

The Practical Design of Constructing Data Transition Interface with ZigBee WSN and RS-485 Wired Interface—Example with Small-scaled Wind-power Electricity Generator System

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Abstract The purpose of this study was to explore the related practical techniques of monitoring and controlling system in designing renewable energy system, especially for Small-scaled wind-power generator. Recently, the whole world was actively developing replaced energy to solve the economic development and daily-life necessities problems resulting from gradually lacking of oil. Taiwan government was progressively planning to develop small-scaled wind-power generators under authority of Energy Bureau of Economy Minister. The real-time running parameters of wind-power generator is very essential for designing the power-generating system, in this paper, a data transition system including how to construct ZigBee Non-Beacon-Enable-Network, communication techniques, data coding, and its interface for collecting running parameters in wind-power generator was designed with both ZigBee wireless-sensor-networks (WSN) module and wired RS-422 Interface to double check the precision of transmitting data. The final result of this study has successfully implemented in a practical small-scaled wind-power generator system which was part of integrated-project of Teaching Superior Projects authorized by Taiwan Education Minister –Constructing Monitoring and Controlling Interface in Small-scaled Wind-power Generator System, and the validity and stability of the system has been proved efficient and successful.

Index words—Small-scaled wind-power generator, Monitoring and controlling system, ZigBee wireless communication,

running parameters, RS-485

I. INTRODUCTION

Because mankind excessively consumed oil for hundreds of years, it made the storage of oil almost exhausted in the last one hundred years. Therefore, the oil price has up-risen near to 100 dollars per barrel. Because overusing of oil energy resulted in huge amount CO₂ emission and greenhouse effect in the earth, furthermore, this phenomenon made the earth more serious condition of getting warmer and climate change. So the issue of environment protection was regarded as more and more essential. In December 1997, the greenhouse gases emission constrain rules was officially announced in Kyoto Agreement, in which clearly assigned the emission standard of greenhouse gases. Therefore, those electricity generators driven by heat and its capacity being more than 500MW would be more and more difficult to build and the distributed renewable electricity generators such as wind-power generators and solar become new alternatives of creating energy resource.

Considering from the trend of international energy

technology development and based on conclusion of several important conferences in our country, there were divided into five main directions how to develop and use renewable energy: solar energy, solar heat-energy, biologic energy, wind-power energy, and tide energy. In 2005 The Energy Bureau of Economy Minister planed the portion of all kinds of possible developed renewable energy from 2005 to 2025 and wind-power electricity generator was the main part of distributed electricity generators that meets the efficient economic benefits, so wind-power electricity generator becomes an important issue in Taiwan technology development.

The most important stage in designing wind-power electricity generator is to refer the practical running parameters such as generated voltage, current, power, wind-direction, wind speed, and rotator speed etc., and then engineers can correct the original design according the real-time collected parameters according whether the system is running optimally efficient or not. How to collect the real-time running parameters from wind-power electricity generator as correct reference depends on the data collecting and transmission interface and its related system. How to develop the monitoring and controlling system in the wind-power electricity generator and how to create and deepen the local techniques of wind-power electricity generator can provide another shining and prosperous industry for Taiwan, according to the study motivation mentioned above the purpose of this study are as following :

- (1) To design and manufacture a remote monitoring and controlling system which meets with the local features and requests for wind-power electricity generator that can real-time transmit all of the parameters during running of wind-power electricity generator.
- (2) To design and manufacture a data transmission interface with high-frequency ZigBee wireless sensor network to replace traditional design.
- (3) To design and manufacture a graph-based monitoring system of wind-power electricity generator in servo computer far away the generator system with Visual Basic Language from which a real-time running parameter can be displayed and read as well as be store in database.

II. Related theory and design plan

Owing to the drifting change of communication techniques development, the brand new WSN (wireless sensor networks) has been implemented in all data transmission system in communication, sensors, and data collecting application; especially in 3C products, intelligent space. But how to take advantages of WSN ZigBee in the small-scaled wind-power electricity generator system is the main work in this study. We try to combined DSP chip and high-speed SPI interface and the WSN ZigBee communication techniques into the small-scaled wind-power electricity generator system to collect related running parameters for further design.

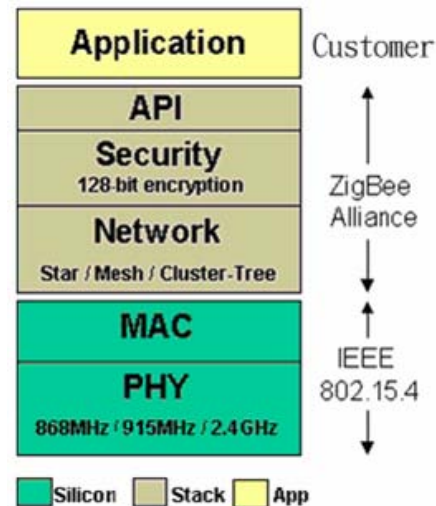


Fig 1 Protocol of software & hardware

ZigBee is a communication system according to IEEE 802.15.4 and ZigBee Alliance organizations to construct its software and hardware specifications. As Fig 1, PHY (Physical Layer), MAC (Medium Access Control Layer), and Data Link (Data Link Layer) was conducted by IEEE [2, 3]. ZigBee Alliance was charged of configure logic net, security coding for data transmission, and specification for application interfaces and linking constrains of system products.

PHY(Physical Layer) mainly conducted items as following[3] :

- (1). To start and close the radio transmitter and receiver.
- (2). To detect the transmission power of radio channel signals (ED, Energy Detection).
- (3). To list the linking quality of received information package (LQI, Link Quality Indication).
- (4). To judge whether (CSMA-CA, Carrier Sense Multiple Access-Collision Avoidance) channel was cleared or not [2] (CCA, Clear Channel Assessment).
- (5). To select proper channel and frequency.
- (6). To receive and transmit data.

The frame structure of PHY [2,4] is consisted of (SHR, Synchronization Header), (PHR, PHY Header), (PSDU, PHY Service Data Unit) which form a PHY Protocol Data Unit as shown in Fig 2:

- (1). Synchronization Header: it can be divided into Preamble Sequence Field, which was used as detected data for guaranteeing synchronized receiving terminal chip or symbol and Start of Frame Delimiter Field, which was used to indicate the start of information package and end of Preamble Sequence Field.
- (2). PHY Header [4]: It included 7 bits of Frame Length Field and one reserved bit.

4 Octets		1 Octets		1 Octets		0~127 Bytes	
Sync.		Heard		PHY Heard		PHY Payload	
Preamble Sequence		Start of Frame Delimiter		Frame Length (7bit)		Resrev (1bit)	
SHR		PHR		MPDU			

Fig 2 Frame structure of PHY

(MAC, Medium Access Control Layer)was responsible of following works in addition to connecting with PHY [3, 4]:

- (1). It was responsible for produce beacon that would synchronize with beacon of coordinator when device itself was configured as Coordinator.
- (2). To support association and disassociation of individual network.
- (3). To use (CSMA-CA, Carrier Sense Multiple Access-Collision Avoidance) mechanism [2] to decide which channel is proper for communication and to control and maintain Guarantee-Time Slots mechanism (GTS, Guaranteed Time Slots).

The stack structure of IEEE 802.15.4 was shown in Fig 3 [1], in which the application program interact with stack layer through stack API of 802.15.4, and this interaction is used to accomplish the request and acknowledge of (MCPS, MAC Data Services)/(MLME, MAC Management Services) that is the symbols and response of information. Finally, the IEEE 802.15.4 stack layer will interact with the bottom layer hardware through registers.

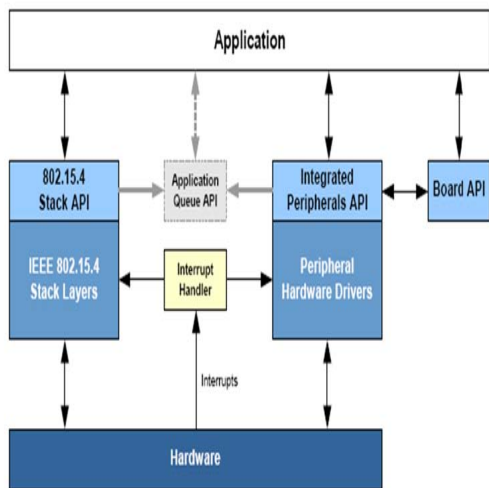


Fig 3 Software structure of API

Beacon cab divided into Beacon-Enable-Network and Non- Beacon-Enable-Network [2], and the former is used to let coordinator synchronize its attached device and clarify the individual local network of the device. In this study, the Beacon-Enable-Network was adapted in which if the attached devices wanted to transmit data or controlled signals, then those devices must wait for a while randomly and then check whether the channel were idle, if it were, then the data could be transmitted.

As indicated in Fig 4, every net must have only one PAN-Coordinator, and the first step for constructing net is to initialize Coordinator [1].

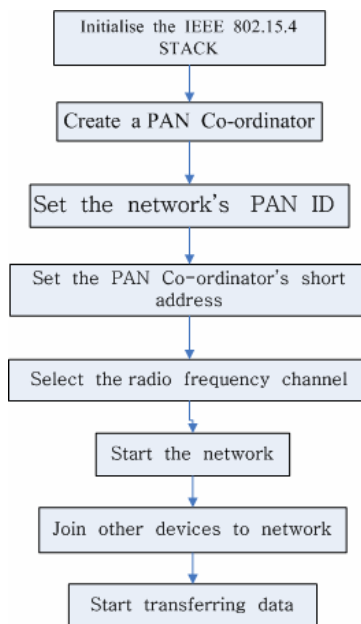


Fig 4 Procedures of constructing wireless net

The initialization of PAN Coordinator only proceeds in the devices agreed with in advance, a selected PAN ID will be used as symbol of the net after finishing initialization. PAN ID can be changed by users, and PAN ID can also select a in-conflicted ID by detecting the ID of other net. PAN Coordinator can scan lots of channel frequency and can also assign fix channel by command devices using way of priority scan to insure no confliction of PAN ID with other net. If PAN Coordinator accepted the End Device, then a 16 bits short address would be sent to End Device as a symbol of End Device in the net. Coordinator directly sending data to End Device [1] was shown in Fig 5 and Fig 6 was the in-directly data transmission between them.

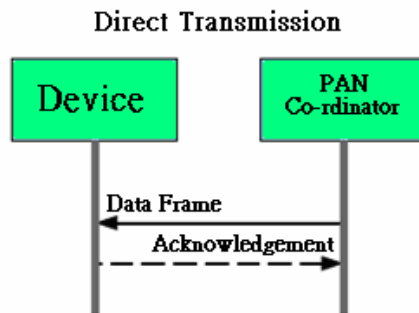


Fig 5 Direct transmission structure

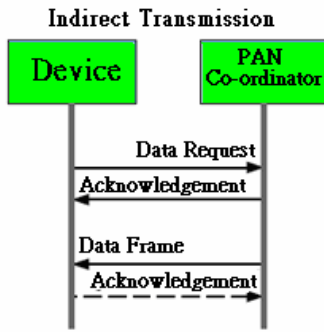


Fig 6 Indirect transmission structure

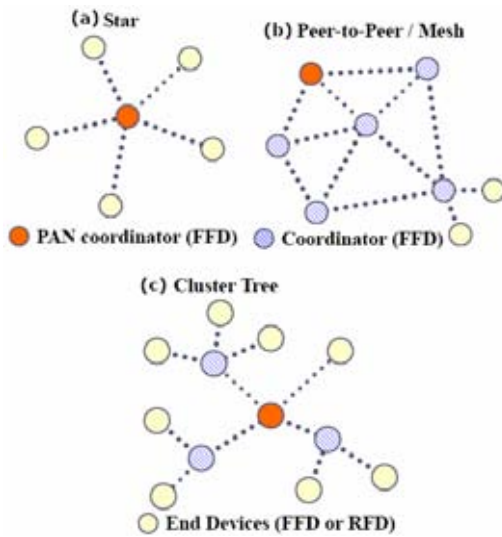


Fig 7 Topology of ZigBee wireless network

The net topology of ZigBee can be divided into three types as shown in Fig 7 [5]; (a) star type (b) peer-to-peer type (c) cluster tree type. In this study we adapted peer-to-peer type to transmit data. The related ZigBee module is products of one Canada Company named Quansera and product No. was FT-6250 [1].

III. Software and hardware design

In this part we are going to describe the whole data transmission circuits design including running parameters both from inner wind-power electricity generator and outer of it as well as its power consumption system. First of all, the AC voltage (analog signal) generated by generator would be converted into digital signal by AD converter controlled with 8051 microprocessor which was built inner generator as shown in Fig 8 [6].

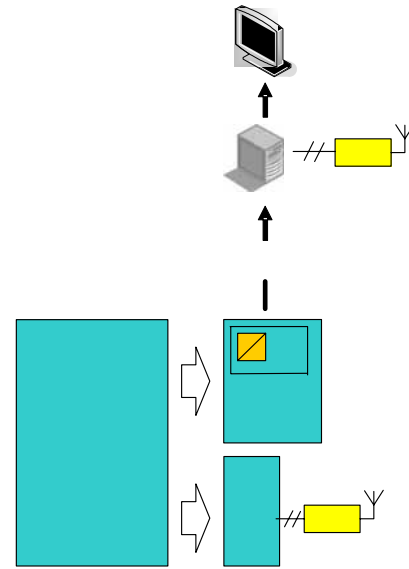


Fig 8 Data transmission system structure of wind-power electricity generator

The related converting program was shown in Fig 10. Then the converted data would be sent to DSP module, which was about 20 meters high under the tower of wind-power electricity generator, by blue-tooth wireless modules, afterwards, the data would be sent to servo computer of monitoring and controlling center far away through (a) wireless net work of ZigBee (b) cabled net work of RS-485.

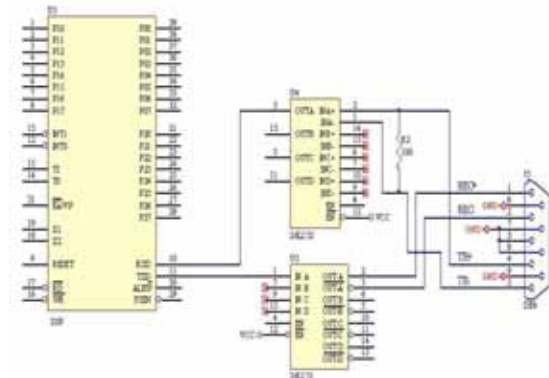


Fig 9 the data transmission RS-485 interface between DSP and monitoring servo computer

A Cable-network of transmitting system design

In cable-network since the monitoring and controlling center must simultaneously monitor several wind-power electricity generators, therefore, we adapted scanning method to sequentially receive the running parameter from generators far away, and the practical design was used RS-485 interface shown in Fig 9.

```

MOV    TMOD,#00100000B    ; To set TIMER1 works in the MODE2
ANL    PCON,#01111111B    ; To clear SMOD bit
MOV    TH1,#0FDH          ; Setting the baud rate is 9600
MOV    TL1,#0FDH
MOV    SCON,#01000000B    ; To set UART works in the MODE1
                                Setting REN bit for prepare to receive data
SETB   TR1                ; The TIMER1 begins to work

BCD_TO_ASCLL:
MOV    A,R4
SWAP   A                  ; The high and low bit exchanges
ANL    A,#0FH
ORL    A,#30H            ; The value is turned into ASCII code
CALL   TO_RS232
MOV    A,R4
ANL    A,#0FH
ORL    A,#30H
CALL   TO_RS232
MOV    A,#40H            ; @ stands for stop sign
CALL   TO_RS232
    
```

Fig 10 AD converter program of DSP serial port

B Wireless-network of transmitting system design with Zigbee and DSP, 8051 Module

The whole system structure can be divided into wireless network and cable network transmission. In wireless network, after the microprocessor 8051 receiving inner running parameters of voltage as shown in Fig 11, current, and speed of rotator, the collected parameters would send out through Bluetooth to the microprocessor 8051 and TI DSP 2407, in which the former is responsible for transmit the data to the monitoring servo computer through ZigBee wireless network (as shown in Fig 14) while the later through cable network with RS-485 interface as in Fig 8.



Fig 11 8051controlled board linking with ZigBee module

TI DSP 2407A as middle transmission station receiving collected running parameters from 8051 through Bluetooth module would transmit the data to servo computer through SPI interface as shown in Fig 13 [9]. In Fig 12, the program was used to configure the interface between DSP and API interface and set the baud rate of 1Mbps, data length 16 bits, and phase delay 1.5 system clocks.

```

void INIT_SPI(void) /* 設SPI啓始工作環境 */
{
    MCRB=0x003c; /* 0011 1100
    5 0=IOPC5 1=SPISTE
    4 0=IOPC4 1=SPICLK
    3 0=IOPC3 1=SPISOMI
    2 0=IOPC2 1=SPISIMO */
    SCSR1=0x0020; /* 0000 0000 0010 0000
    11-9 CLK_PS2=0=000 CPUCLK=40MHz
    6 SPI CLKEN=1 Enable SPI clock*/
    SPICCR=0x000f; /* 0000 0111
    7 SPI SW RESET=0 reset SPI
    6 CLOCK POLARITY=0 SPICLK Polarity =0
    3-0 SPI CHAR3=0=15 Each deliver character length
    to 16-bit */
    SPICTL=0x000c; /* 0000 1100
    4 OVERRUNINT ENA=0 disable receive
    3 CLOCK PHASE SPI=1 SPICLK phase delay 1.5 cycles
    2 MASTER/SLAVE=1 SPI(MASTER)
    1 TALK=0 disable data deliver
    0 SPI INT ENA SPI=0 */
    SPIPRI=0x0000; /* 6 SPI PRIORITY=0 */
    SPIBR=0x0000; /* Setting the baud rate is 9600*/
    SPIST=0x0000;
    SPICTL=0x000E; /* 0000 1110
    4 OVERRUNINT ENA=0
    3 CLOCK PHASE SPI=1
    2 MASTER/SLAVE=1 SPI(MASTER)
    1 TALK=1
    0 SPI INT ENA SPI=0*/
    SPICCR=0x008f; /* SWRST=0,SPI prepare to firinged
    or receive next character */
}
    
```

Fig 12 Part program of configuring DSP-SPI interface

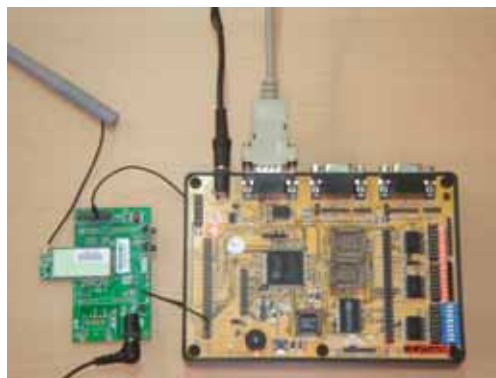


Fig 13 TI DSP 2407A linking with ZigBee module

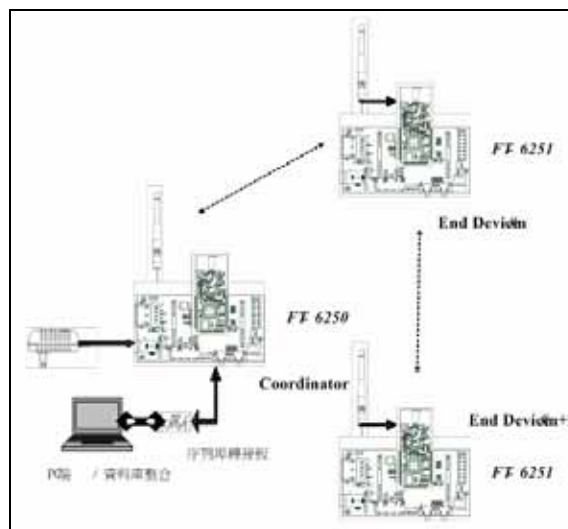


Fig 14 Practical operation of Zigbee module

C Power consumption System with Battery Back-up design

In Fig. 15, the single-phase generated AC electricity by wind-power generator was transferred from AC 110V (when the capacity of generator was 400 mw) to 36V through transformer, and then input from J1 (AC_IN). Then the input electricity was rectified into DC

electricity by Q3 and decreased ripple with designed filter capacity C1 and C2.

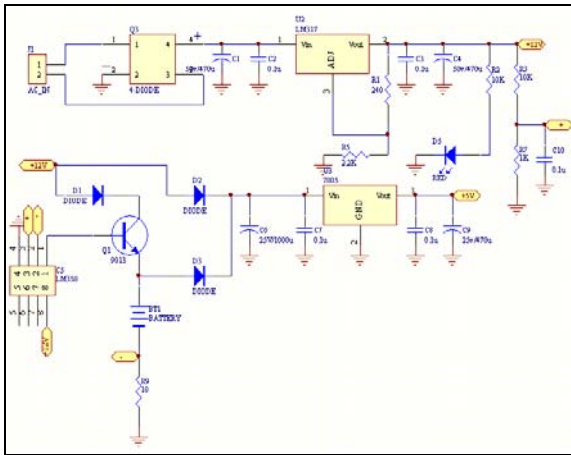


Fig. 15 Battery back-up circuit

The voltage regulator was selected LM317 IC, with proper resistance of R1 and R5 could steadily output DC12V. The voltage drop of battery could be figured out by formula (1).

$$V_{\text{batt.}} = 1.25v * (R1+R5/R1) \tag{1}$$

The battery charge-circuit was designed with LM358 and CS 9013 transistor that constructed emitter-follower to get fixed current for charge-circuit. In this system the input current into battery was constrained in 100mAh (the current flow through emitter of CS 9013 and the battery charged current), and in Fig. 16 the oscilloscope indicated by upper line (measured with CH1) that the 3 pin (+) of LM358 was stable voltage about DC1.2V during generator working, the 2 pin (-) obtained the voltage that was detected from R9 and was equal to level of 3 pin (+), so we could control the battery charged current by dividing R9 with voltage on R9. When DC9V Li-H battery supplied electricity to the system, the voltage level measured on the 3 pin (+) from CH2 (blue line) was zero, and that meant the wind-power generator was entirely no power supply for the system.

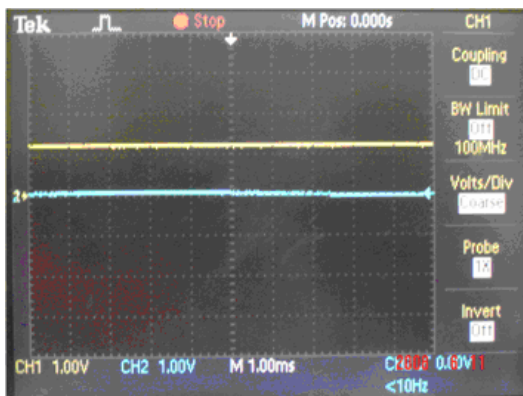


Fig. 16 the input level of pin (+) of comparator LM358

Pin 1 (Output of LM358) connected to B of transistor CS 9013 to control charged current of battery, and the measured level of output by oscilloscope was shown in Fig. 17. CH1 (yellow line) showed out the voltage level

DC11.27V during wind-power generator working and supplying electricity to system. When DC9V Li-H battery supplied the power, CH2 (blue line) showed out the voltage level 1.5V, and we could varied the value of R9 to change input charge-current and charge time or the input voltage on pin3(+). In this system we used battery capacity of 200mAh to conduct charge & discharge experiment with 0.5 C charge constant.

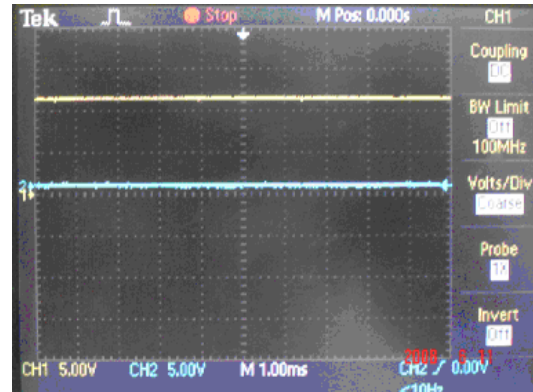


Fig. 17 the output level of comparator LM358

When wind-power generator supplied power, D2 would be ON and system and battery would be supplied power with DC12V. But if the wind-power generator stopped supplying power, D3 would be ON and system would automatically obtain DC9V from battery. LM7805 IC kept stable voltage DC5V and supplied for 89C51, and this design could achieve goal of charge battery and Un-brake Power Supply (UPS effect).

D Lasting Time for Power-supply by DC9V Li-H battery (200mAh)

During normal operation-condition of system, DC9V Li-H battery supplied DC9.7V after completely charged and loading current was about 80mAh. Supposing that the limited input level of battery was DC7.4V and loading current was 64mAh, we got the average loading current about 72mAh and total capacity of DC9V Li-H battery was 200mAh, so if we used total capacity to be divided with average loading current, we could obtain the lasting time of power supply of battery. The related description could be expressed with formula (2)

$$I_{MAX} = \text{Fully charged current}$$

$$I_{MIN} = \text{Loading current during supplying 7.4 V}$$

Electric Discharge Time = Lasting time of power supply (mAh)

$$Total = \text{Total capacity of Li-H battery (mAh)}$$

$$\text{Electric Discharge Time} = \frac{Total}{(I_{MAX} + I_{MIN})/2} \tag{2}$$

$$2.7 = \frac{200}{(80 + 64)/2}$$

E Lasting Time of Battery Discharge

When system was normally operation, the initial voltage of battery was DC9.5V. If system operative voltage was constrained at DC5V and we recorded the voltage of battery every 5 minutes, we could obtain the

lasting time and remained voltage of battery shown in table xx and the change curve was shown in Fig. 18. The front-channel of collecting running parameter system of wind-power generator, including 89C51 microprocessor, Bluetooth module, AD convert circuit was shown in Fig. 19.

Discharge time (Min.)	Voltage (V.)	Discharge time (Min.)	Voltage (V.)
5	9.45	55	8.57
10	9.25	60	8.5
15	9.10	65	8.42
20	9.01	70	8.34
25	8.9	75	8.27
30	8.87	80	8.18
35	8.81	85	8.01
40	8.76	90	6.82
45	8.71	95	5.48
50	8.64		

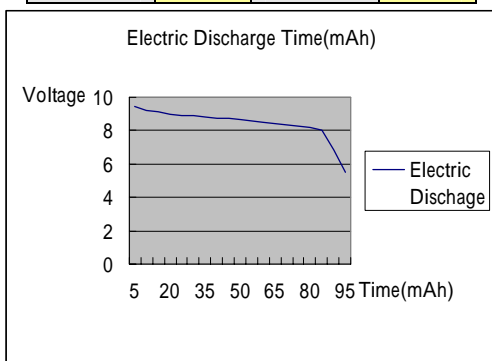


Fig. 18 Electric Discharge Time Curve Change Diagram

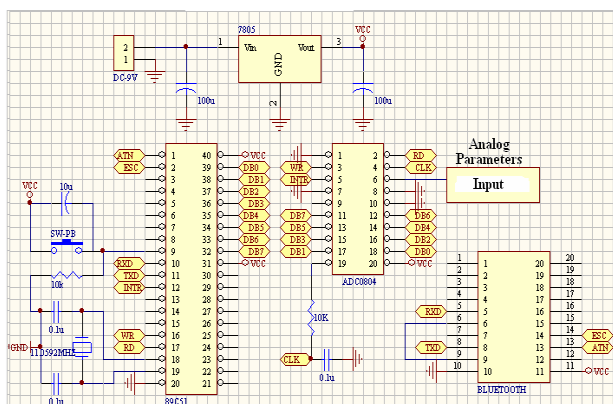


Fig. 19 System Loading Circuit (AD converter + BT transmitting)

In Fig 20, after the running parameters transmitted to the servo computer, the monitoring and controlling center of wind-power electricity generator, the system would real-time show the parameters by the Graph System Interface (GSI) designed with Visual Basic

Language by us.

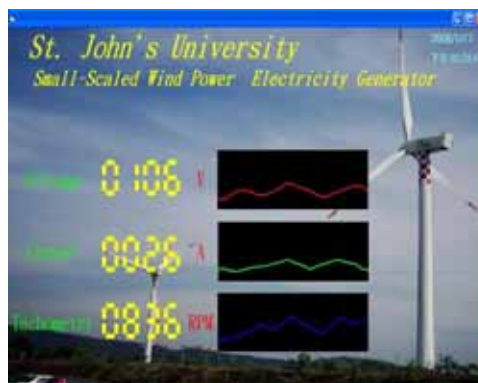


Fig 20 Part screen of Monitoring and controlling software displayed in servo computer

The displayed time-interval was adapted 5 seconds sampled rate after the data collected in the system database. In the Fig 21 was the displayed screen of running parameters offered with curve type and the part of the program designed with VB.

```

Private Sub Form_Activate() 'Program layout of printed sheet and curve range
Picture1.BackColor = RGB(0, 0, 0) 'Set the background colour as black
Xmin = 0 'Set the origin coordinates of x shaft
Xmax = 600 '
Ymin = -100 'Set the origin coordinates of y shaft
Ymax = 1000 '
Picture1.Scale (Xmin, Ymax)-(Xmax, Ymin) '
Picture1.DrawWidth = 1 '
For J = Ymin To Ymax Step 100 'shaft with 100 is a unit
For I = Ymin To Ymax Step 10 'x shaft with 10 is a unit
If X < 600 Then 'x<600 Indicating diagram hasn't ended
X = X + 1 'The x represents time, x=1 indicate to 0.1second
Picture1.DrawWidth = 2 'Setting wire of thick thin
Picture1.PSet (X, Y1), RGB(255, 0, 0) 'Draw on the diagram the voltage received
Picture1.BackColor = RGB(0, 0, 0) 'If the picture finished us to want to is all
X = 0 'clearances the diagram, again from draw lattice
Picture1.Cls 'lately
Xmin = 0 '
Xmax = 600 '
Ymin = -100 '
Ymax = 1000 '
Picture1.Scale (Xmin, Ymax)-(Xmax, Ymin) '
Picture1.DrawWidth = 1 '
    
```

Fig 21 Curved display parameters program in VB

Finally, for the staffs working in the monitoring center being able to dynamically monitor the change condition of running parameters instead of sitting in front of servo computer, we adapted PC Anywhere software [10] in Fig 22 as far-away remote monitoring and this design can let staff monitor the screen of servo computer anytime and anywhere through combining web-net with wireless network ZigBee sub-system in their own notebook or PDA without the limitation of space and distance.



Fig 22 Remote monitoring and controlling software of PC Anywhere

Conclusion

Now ZigBee techniques has been popularly used in many fields in all kinds of products and in this study we first try to implement ZigBee wireless technique combined with microprocessor into small-scaled wind-power electricity generators. After long-term practical running, the whole system proved to be successful and stable, in order to guarantee the transmission accuracy and valid we used wireless and cable network to double check the system operation. In the future, we would try to implement these related techniques into intelligent space study.

ACKNOWLEDGEMENT

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As a teacher and researcher in his major field, he devoted himself in researching of intelligent system work for many years, especially recently he has spent much time participating national projects as a leader and during the study period some related research works has been published in conference and juniors as following: FAQ-master: An Ontological Multi-Agent System for Web FAQ Services, WSEAS TRANSACTIONS on INFORMATION SCIENCE & APPLICATIONS Manuscript received Sep. 17, 2007; revised Feb. 14, 2008. Practical Design of Intelligent Reminder System of Having Medicine for Chronic Patients, WSEAS TRANSACTIONS on BIOLOGY and BIOMEDICINE, Issue 10, Volume 4, October 2007.

Wei-Bin Wu was born in the 1st, January, 1986 in Tanshuei, Taipei County, Taiwan, and he graduated from Hai-shen Vocational High School in July, 2004. Since he was much interested in Electrical Engineering, he entered Saint John 's University in the same year. During his four years study in school, he made a lot of efforts in electrical control engineering, especially participated many national competitions in Intelligent System, and he was awarded many great prize in Academy, finally he applied for entering graduate school of EE Department. Now he is the graduate student under the instruction of Dr. Chun-Liang Hsu.