang *Fu-Hsien Chen

Department of Electrical Engineering,
Saint John's University,
499, Sec. 4, Tam King Road, Tamsui, Taiwan.

*Department of Electrical Engineering,
National Taiwan University of Science and Technology,
43, Sec. 4, Keelung Road, Taipei, Taiwan.

Abstract: - A remote monitoring and recording system for power devices is developed in this paper. It aims at the application of the technology of wireless transmission and signal processing in the transmission of the signals of long-distance electric equipment to the central control station. The terminal visualizes its working states in pictorial system and saves all the historical data into general database for the purpose of future research and examination. Through this proposed system, only requires a GPRS matching acquisition system module which enables the long-distance control center to acquire any signals of the equipment, so that overall supervision is attained. Meanwhile, the task of wire setting on rough landform is avoided, and the time to overhaul can be saved. In addition, by examining the data record or analyzing them theoretically, we come to know the performance, life-span and operation efficiency of the equipment, so as to propose maintenance or replacement, thus the traditional periodical maintenance program is upgraded to a more efficient conditional based one. When anything abnormal happened to the equipment, the system can inform in advance the engineers concerned to repair it immediately or replace it, and reduces the occurrence of unexpected accidents.

Key-Words: - Power Devices, General Packet Radio Service, Wireless Transmission, Remote Monitoring.

1 Introduction

Nowadays, electric power has become an indispensable energy source which is used so widely that it functions as a basic necessity of every walk of life. Regarding the electric facility, high profit is earned when everything works smoothly, otherwise, work-line comes to a halt and results in decreasing output, in particular serious in the power industry. Provided that the power supply is cut, every sectors of the economy will suffer huge losses. If any problem of the equipment is spotted in advance, we replace or repair it timely, huge losses can be avoided.

With technological advancement of information and network, the electric supervisory system, no longer confined to simply electric power utilization, can offer various services by monitoring the state of power consuming in an interactively way, so as to improve the efficiency of overall power utilization. As to the current electric facilities, little timely supervision and analysis of system has been done. If we can make an immediate analysis and supervision, we will get more data, such as load curve, demand, peak load, from which we can work out demand factor, load factor and diversity factor. Based on the data, we are able to make an evaluation of our equipment, energy and utilizing efficiency.

To make sure the high security of electric operating system, SCADA has been recommended by power firms across the world to acquire the data of electric working state, to control the switch device, and to supervise long-distance equipment, so that system dispatchers are able to monitor the operating state of on-site equipment. SCADA comprises control center, on-site equipment and communication network, etc. Before the display of PC screen, the dispatcher can make an analysis of any coming signals. When any abnormal data appears, the dispatcher does an immediate repair to avoid any major accidents to come.

On the basis of the highly developed mobile communications era today [1,4], it is believed that the wireless transmission platform may modify and improve the cable transmission disadvantages. The present day GPRS network system has been established to a perfect level leading to the popular use of mobile phones [2]. And GPRS network can have reliable way to transmit data in addition to voice [3]. There already have many applications that apply the advantage of GPRS network to improve the conventional uses [4-12].

Hence, this research designed a wireless real-time monitoring feedback system to connect the built-in GPRS module, making it possible to send back the monitoring data without material cabling between the monitored ends. The use of GPRS module makes the monitoring commands and information observation not confined to a fixed point, enhancing the monitoring flexibility, convenience and reliability. Therefore, this research applied GPRS in collecting electric power data to further achieve the monitoring purpose, and developed a set of GPRS remote monitoring equipment that mainly monitor the relevant electric data at the monitored ends including the three-phase voltage rms value, electric current, and electric power. In addition, information on the statuses of power source over voltage, under voltage, over current and power status are fed back to the far-located monitoring end by GPRS.

2 Software and Hardware Programming

This section is to elaborate on the system structure and the design procedures of relevant hardware and software. The system structure is as shown in Fig. 1. Install the GPRS remote monitoring device developed in this research at the monitored station. The device collects the information on electric voltage and current with its power calculated. And the monitoring data collected can be sent from the GPRS modules at the monitored end to the central station with internet of the far monitoring end by GPRS network system.

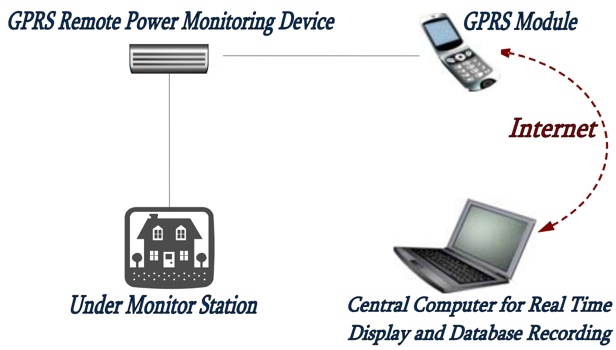

Fig. 1. GPRS remote monitoring system structure

2.1 Framework of the System

The system is made of four parts as describing below and shown in Fig. 2 including: electric signal processing, signal sampling, GPRS transmission and Host end monitoring.

A. Electric signal processing:

Utilize simple circuit to make some proportional processing of signals, and then compare the simulated with the actualized, after that, make some modification to make sure the circuit useable.

B. Signal sampling:

Utilize single chip to sample the voltage, current and phase signal, and to do some calculation of data out of the samples.

C. GPRS transmission:

Make use of the match of Yi Yang's GPRS Module with single chip, and utilize AT command to control the online and data transmission by RS-232 transmission technique.

D. Host end monitoring:

Utilize Visual Basic as the monitoring program of Host end to revert the received data to its original waveform, and then to work out various data after calculation, so as to come to know the state of long-distance equipment.

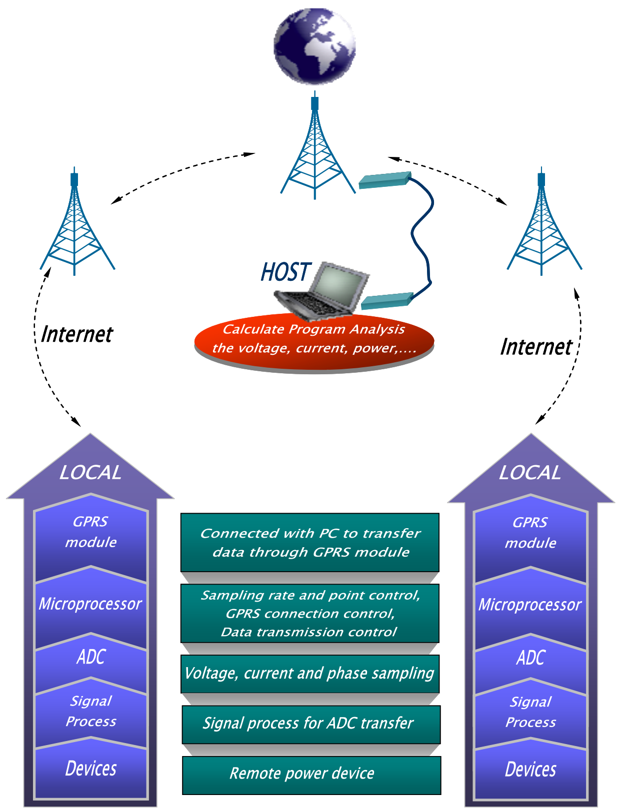

Fig. 2. System Structure

2.2 Function of the System

The main functions of this system can be divided as two parts. The first one is to monitor the equipments and transmit back the relative parameters. The second function is to analysis the received data for further uses as stated below.

A. Monitor the data of electric equipment:

We can collect the voltage and current data from monitored equipments, and transmitted the data to the long-distance PC by GPRS. When receiving the data, the PC saves it into database and visualizes its waveform. At the same time we can calculate the data and get the power consumed by the electric equipment concerned.

B. Analyze the received data:

We also can collect data from many equipments, and then make a comparison. For instance, we can calculate out the loss in the transmission, through which, if anything abnormal, we can inform in advance the engineer to do a repair and maintenance.

2.3 The Principium and Method of the Design

2.3.1 Signal Processing

A. Voltage

The power voltage of equipments is an AC large signal that is not suitable for A/D converter and GPRS transmission. We utilize cement resistance divider to drop the voltage around the range about 2.5V. Then we use adder circuit to raise the AC voltage level for 2.5V, such that the $V_{\max}$ is around 5V and DC value, and then the signal can be sent to ADC for conversions.

B. Current

As to the current, through current transformer (CT) we dwindles the current in proportion. Then we connect in serial the current with a resistance, and then we utilize a reverse amplifier and an adder to amplify its voltage and make a level shift, after that send the signal to the ADC for a conversion.

2.3.2 Phase Difference

Let $V = V_m \cos(\omega t + \theta_1)$ and $I = I_m \cos(\omega t + \theta_2)$

Using multiplier to set the product of V and I then :

$$X = VI = V_m I_m \cos(\omega t + \theta_1)\cos(\omega t + \theta_2)$$

$$= \frac{V_m I_m}{2}[\cos(\omega t + \theta_1 + \theta_2) + \cos(\theta_1 - \theta_2)]$$

$$= \underbrace{\frac{V_m I_m}{2}\cos(2\omega t + \theta_1 + \theta_2)}_{\text{AC term}} + \underbrace{\frac{V_m I_m}{2}\cos(\theta_1 - \theta_2)}_{\text{DC term}}$$

The AC term will only have an offset affected by DC value at this moment as shown in Fig. 6. It is very easy to find the X_{av} through $X_{\max}$ and $X_{\min}$:

$$X_{av} = \frac{X_{\max} + X_{\min}}{2} \tag{1}$$

$$X_{av} = \frac{V_m I_m}{2}\cos(\theta_1 - \theta_2)$$

We using a hardware chip (AD633) to produce the signal of multiplication of V and I, such that the X_{av} can be find according to (1). Therefore, the phase difference between V and I can be find as below:

$$\theta = \theta_1 - \theta_2 = \cos^{-1}\left(\frac{2X_{av}}{V_m I_m}\right) \tag{2}$$

2.3.3 Sample

In signal sampling, the ADC0809 combined with 8284A is utilized to convert analog to digital. In here, 8284A offers 1.2MHZ clock for ADC0809 so that it can work smoothly. It takes about 10 clock for each sample point of ADC0809 to make the conversion, $1/1.2MHz \times 10 = 8.33\mu s$, together with $230\mu s$, delay of program, the sampling frequency is about 4.2KHz. Therefore, sampling 60Hz power signal in such a manner also accords with Nyquist sampling theorem $f_p \geq 2 f_s$, and this won't bring about aliasing phenomenon.

ADC0809 utilize its framework to switchover between 8 analog channels for 8bit conversion. The signal of voltage, current and phase difference is input to connector $V_{REF}(+)$ to +5V, and $V_{REF}(-)$ to GND. Since V_{REF} is 5V, and the resolution of ADC is 8bit, 256 levels is set. Its $\text{step voltage} = 5V/(2^8 - 1) = 0.0196V$. Then the START and ALU of ADC chip are triggered, so that the conversion is activated, and after conversion, the converted data is acquired in the manner of interrupt. Surely, to make ADC0809 work, clock should be provided. In this design, it is ADC0809 that offers the clock, aided by 7.2 MHZ crystal oscillator; 8284A divides by 6. Finally 1.2MHZ clock is obtained by PCLK.

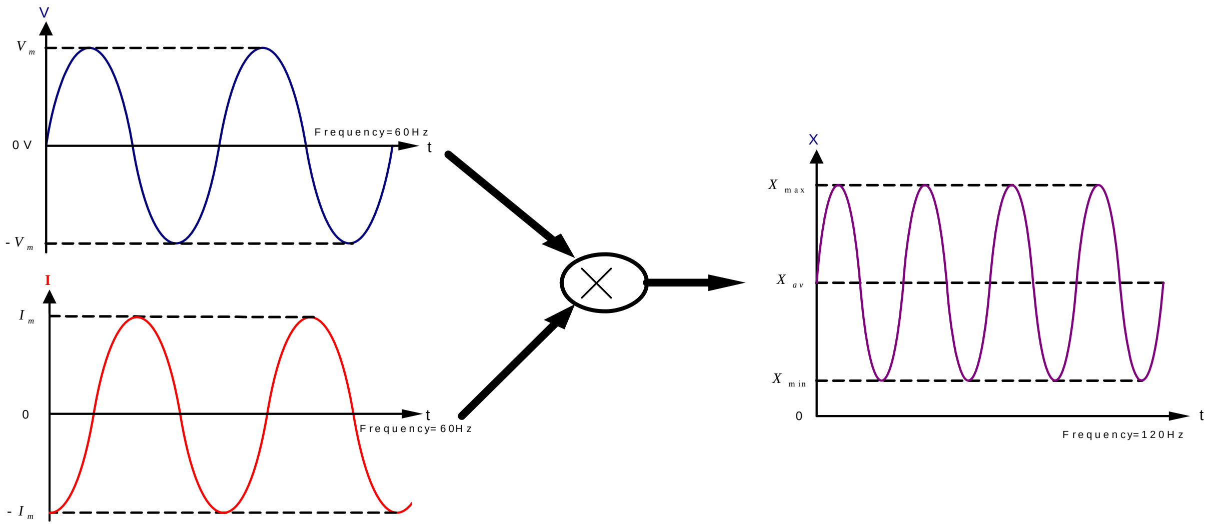

Fig. 6. The waveform after the product of voltage and current

Microprocessor is utilized here to acquire the signal of 70 sampling points, and then GPRS is applied to transmit the data to long-distance supervisory system, where linear interpolation is employed to revert the data to its original signal.

2.3.4 The Connection of 89C52 with GPRS Module

In the application of GPRS module and 89C52, 89C52 is utilized in this paper to give AT Command to control GPRS module through RS-232, so that GPRS can connect to the network to transmit the data. To get GPRS Module to transmit signal smoothly, AT Command is utilized here.

2.3.5 Power Calculation

After calculating the data obtained in sampling, we get V_m、I_m and θ, with which we work out form the formula $P = V_m I_m \cos\theta$. Then the power is easily got.

3 Implementation

Three parts to be discussed here:

3.1 Voltage acquisition

In this part, as shown in Fig. 8, we decrease the voltage to -2.5V~+2.5V as shown in upper portion of Fig. 8, but the sampling scope of ADC0809 is confined to positive value (0V~5V). Therefore, we make a slight adjustment of the voltage, which is done in the lower part of Fig. 8. In this process, we use the IC as TL084. The U1 is the buffer added to prevent the interference between the front and back voltage. The U2 is the non-inverted adder to raise its voltage; it is designed according the following procedure.

Assume the point 3 of U2 is V_A, the output of U1 is point 6 denoted as V_i, V_o is the output of U2 placed in point 6

R=1k，R7=R8=R9=R，R5=R6=2R

$$\frac{V_A-5}{2R}+\frac{V_A-0}{2R}+\frac{V_A-V_i}{R}=0$$

$$V_A-5+V_A+2V_A-2V_i=0$$

$$4V_A=2V_i+5$$

$$V_A=\frac{1}{2}V_i+1.25$$

$$V_o=(1+\frac{R}{R})\times V_A=(1+1)\times(\frac{1}{2}V_i+1.25)=V_i+2.5$$

After passing U2, the level of voltage V_i (-2.5V~+2.5V) rises by 2.5V, thus the V_o scope is expanded between 0V~5V. After such adjustment, ADC0809 is well prepared for voltage value.

3.2 Current conversion

As shown in Fig. 9 is the current conversion circuit. When collecting real signal sample of voltage and current, we connect the equipment to 110V voltage, R3(1k) in serial, LOAD and CT. R3 is set to prevent excessive short-circuit current; LOAD is set to detect the state of voltage and current value for a easy examination, which is also the purpose of our experiment; CT is set for two examination: the first one is to measure the current passing the LOAD, and the second one is to transform the current inducted into the voltage waveform through R4(9.9K). The voltage of R1 and R2 falls into 110V, close to the voltage for LOAD. For a convenient detecting, we divide the 110V so that the voltage falls into the scope (-2.5V~+2.5V), convenient for its analysis to come.

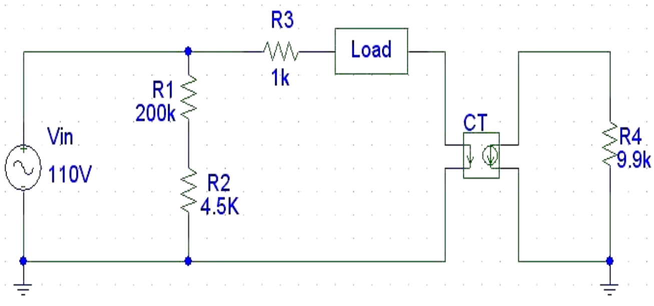

Fig. 9. Current transform by CT

3.3 Current acquisition

As shown in Fig. 10 is the current acquisition circuit. The current value has been inducted from primary to secondary through CT in part 2. Next, the current value is transformed into the voltage through R4. Since the current is transform to secondary, due to the turn ratio, the previous big current is converted into small one, the value inducted in measurement is even small. For a convenient measurement, we utilize a reverse amplifier (U3), whose rate is R11: R10 => 31.5 times, to amplify the voltage to the scope, -2.5V~+2.5V. After that, by the means of voltage acquisition, we utilize a non-reverse adder (U4) to adjust the voltage to 0V~5V, convenient for ADC0809 to receive.

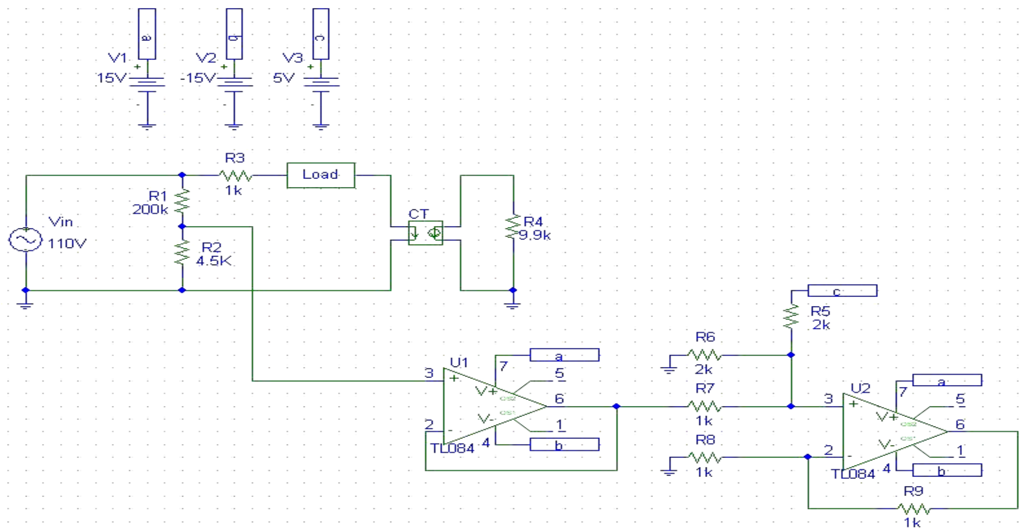

Fig. 8. Voltage acquisition circuit diagram

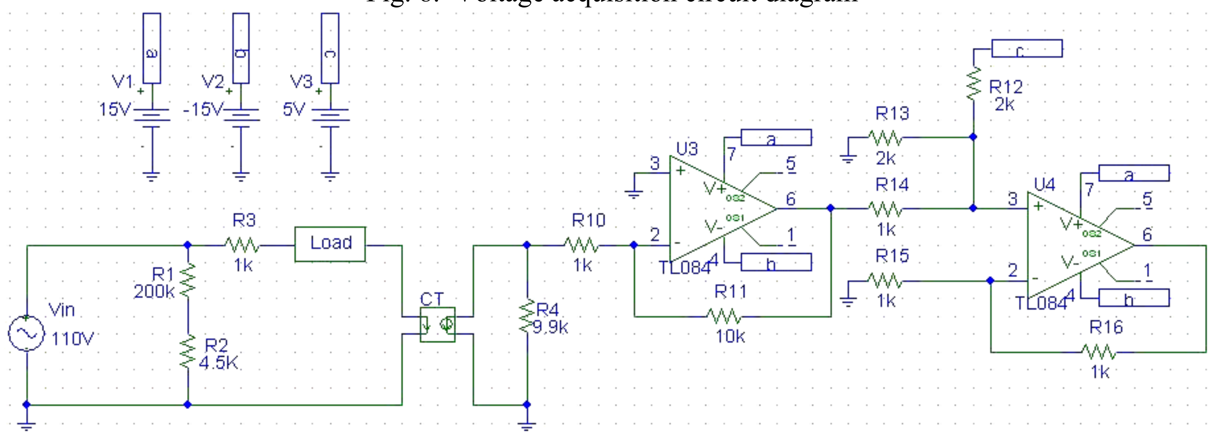

Fig. 10. Current acquisition circuit diagram

3.4 Phase Process

The multiplier circuit of voltage and current is shown in Fig. 11. Using the product of voltage and current to get the phase difference

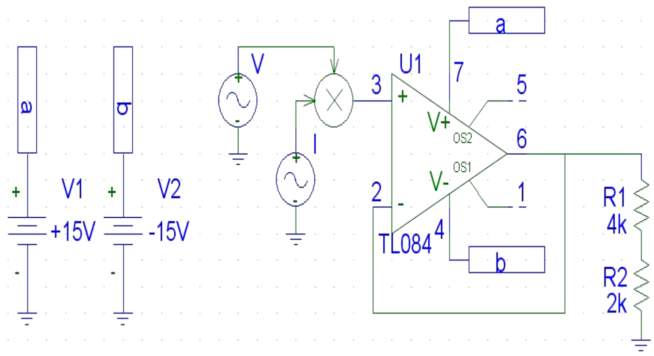

Fig. 11. multiplier circuit of voltage and current

For example: The input value are $V = 2.5\cos(\omega t + 45°)$, $I = 2.5\cos(\omega t + 30°)$

Suppose the angle of voltage and current are θ_1 、 and θ_2, respectively.

$$X = VI = 2.5\times 2.5\cos(\omega t+\theta_1)\cos(\omega t+\theta_2)$$
$$= \frac{6.25}{2}[\cos(2\omega t+\theta_1+\theta_2)+\cos(\theta_1-\theta_2)]$$
$$= 3.125\cos(2\omega t+\theta_1+\theta_2)+3.125\cos(\theta_1-\theta_2)$$

the angle θ can be calculated by the DC term that is the mean value of the waveform.

$$X_{av} = 3.07$$
$$X_{av} = 3.125\cos(\theta_1-\theta_2) = 3.07$$
$$\theta = \theta_1-\theta_2 = \cos^{-1}\left(\frac{3.03}{3.125}\right) = 14.16° \approx 15°$$

Then, the phase difference of voltage and current can be found.

4. Future Development and Application

The system can be applied in the supervision of electric equipments, which not only saves labor cost, but also obtains the signal of equipment timely. The system can be established in every circuitry to monitor the state of equipments and then transmit their signal for analysis. Apart from analyzing the current state of the equipment concerned, the system can utilize its database to compare the state of all equipments to determine if anything needs to be improved and come to know the life-span of the equipment, etc. This not only maximizes the performance of all the equipment, but also minimizes the occurrence of accidents. In addition to simple signal transmission, GPRS is very convenient for the local end or the Host end, convenient for a setup and easy for amateurs to operate.

The development of long-distance electric supervisory system, based on GPRS transmission, is promising. Hence, future research shall focus on an automatic control of the supervisory system, which can automatically control the state of long-distance equipment with the result obtained from analyzing the signal. The system is expected to come into factory, company and even residence for a long-distance supervision, so as to bring security and efficient supervision everywhere.

5 Conclusion

The development of wireless communications has been improving and enhancing the remote monitoring technology. It is an important link of the remote monitoring technology to transmit data or control commands accurately and quickly between the monitoring end and the controlled end. In this paper, a wireless transmission through GPRS network for power equipments monitoring and controlling system is implemented. The GPRS scheme is used in the proposed transmission structure and shows a good performance in the real application. The presented devices for remote monitoring and controlling are tested under Taiwan Power Company with rather encouraging results. It shows the ability for future technique in wireless monitoring of power equipments.

6 Acknowledgment

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