

Research on the Power Information Collector of Optical Fiber Based on EPON Technology

Yannian Wu, Yinggang Zheng, Zhibin Zang, Xiaohui Song, Yongbo Liu

Beijing R&D department of Gridcom Co.,Ltd China

wuyannian@sgepri.sgcc.com.cn, zhengyinggang@sgepri.sgcc.com.cn, zangzhibin@sgepri.sgcc.com.cn,
songxiaohui@sgepri.sgcc.com.cn, liuyongbo@sgepri.sgcc.com.cn,

Abstract—EPON(Ethernet Passive Optical Network) technology is a new kind of fiber optical broadband access network technology. The EPON system mainly includes OLT, ONU and ODN. It inherited the low cost of Ethernet and the high bandwidth of light network, so it has Broad prospects of application in the Residential electricity information collection fields. Based on above, this paper combines the characteristics of EPON technology and the requirement of information collection system in the Residential electricity, developed a design and application methods of Optical Fiber collection terminal equipment for the power consumption data acquisition system based on EPON technology, which is an important application part of EPON system. This paper mainly studies the hardware and software design of Optical Fiber collector, and its application in the Lain Xiang Community in Beijing.

Index Terms—EPON, ONU, Optical Fiber Collector, eCos System, Smart community

I. INTRODUCTION

EPON(Ethernet Passive Optical Network)is a new technology that adopts one-to-multi-points topology, realizes data transmission on the physical layer by optical fiber and optical passive devices, and provides various internet accesses by Ethernet. It is comprised of OLT (Optical Line Terminal), ONU (Optical Network Unit) on consumer side, and ODN (Optical Distribution Network), and can be flexibly organized into tree topology, star topology, bus topology, etc (e.g. [1]).

Manuscript received Jan 28, 2013. This work was sponsored by the National State 863 projects of China, the project "Research and Development of Intelligence with power information and communications technology" Grant No.2001AA05A116, it was also supported by National State Grid Corporation.

Yannian Wu is with the Department of Beijing Research Center at company of China Gridcom. Beijing, China (Tel:86-13651374161; fax: 86-010-51964890; email: wuyannian@sgepri.sgcc.com.cn).

Yinggang Zheng is with the Department of Beijing Research Center at company of China Gridcom. Beijing, China (Tel:86-13105123823; fax: 86-010-51964890; email: zhengyinggang@sgepri.sgcc.com.cn).

Zhibin Zang is with the vice-general manger at company of China Gridcom. Beijing, China (Tel:86-13501025419; fax: 86-010-51964800; email: zangzhibin@sgepri.sgcc.com.cn).

Xiaohui Song is with the Department of Beijing Research Center at company of China Gridcom. Beijing,China(Tel:86-13843589756; fax: 86-010-51964890; email: songxiaohui@sgepri.sgcc.com.cn).

Yongbo Liu is with the Department of Beijing Research Center at company of China Gridcom. Beijing,China(Tel:86-15810510126 fax: 86-010-51964890; email: songxiaohui@sgepri.sgcc.com.cn).

EPON technology combines the advantages of both passive network and Ethernet technologies, with a transmission rate of both upstream and downstream reaching 1.25Gbps. It is featured with high-reliability, low maintenance cost, high compatibility with multiple topologies and interfaces, hence an ideal communication solution for the power system, which satisfies the unique requirements of network structure, security, maintainability and interface types for utilities.

Power consumption data collectors of traditional communication mode are well developed and widely applied. Collectors, concentrators and meters are integral parts of traditional power consumption data acquisition system. Differences between various solutions lie in the adoption of communication methods, such as GPRS, CDMA, RS485, carriers, and other integrated methods. The main problem regarding PLC is the rapid attenuation of high-frequency signal in low-voltage grids, while the GPRS and CDMA are affected by package loss, limited maximum rate, long switching delay, operation instability, uncertainty of fault processing time (e.g. [2]). The communication architecture of the system consists of two layers: one is communication between master station system and concentrators, called remote communication; the other is the communication between concentrators and meters, called local communication. Since the collecting points are numerous and collecting intervals short, large amount of data will come out. Thus it is ideal to adopt EPON optical fiber technology with broad bandwidth, low cost, and high scalability in the remote communication between master station system and concentrators to collect real-time, accurate and reliable power consumption data. In addition, EPON is compatible with current Ethernet technology, and can be easily maintained and managed. This paper focuses on the design and development of ONU, which is the key part of power consumption data acquisition system. By means of joint debugging of OLT and master station system, ONU has met its design requirements and SGCC (State Grid Corporation of China) standards.

II. OPERATING PRINCIPLE AND APPLICATION SOLUTIONS OF EPON SYSTEM

The EPON is the primary type of PON technology that reduces Optical Fibre deployment dramatically while preserving the merits of Ethernet networks. EPON is based on the IP/Ethernet structure. Currently, the IP/Ethernet implementation accounts for more than 95% of the total LAN

communications. With this cost-effective and efficient structure, the EPON becomes the most effective way to connect the end users to the access networks. The emergence of the 10 Gb/s Ethernet backbones and the metropolitan area rings also makes EPON the optimal last-mile solution of the future all-optical networks.

A. Operating Principle of EPON

In this paper, ONU refers to the equipment integrating traditional ONU and power consumption data collector, which is called optical fiber collector. Through single-mode bi-directional optical fiber, the upstream and downstream data of EPON has realized full-duplex communication by WDM (Wavelength Division Multiplexing) with a data rate of 1.25 G b/s. The downstream communication (from OLT to ONU) adopts TDM (Time Division Multiplex) broadcasting mode. The data is broadcasted from OLT down to all ONU by variable length information packet, and the maximum length of information packet can be 1518 bytes. Based on LLID (Logical Link Identifier), ONU receives packets that belongs to it and abandons other packets (e.g. [3]). The wave length of downstream communication is 1490 nm. The upstream communication shares the system by TDMA (Time Division Multiple Access). For each ONU upstream data, a private timeslot is allocated to ensure that only one ONU is sending upstream data at a time. The procedure is as follows: all data is marked with a unique LLID tag at ONU, then the OLT will allocate each registered ONU with a LLID tag, and finally the data is sent to OLT according to its timeslot. More details about the registration phase can be found in the current version of the IEEE 802.3ah standard as well as in [4]. The wave length of upstream communication is 1310nm.

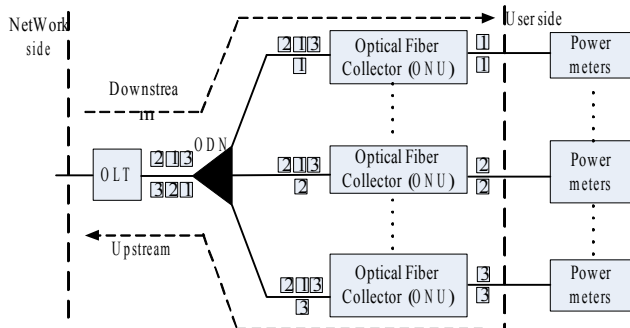


Fig. 1. Typical network diagram of EPON

As the branch-side equipment of EPON network, OLT aggregates data from ONU, which provides internet ports and other interfaces on consumer side. Each ONU transmits the customers' Ethernet frames to the OLT in the transmission timeslot which is assigned by the OLT. ODN is a 100% optical network of different topologies enabled by splitters of various split number and split ratio. EPON system adopts the broadcast method in downstream direction. Ethernet frames of different ONU are transmitted in one downstream timeslot. The packet which carries all the ONU data reaches different ONU and each ONU only extracts its own data frames and

transmit them to the users while others frames are discarded. The architecture of the EPON systems is illustrated in Fig.1 (e.g. [5]).

B. Application Solution

With optical fiber communication, the dedicated network of power system can be divided into two parts: the optical fiber backbone network and the optical fiber access network. The backbone network is comprised of SDH (Synchronous Digital Hierarchy) equipment, while the access network is comprised of EPON equipment. This article mainly focuses on the access network, which is directly applied in the local communication of power consumption data acquisition system.

In communities, as network-side equipment, OLT is both a switch or router and a multi-service platform which provides EPON-oriented optical interfaces. Besides the network assembling and access functions, OLT could also perform bandwidth assignments, network security and management configurations according to the customers' different QoS/SLA requirements. In electric power collection system OLT directly gets access to the acquisition server (master station system) by Ethernet in engine room, and works as a data bridge between master station system and ONU, providing PON interfaces for ONU. ODN is mainly composed of one or more passive optical splitters which connects OLT and ONU, and provides optical transmission channel between the two sides. It allocates the optical signal power, and split downstream signal from one fiber into several fibers and combine optical upstream signals from multiple fibres into one, the optical ratio can be 1:8, 1:16, or 1:32, and can be connected to each other. The longest distance the ODN can cover is 20 kilometres.

As the core part of power consumption acquisition system, ONU reach meters through RS485 bus, and collects power consumption information of end users. At present, each ONU can collect data from 32 meters, and its basic functions are in line with the specifications of SGCC. In a power consumption acquisition program based on EPON (e.g. Fig. 2), ONU collector refers to the power optical Fibre collecting equipment.

III. H&S DESIGN OF ONU

ONU adopts the idea of embedded and modular design. Compared with upstream GPRS, CDMA and 230MHz dedicated network of traditional concentrators, ONU takes optical Fibre as its communication medium. This has greatly improved the timeliness, stability and security of meter reading, hence an essential difference from traditional concentrators in terms of hardware structure. This design is expected to reach the goal is that the throughput performance, in multi ONU case, the upstream is greater than 90%, the downstream is greater than 95%; The overload packet loss rate, upstream is less than 10%, downstream is less than 5%; The forward delay, downstream is within 500us ,while the upstream within 1.5ms or less.

A. Hardware Design of the System

The hardware of ONU mainly consists of 4 parts: EPON processor module, optical transceiver module, power supply module, FE interface module, bus and storage module (e.g. Fig. 3).

The core part of ONU is EPON processor module, which adopts the PCC8016 chip solution of CORTINA. This kind of chip is a single-chip solution functioned with traffic management and dispatching. It has built-in frame buffer,

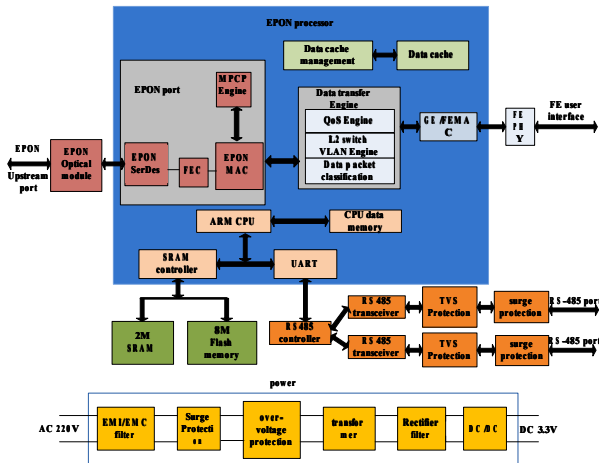


Fig. 3. Hardware schematic of Optical Fiber collector

Gigabit PON interface, serial port, JTAG debugging interface, FLASH and SRAM interfaces, and 5 volts power supply. And a built-in ARM-9 processor is responsible for management and control. As a standard IEEE 802.3ah compatible chip, it supports EPON Technological Specifications of China Telecom and MPCP (one-to-multi-points control protocol). The entire EPON system realizes the discovery and registration of ONU by means of MPCP Protocol (e.g. [6]). The operation principle of the MPCP mechanism can be explained as follows: the whole available upstream channel bandwidth is divided into transmission units (typically termed slots) using the Time Division Multiplexing (TDM) technique, which can be assigned to the active ONU (more specifically to the respective LLID) based on the DBA mechanism under operation in the OLT central packet schedule (e.g. [7], [8]). On consumer side, PCCS8016 also provides wide range of QoS (quality of service) and traffic management functions to guarantee that the bandwidth, delay, and jitter of each ONU are satisfied when the traffic is allocated by SLA. The optical module of this system adopts LTB34D2 and Optical transceiver provided by Hisense. The optical transmission distance of this module can reach 20 kilometers. The FE interface module for consumer business is a high speed Ethernet interface, which provides operation control platform for consumers and work as the debugging supporting interface for maintainers in the operation of ONU.

The Optical module of this system adopts LTB34D2 serials provided by Hisense. The Schematic of Optical transceiver is illustrated by Figure 4. The module incorporates 1310 nm burst-mode transmitter and 1490 nm continuous-mode receiver. An integrated WDM coupler can separate 1490nm

input laser light and 1310nm output laser light. The Optical transmission distance of this module can reach 20 kilometres. The FE interface module for consumer business is a high speed Ethernet interface, which provides operation control platform for consumers and work as the debugging supporting interface for maintainers in the operation of ONU.

In the process of power consumption data acquisition, as the core equipment, ONU receives meter-reading order from master station and handles it. The upstream communication uses optical fiber, while the downstream communication with meters uses RS485 bus.

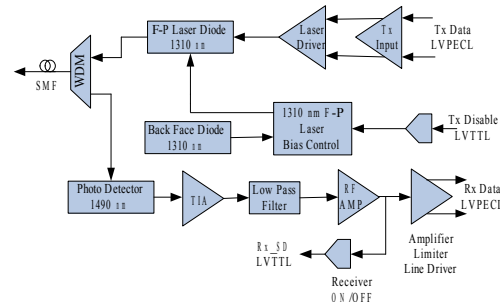


Fig. 4. Schematic of EPON Optical module

Tailored to the meter-reading system, a RS485 controller chip MAX3082 is added to the PCCS8016 processing chip to facilitate the switch from serial port to RS485 interface. For the bi-path RS485 interface, one path is used to connect RS485 BUS of meters; the other is used as engineering maintenance interface as well as meter connection. The extended FLASH is used to solidify the bootstrap and store data document of automatic meter reading. It is also functioned with data freezing, historical and curve data storage. The JS28F128 FLASH has a capacity of 16M, which basically meets application requirement. The SDRAM (HY57V1601 by HYNIX, 16M) is mainly used for operating system document copy from FLASH and caching of applications. The power supply module is also a key part of the system. It not only supports EMC, but also provides surge protection. With filter and transformer, it can provide a service voltage of 3.3 volts for the chip. In addition, the system has the function of hard clock. It uses the SD2405, high-accurate and real-time clock chip of built-in battery to realize the clock synchronization of the master station and collecting terminals of power consumption data acquisition system.

B. Software Design of the System

The software of ONU adopts embedded design idea. This article will skip protocols relating the upper layer OLT and focus on applications. Considering the real-time requirement of power consumption data acquisition system, the operating platform of ONU adopts the eCos (embedded Configurable operating system) by RedHat. This open source system is a configurable, portable, royalty-free, and real-time operating system for deeply embedded applications. Compared with Linux, the advantages of eCos lie in its flexible configurability, and less occupied kernel space, which makes it suitable for the

cost-sensitive terminals of power consumption data acquisition. Fig. 5 illustrates the software framework of the system. Similar to other embedded equipment, the bottom layer of the system as BSP (Board Support Package) are device drivers such as serial port, internet port, clock, FLASH, etc., enabling upper layer applications to access the hardware. The eCos realizes thread management, thread dispatch, interrupt and anomaly handling, and synchronization of the system on the platform layer.

According to the requirements of power consumption data acquisition system, the software adopts modular design. All the modules are independent threads, and communicate by message mechanism such as mailbox, queue and shared data structure. `Cys_user_start()`, the main function of applications,

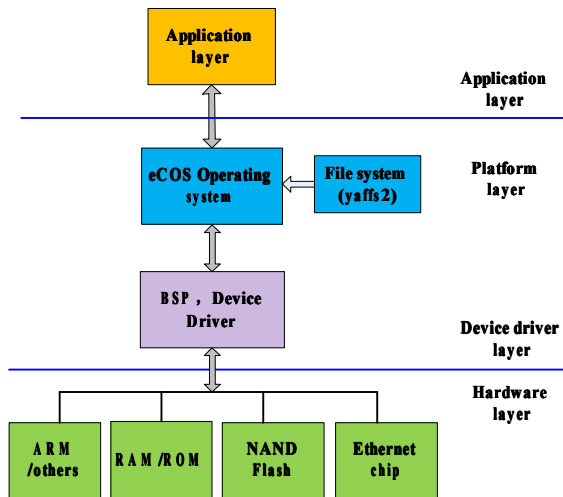


Fig. 5. Software diagram of Optical Fiber Collector

is responsible for creating main threads regarding to specific tasks, including:

- 1) *ONU_heart_thread and Task_thread:*** Responsible for Freeze data of day, Freeze data of month and Freeze curve of meters for one month.
- 2) *Read_meter_rs485_thread:*** Responsible for meter reading by collector at fixed intervals.
- 3) *Rx_thread and term sever rx_thread:*** Responsible for sending data to RS485 meters from collectors and finish relevant protocol conversion.
- 4) *Protocol_Comm_thread:*** Responsible for the protocol data analysis and processing for the master station and meters.
- 5) *Term_client_thread:*** Responsible for the interaction between data and the master station.

All the threads are interdependent and compose the software of entire meter reading system.

IV. APPLICATION OF OPTICAL FIBER COLLECTORS IN SMART COMMUNITY

Smart community contains the power information collection, interactive services, residential distribution automatic, distributed power and energy storage of user side, electric vehicles charging, smart home furnishing and some new technological achievements. Smart community aims to achieve both economic growth and a low-carbon society. With this convenience community can achieve reliable power supply and the electricity consumption information is collected automatically. The smart community management system can promotes environmental quality improvement and energy saving in diverse urban activities. Optical Fibre Collectors make sure the power consumption information is real-time acquired and make some guides to there users.

A. Deployment of ONU Collectors

Deployment of optical Fibre collectors as the key of smart power consumption has been finished in Lain Xiang Community, the first smart community of commercial operation in Beijing.

Figure 6 illustrates the distribution of optical Fibre collectors in 2 buildings of Lain Xiang Community. About 20 collectors were installed; each of them covers 2 floors. Data from up to 700 meters is then time multiplexed by the splitter and transmitted to OLT and the master servers system in the basement. The master system can read meters at real time and store these data information into the local database, and the master station system can be connected to the public network.

Figure 7 shows an on-site installation of Optical Fibre Collector in Lain Xiang smart community. The Optical Fibre using OPLC (Optical Fibre Composite Low-voltage Cable) ensures high reliability of data transmission. With a smart home gateway, consumers can gain access to the database and

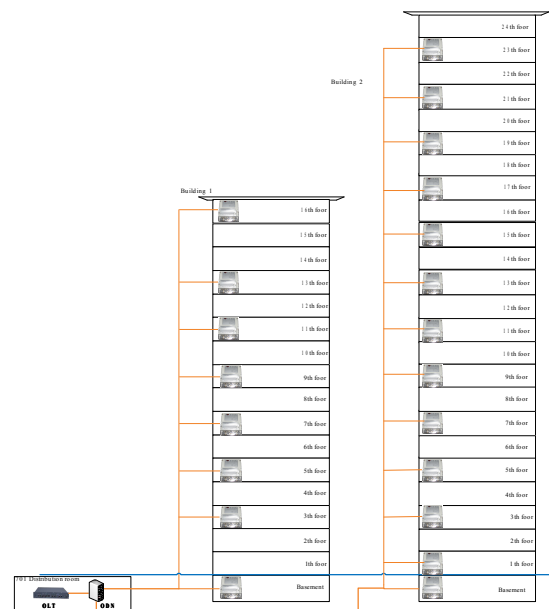


Fig. 6. Deployment diagram of Optical Fiber collector in the L.X.Y Community

check their daily or monthly power consumption information.

B. Comparison of Collection Success Rate

Collection success rate of meter reading system is the main purpose for electric power company, the ultimate goal is full coverage, full collection and full cost control. Base on above, the Optical Fibre Collectors arise at the historic moment. Table 1 show reading meters using Optical Fibre Collectors in

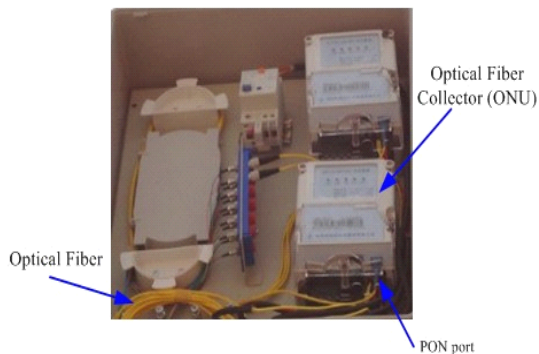


Fig. 7. On-site installation diagram in smart community

Lain Xiang community and table 2 shows reading meters using Power Line Carrier Collectors in Hue Xian community similar as Lain Xiang community, from November 1th. to 15th. In 2011. In the table user num refers to the meter numbers, collect num refers to the success reading numbers of meter, purchase num refers to the times of user purchase power, and sending num refers to the master station send purchase power data to the meters. Comparison between the two tables we can easily find the Optical Fibre Collectors have outstanding collect rate than the Power Line Carrier Collectors. This will be a trend by using ONU Collectors for electric power company make a choice for future Collector purchase and deployment.

TABLE 1. READING METERS USING OPTICAL FIBRE COLLECTORS

Date	Optical Fibre Collector (or ONU)					
	User Num	Collect Num	Collect Rate	Purchase Num	Sending Num	Sending Rate
11/1	694	694	100%	68	68	100%
11/2	694	693	99.9%	17	17	100%
11/3	694	694	100%	8	8	100%
11/4	694	694	100%	23	22	95.7%
11/5	694	694	100%	21	21	100%
11/6	694	694	100%	16	16	100%
11/7	694	694	100%	13	13	100%
11/8	694	694	100%	9	9	100%
11/9	694	694	100%	5	5	100%
11/1	694	694	100%	15	15	100%
11/1	694	694	100%	11	11	100%

TABLE 2. READING METERS USING POWER LINE CARRIER COLLECTORS

Date	Power Line Carrier Collector (or PLC)					
	User Num	Collect Num	Collect Rate	Purchase Num	Sending Num	Sending Rate

11/1	815	808	99.1%	9	6	66.6%
11/2	815	808	99.1%	13	13	100%
11/3	815	805	98.7%	13	13	100%
11/4	815	807	99.0%	9	7	77.7%
11/5	815	786	96.5%	13	10	76.9%
11/6	815	808	96.1%	10	9	90%
11/7	815	800	98.2%	8	7	87.5%
11/8	815	804	98.6%	11	11	100%
11/9	815	808	96.1%	12	11	91.6%
11/1	815	800	98.2%	7	6	85.7%
11/1	815	809	99.2%	15	15	100%

V. CONCLUSIONS

In this paper, we presented the development background of EPON technology, studied the development present situation and the application situation at home and abroad, and then proposed a new method for power information collection system using Optical Fibre Collector based on EPON technology. The implementation of power consumption information acquisition system is a vital part of smart grid construction, and is in line with the development of international grid technology. As a representative smart grid technology, power Fibre to home has been widely supported by the government and State Grid. Power Fibre communication network has covered more and more communities, providing residents with power consumption information acquisition services. Optical Fibre collectors based on EPON technology will be the mainstream of future power consumption information acquisition system.

ACKNOWLEDGMENT

The authors would like express their gratitude to the National State 863 projects, the project "Research and Development of Intelligence with power information and communications technology" with NO.2001AA05A116. The authors also would like express their gratitude to the Engineering Department of Gridcom, they provide over all project drawing paper.

REFERENCES

- [1] F.J. Effenberger, T.S. El-Bawab, "Passive optical networks (PONs): Past, present, and future," Optical Switching and Net- working, Vol.6, No.2, pp.143-150, 2009.
- [2] Gao Feng, Dong Yabo, "Signal Transmission Characteristic Analysis In Low Voltage Power Line Carrier Communication," Chinese Journal of Automation of Electric Power Systems, Vol.7, pp.15-19, 2008.
- [3] SUN Zhongwei, WU Juying, "Identity-based Access Control for Distribution Automation Using EPON," Chinese Journal of Electronics, Vol.20, No.3, 2011.
- [4] G. Kramer, Ethernet Passive Optical Networks, 1st ed., New York: McGraw-Hill, 2005.
- [5] Zhang Hao, Bu XianDe, "Application of EPON Technology in Power Consumption Information Collection System," Chinese Journal of Automation of Electric Power Systems, Vol.213, pp.42-45, 2010.
- [6] S.S. Roh, S.H. Kim, "Security model and authentication protocol in EPON-based optical access network," IEEE ICTON, pp.99-102, 2003.
- [7] H.-J. Byun, J.-M. Nho, J.-T. Lim, "Dynamic Bandwidth Allocation Algorithm in Ethernet Passive Optical Networks," IEEE Electron. Letters, vol. 39, pp.1001-1002, 2003.

- [8] M.P. McGarry, M. Maier and M. Reisslein, "Ethernet PONs: A survey of dynamic bandwidth allocation (DBA) algorithms", IEEE Commun. Mag., Vol.42, No.3, pp.8–15, 2004.



Yannian Wu He was born in Liaoning Province, China. He received his M.Sc. degree in 2006 and major in Communication and Information System from Beijing University of posts and telecommunications. Since October 2009, he was an Electrical Engineer at company of China Gridcom in the Department of Beijing Research Center. His current research interests include Modeling and control of power electronics systems, Optical fiber communication systems, Analysis and Control of Dynamic Systems, robust and adaptive controls, and

Power and Control Systems technology.



Yinggang Zheng He was born in Shandong Province, China. He received the B.Sc. degree in 2001 and major in computer science technology and application. Since October 2009, he was an Electrical Engineer at company of China Gridcom in the Department of Beijing Research Center. His current research interests include process modeling, system identification, adaptive control, self-tuning control, optical fiber sensing technology and power information collecting technology.



Zhibin Zang He was born in Heilongjiang Province, China. He received the M.Sc. degree in Guanghua School of Management, Peking University. Now, he was vice-general manager at company of China Gridcom. His current research interests include Power system automation, system identification, optical fiber sensing technology and power information collecting technology.