Design of Transmission Tower Inclination Remote Online Monitoring System

Junlong Fang, Zhaoyang Zhao, Jin Zhang, GuifangZhang, Tu Luan, Donghai Yang

College of Electric and Information, Northeast Agricultural University, Harbin, 150030, China

***Abstract* — A transmission tower inclination remote online monitoring system was designed to overcome the problem of inaccurate and not immediate feedback of transmission tower inclination information during manual line patrol. Certain amount of transmission tower within the region connected through ZigBee network, and each tower monitor node could successively send collected inclined tower information to the monitoring Coordinator. The Coordinator collected regional microclimate information and meanwhile packed information of each node and uploaded to monitoring center through GPRS. The monitoring center would then process, real-time display and restore the information. Each node used solar energy and battery as power and chose low power consumption devices. Under practical operation test, the precise systematic monitoring information, stable wireless network and reliable systematic performance can meet the need of engineering application.**

Keywords - Transmission tower; Inclination; Online monitoring; Wireless network

I. INTRODUCTIOS

The transmission tower plays an important role in transmission network, however, the rain, snow and gale and other natural disaster as well as soil subsiding, engineering construction, man-made sabotage and other reasons always make transmission tower to incline and result in interruption of electric transmission line, which have great impact on national defense, industrial and agricultural production and daily life. Besides, electric transmission line is easily affected and interrupted by regional meteorological environment. The single manual patrol that are mostly applied in electric system not only consume large amount of human labor and material resources, but also has major potential risk due to not immediately discovery of tiny and tapered inclination of tower.

II. TOWER INCLINATION DETECTION METHOD

A common method to confirm systematic inclination is integrating gyro output. But with increased integration periods, the related systematic error would rapidly enlarge as well. Therefore, in this paper, a tri-axial accelerometer is used to measure inclination angle of tower.

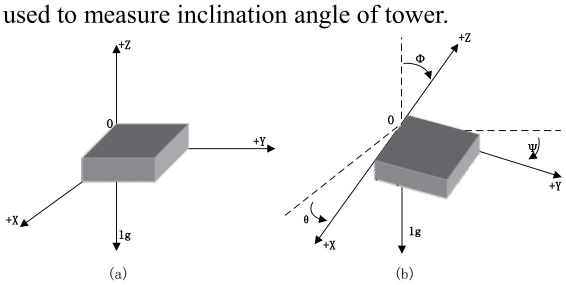

Fig.1 Angles for inclination sensing

As shown in Fig 1a, when a tri-axial accelerometer is placed horizontally, the x and y axial are located in a horizontal field to form 0g field, and Z axial is perpendicular to horizontal line to form 1g field. The state of accelerometer being horizontally displayed is chosen as reference point. The inclination angles of each axial are shown in Fig 1b. In which, θ is an included angle between horizontal line of plane xoz and x axial of accelerometer, ψ is an included angle between horizontal line of plane yoz and y axial of accelerometer, and ϕ is an included angle between gravity vector and z axial. The formulas of each inclination angle are shown in equation (1), (2) and (3), in which A_X , A_Y and A_Z represent the acceleration magnitude of x, y and z axial respectively measured by accelerometer.

$$\theta = \tan^{-1}\left(\frac{A_Z}{A_X}\right) \quad (1)$$

$$\psi = \tan^{-1}\left(\frac{A_Z}{A_Y}\right) \quad (2)$$

$$\phi = \tan^{-1}\left(\frac{\sqrt{A^2{}_X + A^2{}_Y}}{A_Z}\right) \quad (3)$$

Assuming that if θ and ψ were below plane xoy, then they would be negative. In practical installation, let +X axial point to due south and +Y axial point to due east. The specific inclination direction of tower should be judged on positive or negative values of θ and ψ , as shown in Table I.

TABLE I. COMPARISON OF TOWER INCLINATION DIRECTION

θ	ψ	**Inclination direction**
0	0	No inclination
−	0	Due south
+	0	Due north
0	−	Due east
0	+	Due west
−	−	Southeast
−	+	Southwest
+	+	Northwest
+	−	Northeast

III. OVERALL DESIGN OF TRANSMISSION TOWER INCLINATION REMOTE ONLINE MONITORING SYSTEM

The designed transmission tower inclination remote online monitoring system mainly consists of tower monitoring router, coordinator, wireless sensor network, etc. This system integrates tower inclination information monitoring, regional information monitoring including temperature, humidity and wind direction, and various functions.

The overall system uses the design of a structure with coordinator and routers. In which, the coordinator includes ZigBee communication module, microprocessor, GPRS communication module, inclinometer, microclimate sensor and power module; while the routers include ZigBee communication module, microprocessor and inclinometer. Certain amounts of transmission tower nodes within the region are connected through ZigBee network. According to practical tower distribution, chain-typed transmission mode is used. The overall systematic structure chart is shown in Fig 2. One of the towers is chosen as host tower to install coordinator and the rest towers are installed with routers. The routers monitor inclination information of each tower, then successively send data to coordinator through ZigBee network and transmit data of other routers. The coordinator monitors its own inclination information as well as some microclimate information such as regional temperature, humidity, illumination intensity, wind speed and direction. After coordinator processes all information obtained, it will transmit all information to server via GPRS. The monitoring center will then acquire information from server and display in real time and finally restore them. In which, data collection period could be set through procedure. The damage of any one or two nodes will not affect transmission of signal. The amount of tower should depend on its practical distribution. In consideration of stable communication and effect of transmission time, the amount of tower should not exceed 200 in general.

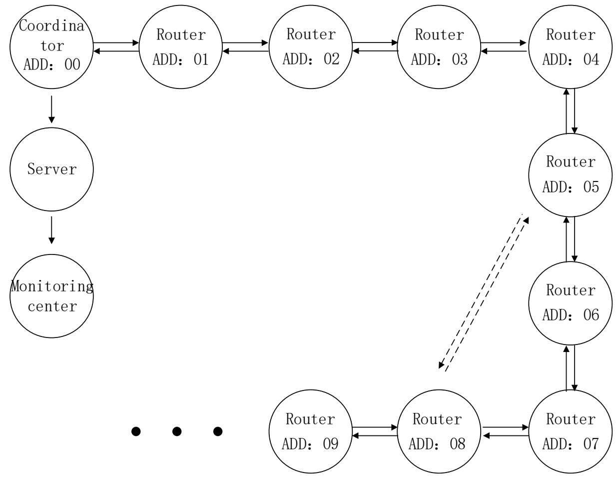

Fig.2 Overall systematic structure chart

IV. SYSTEM HARDWARE SELECTIONS AND DESIGN

A. *Wireless communication module*

Wireless sensor network is the core of Internet of Things technology. All nodes within ZigBee network connected regions were used in transmission tower inclination remote online monitoring system. Both information transmission and remote monitoring are implemented through TCP/IP protocols of GPRS.

1) *ZigBee wireless communication module*

ZigBee network is established based on ZigBee protocol stack. The systematic structure of ZigBee protocol consists of physical layer (PHY), media access control (MAC), logic link layer and application layer. In above, IEEE 802.15.4 protocol standards are used in physical layer and media medium access layer. The upper MAC, logic chain layer and network layer are defined by ZigBee Union. The application layer could implement the function to manage advanced protocol stack. There are two kinds of nodes in ZigBee module: Coordinator and Router. In a same ZigBee network, all nodes must own the same channel PAN ID.

In this system, the latest-generation low-consumption system on chip CC2530F256 is used as ZigBee communication module, which has already had its own IEEE address (MAC address) when leaving factory. Inside it, there is an enhanced 8051MCU core integrated with a high-performance CC2420 RF transceiver and 2 UART included. Through internal programming of

DOI 10.5013/IJSSST.a.17.30.10 ISSN: 1473-804x online, 1473-8031 print

CC2530, after solidifying wireless function, the module should be set as transparent transmission, which means to set module and transmit information through serial port. Under transparent transmission mode, it is possible to set node type, communication channel and target address of each node in the network. The setting instructions are shown in Table II, in which, nine tower extension nodes are chosen for this system and module Router address is defined from 01 to 09.

TABLE II. ZIGBEE MODULE SETTING INSTRUCTIONS

Setting instruction	Function
FC 02 91 01 XX XX	Set module PAN ID as XX XX
FC 01 91 06 XX F6	Set Baud rate of serial port of module
FC 00 91 09 A9 C9	Set module as Coordinator
FC 00 91 0A BA DA	Set module as Router
FC 01 91 0C XX 1A	Set wireless channel of module
FC 32 C3 X1 X2 01	Set Router address

Power amplifier chip RFX2401C for amplifying signal combined with 2dBm antenna externally connected by IPEX could enable transmission distance to reach 1600m and satisfy the need of span of transmission tower.

2) GPRS communication module

The GPRS module is GTM900C produced by Huawei Company. Huawei GTM900C is a GSM/GPRS module highly integrated by duel-band 900/1800MHZ and embedded with TCP/IP protocol, which uses standard AT command set and communicated with CPU via UART port.

B. Design of information processing unit

Both MCU and sensor jointly compose the information processing unit of each node. The information processing unit of each extension node consists of MCU and inclinometer, and host node also includes temperature/humidity sensor, wind speed/direction sensor, illumination intensity sensor and other microclimate unit.

The MCU is a composite signal processor MSP430F5438A produced by TI Company. MSP430 is a 16-bit composite signal processor based on RISC with minimum working power consumption. Within an operating voltage scope of 1.8V-3.6V, its performance can reach up to 25MIPS.

The inclinometer is a low power consumed tri-axial accelerometer ADXL345 produced by ADI Company. This device uses an integrated memory management system with 32 level FIFO buffer to save data so as to reduce load of host processor to minimum degree and bring down overall systematic power consumption.

The temperature/humidity sensor is a low power consumed sensor SHT11 based on CMOSensTM technology. It is equipped with industrial standard 12C bus digital interface and its output solution of temperature and humidity values are 14 bits and 12 bits respectively, which enables it with good stability.

The wind speed sensor is a three-cup photoelectrical speed sensor with low threshold value and measuring scope of 0-75m/s. Its output signal is pulse signal with signal frequency proportional to wind speed. It implements speed measurement through counting frequency of unit time.

The wind direction sensor is a mono-wing weather cock. When the weather cock rotates, it drives Gray code disc to twirl and generate Gray code digital signal output.

The illumination intensity sensor is BH1750 light intensity sensor with digital quantity output.

C. Design of power module

Due to discontinued and unstable power supply of solar battery, the power supply of solar and battery is combined and used in transmission tower inclination remote online monitoring system. In which, solar panel and battery are connected under charging protective circuit; and a charge-discharge circuit is used between battery and power utilization module to realize a stable and continuous supply of power.

V. SYSTEM SOFTWARE DESIGN

A. Design of monitor node software

When each CC2530F256 chip leaves the factory, it has already had its own globally unique MAC address of 8 bytes which will not change with network. Therefore, the MAC address of each module is utilized to mark the module.

In transparent transmission mode of ZigBee module, each Router receives command of Coordinator and transfers information to Coordinator. The command frame formats that Coordinator transfers to each Router are shown in Fig 3.

DOI 10.5013/IJSSST.a.17.30.10 ISSN: 1473-804x online, 1473-8031 print

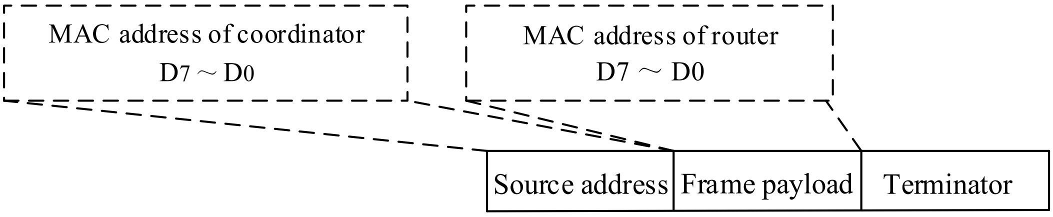

Fig.3 Command frame format

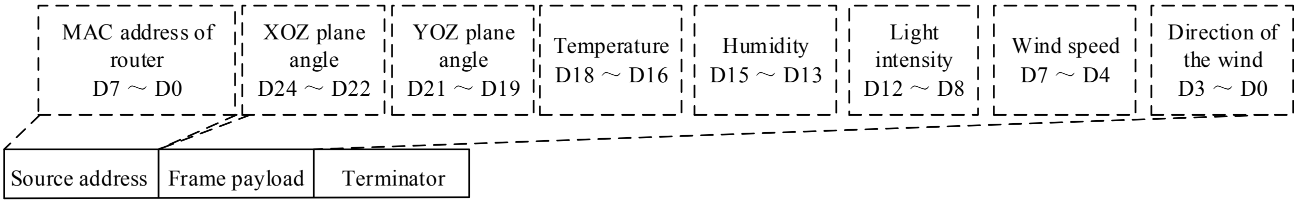

Fig.4 Data frame format

The data frame formats that each Router returns to Coordinator and the Coordinator transmits to server are shown in Fig 4. In which, the Router has not been mounted with microclimate sensor, so D_{18}~D_0 bytes of Router shows null byte.

After Coordinator and Router are initialized, the ZigBee network should be checked firstly. If communication turned normal, the Coordinator should send control command to each Router by way of polling. When the Router receives these data, it should firstly judge MAC address and then depends on judgment results to read data of sensor and send to Coordinator. After one inquiry period finishes, the Coordinator will send data to the server.

B. Design of monitoring center hardware

The monitoring center interface is shown in Fig5.

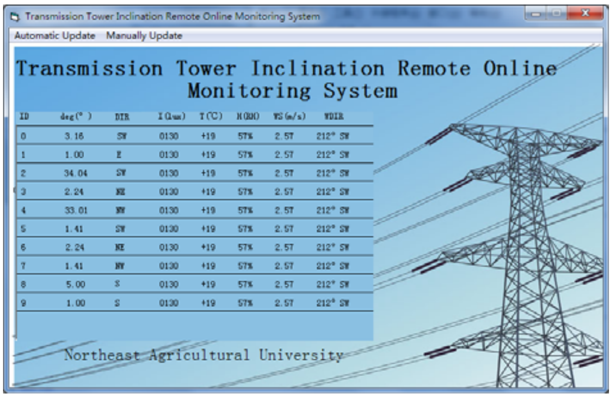

Fig.5 Monitoring center interface

The monitoring center interface includes server and customer. The server obtains data that GPRS sends to server through network and then distributes data to the customer to realize remote monitoring. MD5 algorithm encryption is used in data transmission to guarantee safety of information. In above, Winsock control is used to realize the connection of service end and server as well as of each customer and service end.

VI. SYSTEM TEST AND ANALYSIS

The test object is No. 51-60 reinforced concrete poles of chemical trunk of chemical region line of Harbin. The installation site is shown in Fig 6.

Fig.6 Device installation site

Let data collection period be once every 15min and choose the temperature, humidity, wind speed and direction of integral point in data storage of May 26th in monitoring center. Then we can compare them with data of same time in microclimate, as shown in Fig 7. In this figure, among wind direction data, 0 degree refers to north wind, 90 degree refers to east wind and 180 degree refers to south wind. The measured tower inclination angle information is shown in Table III.

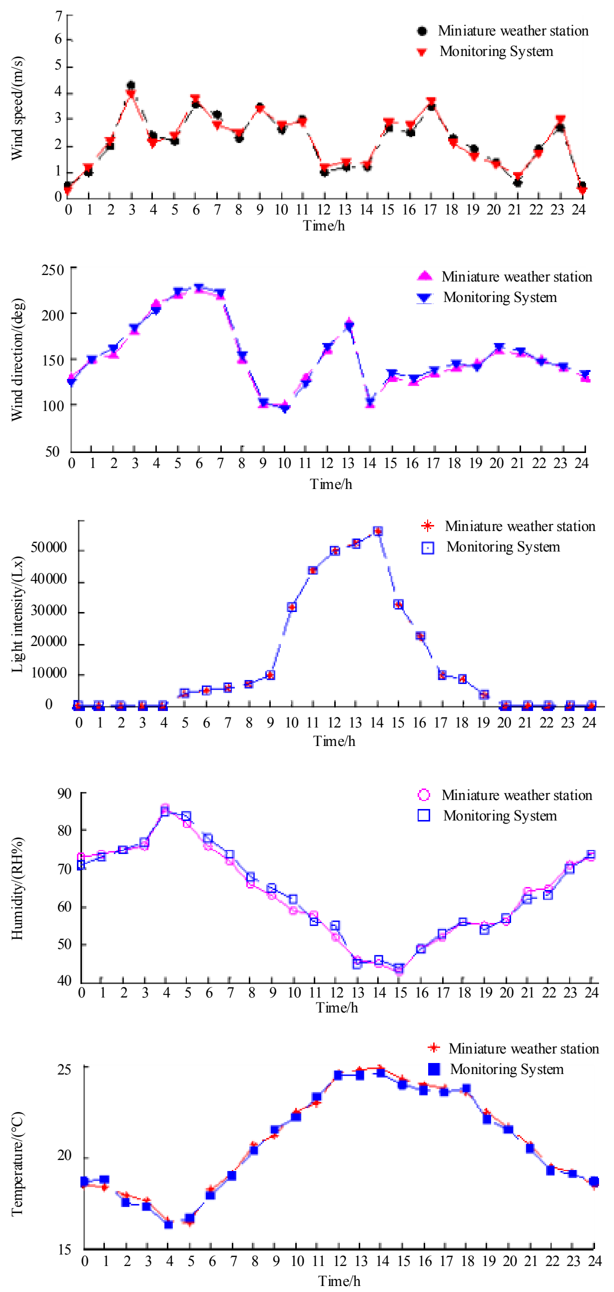

Fig.7 Microclimate data test results

During measurement process, arbitrarily closing the power of two nodes will not affect a normal communication of ZigBee network. The test results indicates that, tower inclination measuring deviation is within 5% and microclimate data falls within the scope of allowable error, which could satisfy the need of precision.

TABLE III. TOWER INCLINATION TEST RESULTS

S/N	Inclination angle ϕ /(°)		Relative error /%
	This system	Inclinometer	
1#	3.16	3.28	3.66
2#	1.06	1.11	4.50
3#	2.04	1.99	-2.51
4#	2.24	2.23	-0.04
5#	3.01	3.06	1.63
6#	1.41	1.48	4.96
7#	2.24	2.26	0.09
8#	1.31	1.29	-1.52
9#	0.90	0.89	1.12
10#	1.15	1.19	3.36

VII. CONCLUSIONS

(1) Through practical installation and measurement, we can conduct real-time monitoring of tower inclination information and regional microclimate information (temperature, humidity, wind speed and direction) and implement smart monitoring to take the place of manual patrol, which can save human labor, improve precision of monitoring and will be of great importance to guarantee safe operation of electric line.

(2) Solar energy and ultra-low power consumption chip are used in each nodes of the system to save energy and realize stable operation. The upper computer could be login in multiple computers and MD5 is used to encrypt between the service end and customer, which will guarantee the stability of data transmission.

REFERENCE

[1] ZHANG Meng,FANG Junlong,HAN Yu.Design on r-omote monitoring and control system for greenhousegroup based on ZigBee and Internet.Transactions of th-e Chinese Society of Agricultural Engineering ,29(Supp.1):171-176.2013

[2] ZHOU Fengxing, YANG Jing, LAN Jianwu et al. Wireless remote monitoring system of highvoltage tower steel stress [J]. Electric Power Automation Equipment, 30(11): 115-119.2010

[3] GAO Yang, PAN Hongxia, WU Sheng et al. Remote monitoring and analysis system based on DSP for electrical equipment [J]. Electric Power Automation Equipment, 30(1): 127-132.2010

[4] HU Zhijian, LI Hongjiang, WEN Xishan et al. Online monitoring of transmission conductor wave and wind gallop based on differential GPS [J]. Electric Power Automation Equipment, 32(3): 120-125.2012

[5] WANG Caibao, SHENG Gehao, ZENG Yi et al. Cluster monitoring system of transmission line joint temperatures based on ZigBee technology [J]. Electric Power Automation Equipment, 29(11): 45-50.2009

[6] HUANG Xinbo, FANG Shouxian, WANG Xiaokuan et al. High voltage switchgear cabinet based on IOT technology [J]. Electric Power Automation Equipment, 33(2): 147 152.2013

[7] HUANG Xinbo, SUN Qindong, DING Jianguo et al. Transmission line icing monitoring system based on GSM SMS [J]. Electric Power Automation Equipment, 28(5): 72-77.2008,

[8] ZHAO Zenghua, SHI Gaotao, HAN Shuangli et al. A Heterogeneous Wireless Sensor Network Based Remote Distric- t High-voltage Transmission Line On-line Monitoring Syst-em. Automation of Electric Power Systems, 33(19): 80-84.2009
[9] LIU Hongwei, LI Junfeng, WANG Changfei . Research and Application of On-line Monitoring Management Platform for 1000 kV AC Transmission Lines. Automation of Electric Power Systems, 33(23): 98-102.2009
[10] HUANG Xinbo, SUN Qindong, CHENG Ronggui et al. Mechanical Analysis on Transmission Line Conductor Ic- ing and Application of On-line Monitoring System. Automation of Electric Power Systems, 31(14): 98-101.2007
[11] ZHANG Zhanlong, LI Bing, YANG Ji et al. On-Line Monitoring System of Electric Power Line Guard Against Theft by Microwave Induction. Automation of Electric Power Systems, 30(22): 93-95,2006
[12] HUANG Min, LI Da , ZHU Tin g . CDMA1X based over- head transmission line wireless video monitoring system . Automation of Electric Power Systems, 31 (5): 105-107.2007
[13] HUANG Xinbo , LIU Jiabing , WANG Xiang li, et al. On-line remote-monitoring system for transmission line insulator contamination based on the GPRS NET . Automation of Electric Power Systems, 28(21) : 92 - 96.2004,
[14] HUANG Xinbo ,Zhang Xiaowei,LI Guochang .Application of Online Monitoring Technology of Transmission Lines in Interconnection Project from Qinghai to Tibet. High Voltage Engineering, 39 (5) : 1081－1088,2013
[15] LI Huwei, LI Shenglai, LI Hui. Design and research of warning devices for inclination of poles and towers. Guangdong Electric Power, 24(2) : 56-59,2011
[16] HAO Lihua, JIANG Min, LIU Hong. Study on the A-pplication of Tower Inclination on-line Monitoring.Sha-nxi Electric Power, 6:22-24.2013.