Design and Application Research of WPLC Cross Zone Area Data Acquisition System

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***Abstract*—Common communication mode of electric energy data acquisition in power supply enterprise is PLC (power line carrier) or micro power wireless module with GPRS, but in the area with many mountains, disperse electric users, long distance to read meter, or rural power grid with GPRS or other mobile signal coverage limited, it is unable to realize automatic meter reading. WPLC takes advantage of small distortion of grid voltage and current waveforms to carry information, uses distribution network (10kV and 380V line) as communication medium, and realizes digital bidirectional communication. The WPLC cross zone data acquisition system is applied in a 35kV substation, and is tested after system is stable. Test data analysis indicates that the system performance meet the requirements; The average reading success rate of 10 consecutive days is 97.24%; integrated meter reading success rate is 97.92%; check the differences of daily frozen data, a real-time data and base data of power meter respectively, the correct rates are all 100%; select the zone with the furthest system installation which is 20km away to test, reading success rate is 100%.**

***Index Terms*—WPLC, data acquisition, power frequency distortion, system testing**

I. Introduction

It is a long time since enterprise of power supply takes manual mode to acquire electric energy data from electrical energy meter. At present, Common communication mode of power supply enterprise electric energy data acquisition is PLC (power line carrier) or micro power wireless module with GPRS. They achieve the communication between the collection point and the concentrator of zone area with PLC. Communication between concentrator of zone area and the master station is accomplished by GPRS public network, it works in the city area with short communication distance and users relatively concentrated[1][2], but we also discovered many problems in engineering realization[3]:

(1) In the condition that the acquisition point is far from the zone area, PLC requires several times of relay transmission, routing is not relatively fixed either, multiple relay transmission mode seriously affects the reliability of communication, the one-off reading success rate is not high;

(2) When GSM/GPRS network coverage is limited, or signal is adverse, the application is limited, especially in mountainous areas and remote areas;

(3) Taking GSM/GPRS communication mode, we need to pay for the communication cost to mobile operators every year;

(4) Concentrator of zone area is vulnerable and need regular maintenance and replacement, which means high maintenance cost.

WPLC (Wide Power line communication) takes advantage of small distortion of grid voltage and current waveforms to carry information, use distribution network (10kV and 380V line) as communication medium, and realizes digital bidirectional communication. Traditional frequency of PLC modulation signal is 100kHZ~120kHZ, the signal frequency of broadband power line carrier modulation is a few ~ tens of MHZ, while signal frequency of WPLC modulation is 100~400HZ, so attenuation of signal in power line is smaller than traditional PLC, it realizes communication with 10KV line, transformer, 220/380V line as medium, long distance transmission, signal through distribution transformer, signal transmission without relay between two power lines with different voltage levels, resistance against signal attenuation, strong anti-interference ability, high reliability[4][5]. WPLC communication technology uses existing power lines, no running cost, communication cost is 0.

Yunnan province and southern power grid face geographical environment with many mountains. In rural power grid with disperse electric users, long distance to read meter, or rural power grid with GPRS or other mobile signal coverage limited, it is unable to make automatic meter reading.

Considering the above problems, it is necessary to seek a new electric energy data acquisition method which does not need communication cost with convenient maintenance, as supplement of existing PLC meter reading system, so WPLC communication technology

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can meet the requirements of communication in rural power grid.

II. DESIGN OF WPLC CROSS ZONE AREA DATA ACQUISITION SYSTEM

A. Structure of WPLC cross zone area data acquisition system

WPLC cross zone area data acquisition system is consists of main station management system software, application Web server of station master station, inner station concentrator, data acquisition terminal and modulation device generating modulation signal, etc. It is showed in Figure 1 (system structure diagram).

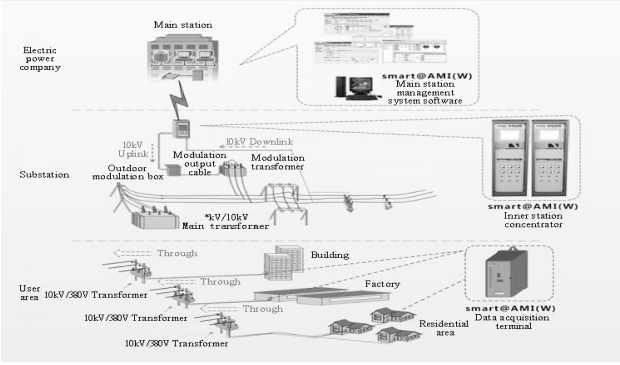

Fig.1 Structure of WPLC cross zone area data acquisition system

The entire communication is master/slave mode, we can read data from inner station concentrator (substation end) directly or from remote operation through MODEM and optical fiber in companies operating room. Inner station concentrator give orders by control modulation device of modulation signal (command) to remote terminal (user area), each acquisition terminal judges address information is same to itself or not based on received information, when it is same, execute inner station concentrator command, inner station concentrator acquires information through acquisition plate from acquisition terminal. After that, we take analysis operation on information by host computer software to obtain required correct information.

B. Function of WPLC cross zone area data acquisition system

(1) Management of resident user meters

Maintain information of user and meter, freeze readings of user meters automatically, collect and save readings of power meters automatically.

(2) Management of zone area meters

It maintains zone area and information of meter, freeze readings of zone area meters automatically, collect readings of meters automatically.

(3) Management of amount of electricity supply and sales.

It can achieve freezing readings of inner station gateway meter, zone area meter, user meter, low pressure and 10kV line loss statistics.

(4) Data acquisition part

Function of inner station concentrator

Inner station concentrator is installed in 35kV/10kV or 110kV/10kV substation, it takes transformer substation as collecting unit to collect information from meters of transformer substation electricity users, special transformer and zone transformer. It is in charge of commands issuing and collected data receiving of subordinate collection objects, including parameter settings, voltage zero crossing detection and modulation, acquisition of current signal, signal decoding, self diagnosis, time adjusting etc..

Outdoor modulation box

Outdoor modulation box is installed in user transformer or zone transformer which capacity is 2% or more of main variable capacity, to generate modulation signal for data transmission.

Acquisition terminal

It is gathering equipment which is installed in electric end. Acquisition terminal can realize voltage acquisition, electrical energy accumulating, receiving concentrator commands, data transmission, testing and presetting channel, outage data preservation, and communication with 485 meter, power control.

C. Realization process of data acquisition system

Data acquisition includes commands transmission from inner station concentrator to acquisition terminal and communication from collection terminal to inner station concentrator.

Inner station concentrator terminal voltage is bus voltage which is 10kV, so we need to isolate step-down modulation by transformer modulation. Change signal is caused by transient breakover of voltage near zero crossing point in controlled silicon. When change happens is entirely decided by computer or microcomputer which controls controllable silicon.

Acquisition terminal is directly connected to low voltage user (220V), it control silicon make transient breakover near voltage zero, then controlled silicon transient breakover, which lead to produce of peak current. It adds to load current, which cause small changes of load current. Expressed as "0 " or " 1 ",small changes of voltage and current can become identifiable information after signal processing[6].

(1) Downlink communication process

According to instruction of collection system of master station, we send downlink modulation control signal to outdoor modulation box. According to modulation control signal, trigger unit of outdoor modulation box sends a trigger signal to control silicon. Controllable silicon is connected to the 380V side of modulation transformer (3phase), it make voltage waveform modulation on low voltage side of transformer. Because 10kV side of modulation transformer is connected to 10kV bus of transformer substation, all 10kV outlet on AC voltage waveform produces a small transient changes at zero crossing. When power frequency voltage information of every 10kV outlet cross user transformer, to transformer connected to all passed into low pressure (380V) user data acquisition terminal, which means completing downlink communication process in way of broadcast. Downlink communication

signal contains address information and instruction information.

(2) Uplink communication process

In downlink communication processes, all user side collection terminals received address information and instruction information from master control panel, each terminal has a preset address from main control unit, collecting terminal only executes corresponding instruction information of terminal address, and in accordance with instructions, it reads electricity meter data through connection to user electric energy meter 485 port, main control unit is responsible for uploading data to inner station concentrator, which is uplink communication process. Specific implementation process is: main control unit of data acquisition terminal sends uplink modulation control signal, and control silicon in low voltage side (380V) to produce a current waveform changes. This current waveform changes of signal passed to 10kV side across user transformer, after crossing 10kV power line it reach distribution substation, where every 10kV outlet has CT. Current waveform change information on CT is received by station concentrator uplink signal parallel demodulation receiving unit, processing and demodulating data signal uploaded to acquisition terminal of main control unit. Data is uploaded to site concentrator collection master database by inner station concentrator, which means uplink communication process is complete.

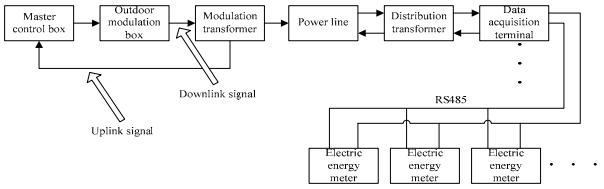

Fig. 2 Data collection process

III. WPLC CROSS STATION DATA ACQUISITION SYSTEM

The system is applied in Yunnan power grid 35kV Song Yang substation. Main transformer capacity is 20000kVA. Songming area had built PLC system, it takes GPRS/GSM/CDMA as communication channel, which only solve 50% low voltage electric energy meter electric energy information acquisition of stage zone. But in remote and mountainous areas, it is impossible to realize meter reading automatically because of are wide, residents dispersed, none GPRS/GSM/CDMA public network signal or poor quality signals. Application of WPLC cross station data acquisition system, solved problems of these areas such as it is difficult to read user meter, electricity information cannot upload in any network signal covered area.

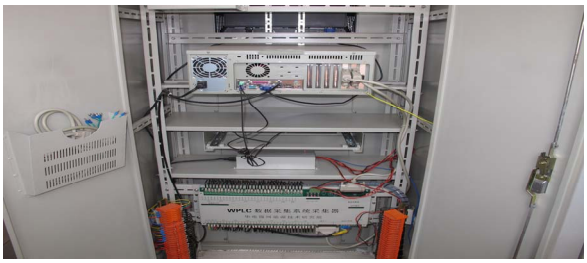

Fig. 3 Inner station concentrator of data acquisition system

Fig. 4 acquisition terminal of data acquisition system

Song Yang substation low-voltage distribution indoor installation site concentrator, is main gathering point of power consumption data collection; 10kV Dong Song II, loop town dedicated transformer for low-income urban leading group (S11-M-400) is installation transform of modulation box; 10kV Ⅰ SongDong Ⅰ loop, 10kV East Village II line, 10kV East Village line is distal test of long power supply distance line; wall cat cyanine area, Bi Mao-jing, Yu Ming Garden Community, East Village, West Village 1# area, 2# area are collection objects.

As shown in Table I, it is study on measuring point arrangement.

TABLE I. STUDY ON MEASURING POINT ARRANGEMENT

Zone Area	Measuring point number (a)	10kV line	Communication distance	Zone Area transformer
Bi Mao-jing	9	10kV East Village II line	15km	S11-M-50
Yu Ming Garden Community	215	10kV SongDong Ⅰ loop	5km	S11-M-800
East Village	260	10kV East Village line	18km	S11-M-160
West Village 1#	67	10kV East Village II line	20km	S7-50
West Village 2#	24	10kV East Village II line	20km	S11-M-50
Total	575			

As shown in Figure 5, it is installation distribution diagram of WPLC cross zone area data acquisition

system on-site equipment.

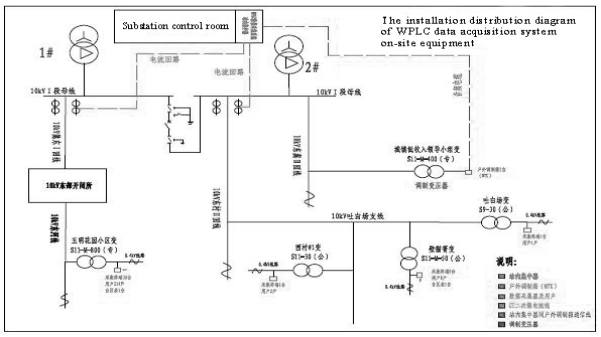

Fig. 5 Installation distribution diagram of WPLC data acquisition system on-site equipment

IV. SYSTEM TEST AND ANALYSIS OF TEST DATA

Entrusted by Songming power supply Co.Ltd, Yunnan Electric Power Research Institute test WPLC cross station data acquisition system of 35KV Song Yang substation in three aspects that master functionality, acquisition terminal function and performance of system. The test is made according to corresponding regulations of country, South Power Grid Corp, Yunnan Power Grid Co, and it is combined with technical requirements of actual work.

The test on station zone on daily meter reading success rate is performed through choice of test zone area, setting test data items and frozen time. Then we compare results of master station with actual data of power meter. The test result is shown in table II.

TABLE II. DAILY READING SUCCESS RATE OF ZONE AREA

Testing comprehensive results				
Basic situation		Day freeze data		
Name	Start-stop date	Day collection total number	Day collection total success number	Day acquisition success rate
Bi Mao-jing	2012/05/09-2012/05/18	80	77	96.3%
Yu Ming Garden Community	2012/05/09-2012/05/18	2040	2006	98.3%
East Village	2012/05/09-2012/05/18	2510	2405	95.8%
West Village 1#	2012/05/09-2012/05/18	670	670	100%
West Village 2#	2012/05/09-2012/05/18	240	229	95.4%
Comprehensive test results	/	5540	5387	97.24%

Test of success rate of meter one-off reading is erformed through choice of test zone area, setting test

Data reliability test is performed through choice of test area, setting test data item, master display results with actual data are compared respectively meter; checking consistency of daily frozen data, one-off meter reading data and meter bottom data respectively. Test results are shown in Table III, table IV.

Master station system meter reading E and real power meter reading E0 should satisfy the formula (1)

data items and frozen time. Then we compare results of master station with actual data of power meter.

$$\left|E-E_0-\Delta E\right| \le 0.05E_0+1\times10^{-(\alpha+1)}+\gamma\times10^{-\beta} \quad (1)$$

In the formula, ΔE means D-value of E and E0 when initializing; α means decimal of user electric energy meter register; β means decimal of system electric energy reading; γ means carry error, when $\left|E-E_0-\Delta E\right| \ge 0$, $\gamma=0$,when $\left|E-E_0-\Delta E\right| \le 0$, $\gamma=1$.

TABLE III. ACCURACY OF DAILY FREEZE DATA

Zone area	Accuracy of daily freeze data			Results
	Number of meters	Correct number	Over error number	Success rate
Bi Mao-jing	8	8	0	100%
Yu Ming Garden Community	200	200	0	100%
East Village	200	200	0	100%
West Village 1#	67	67	0	100%
West Village 2#	24	24	0	100%

TABLE IV. ACCURACY OF REAL-TIME DATA

Zone area	Real-time data accuracy			Results
	Number of meters	Correct number	Over error number	Success rate
Bi Mao-jing	8	8	0	100%
Yu Ming Garden Community	200	200	0	100%
East Village	200	200	0	100%
West Village 1#	67	67	0	100%
West Village 2#	24	24	0	100%

The test on distance of communication is performed through selection of the furthest zone area, setting test data item, testing reading effect of the furthest zone area. Test results are shown in table V.

TABLE V. COMMUNICATION DISTANCE

Name of zone area	West Village 1#	Number of test meters	67	Distance of communication	20km
Real-time copy					
Serial number of test	Numbers of actual read meters	Start time	Finish time	Time consume	Success rate
1	67	2012-05-18 21:48:15	2012-05-18 21:59:15	660 s	100%
2	67	2012-05-18 22:08:05	2012-05-18 22:18:45	640 s	100%
3	67	2012-05-18 22:31:34	2012-05-18 22:42:25	669 s	100%
4	67	2012-05-18 23:07:38	2012-05-18 23:18:14	624 s	100%
5	67	2012-05-18 23:23:20	2012-05-18 23:33:55	635 s	100%
Average		/	/	645.6 s	100%

V. SUMMARY

WPLC takes advantage of small distortion of grid voltage and current waveforms to carry information, makes signal cross transformer to realize communication, and transmits electric user meter data remotely to substation directly[7]. The system is applied in 35kV substation of Song Yang, and is tested after system operates stably. Analysis of test data indicates that system function meets requirements; average reading success rate 10 days consecutive test is 97.24%; comprehensive meter reading success rate is 97.92%; check differences of daily frozen data, one-off real-time data and power meter N base respectively, correct rates are all 100%. The system has advantages of simple structure, reliable operation, at present, it is the best method to resolve centralized meter reading of areas which are no mobile signal covered, remote or have dispersed users.

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