Development of PV Output Power Indicator Using PIC for Battery Charging System

Farah Fatin Binti Zulkifli
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
e-mail:frh_fatin@yahoo.com

Abstract— **Development of photovoltaic (PV) output power indicator using Programmable Interface Controller (PIC) for battery charging system is one of the improvements to the photovoltaic monitoring system. This project was inspired by the problem of measuring power manually which need quite some time to get the output. By this project, power of PV output would be display on the Liquid Crystal Display (LCD). PIC is use to program the LCD. First of all, student have to understand basic concepts of each elements involved in photovoltaic system such as PV module, charge controller and battery charger. Current sensor ACS 712 is use to detect current while voltage divider is use to step down the voltage of battery charger. Student need to research on how to match output of sensor as an input of PIC. Then, program was designed to indicate power by C programming.**

Keywords- Programmable Interface Controller; Current sensor ACS 712; Voltage divider; C programming.

I. INTRODUCTION

Recently, global warming is a burning issue as the *CO2* density increased highly in the atmosphere. Therefore, clean and renewable energy sources must be introduced to reduce the *CO2* density. Among various renewable energy systems, Photovoltaic (PV) system is expected to play a promising role as a clean power electricity source in meeting future electricity demands. However, the power output of PV systems fluctuates depending on weather conditions, season, and geographic location. It plays the match role in internal resistance and external load impedance of PV battery.

PV is the direct conversion of sunlight to electricity by solar cells. When photons of sunlight are absorbed in solar cells, the photons free electrons from the cell's atoms, creating a voltage potential. This is known as the PV effect. This is possible because various elements, added to the cell materials, establish an electrical field that causes electrons to move in one direction. Connecting wires to the two sides of a cell and to a load allows an electrical current to flow, just as with a battery. A 100-square-foot (9.3-square-meter) PV system will generate a peak power of about 1 kW, energy enough to meet many power requirements of an average home.[1]

A PV module is a packaged interconnected assembly of solar cells, also known as PV cells. The solar module is used as a component in a larger PV system to offer electricity for commercial and residential applications. Since a single solar module can only produce limited amount of power, many installation contain several panels. When several panels combine together, it was called as PV array. A PV installation typically includes an array of solar module, an inverter, batteries and interconnection wiring. PV systems are used for either on-grid or stand alone applications. [2]

Battery charger is one of the important elements in stand alone PV system. Battery accumulates excess energy created by PV system and stores it to be used at night or when there is no other energy input. Battery can discharge rapidly and yield more current that the charging source can produce by itself. However, battery charging house always close and dark. People do not know the output power at every single time without measuring it by using Multimeter. The process of measuring will take time. Therefore, by develop PV output power indicator using PIC, it will help people to know the output power instantaneously.

Analog to digital converter (ADC) is an important factor to the digital display system because it will convert analog value to digital. As PIC microcontroller also have built-in ADC, so the analog circuitry can be connected directly to the PIC microcontroller unit. However, it depends on how much data unit supported in electrically erasable programmable read only memory (EEPROM). [3]

PIC microcontroller is a device that has internal memory; Random Access Memory (RAM) and Read Only Memory (ROM), Central Processing Unit (CPU) and Input/ Output (IO) ports. All of these parts are built on a single chip named microcontroller. PIC basically has a few Kb of ROM, 256 or less bytes of RAM, 256 bytes of Electrically Erasable Programmable Read Only Memory (EEPROM) and several analogue and digital IO lines. Similar to ADC, microcontroller also has many types and different pins such as 28, 40 and 44 pins depend to the function of the microcontroller. The important is microcontroller must have input and output port. For example, PIC 16F877A has five ports; Port A, B, C, D and E so it can support many input and output ports. It also has typical 368 bytes of data memory, 256 bytes of EEPROM and operating frequency of 20 MHz. Digital input data from ADC will be connected to any of five IO ports, assumed to be Port D and the outputs are assumed to be Port B. The programming must be done to ensure that the analogue input and digital output are analyzed properly to be displayed on Liquid Crystal Display LCD. [3]

Programming of PIC is also important factor to the microcontroller functions because microcontroller can do anything that programmed into the data memory and registers. Basically, a register is a place inside the PIC that can be written to, read from or both. It has two banks – Bank 0 and Bank 1. Bank 1 is used to control the actual operation of the PIC, for example to tell the PIC which bits of Port A are input and which are output. Bank 0 is used to manipulate the data. For example, one bit on Port A is set to high. So, particular bit or pin on Port A is set as output in Bank 1. Then, a logic 1 (bit 1) is sent to that pin in Bank 0. The most common used registers in Bank 1 are TRISA, and TRISB. In Bank 0, TRISA allows to select which pins on Port A are output and which are input while TRISB allows selecting which pins on Port B are output and which are input. The programming of microcontroller has many aspects and functions so microcontroller is selected to be main controller of the circuit because its wide functionality can produce good input and output respectively. [3]

II. METHODOLOGY

Power Sensor consists of combination of current sensor and voltage divider circuit to detect current and voltage generated from battery charger. These sensors would send data to PIC 16F877A and LCD would display the values.

A. Current Sensor

Current sensor used was ACS712. It provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging. The output of the device, has a positive slope when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sampling. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the signal leads (pins 5 through 8). [4]

B. Calibration of Current Sensor

Before install current sensor on board, a scaling process need to be done. This step is important to obtain equation to be inserted into C Programming. The result was as shown in Figure 1.

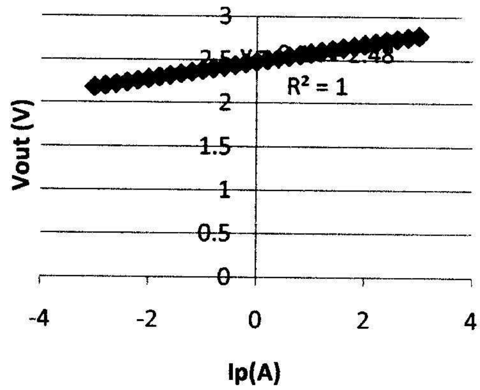

Figure 1: Graph shows output voltage versus sensed current.

In Figure 1, equation for current sensor was obtained which was y= 0.1x + 2.48 where y stands for output voltage of current sensor while x stands for sensed current.

C. Voltage Sensor

Voltage divider was used as voltage sensor. Voltage division refers to the partitioning of a voltage among the components of the divider. Voltage from battery charger would be supplied directly to voltage divider. Voltage divider was used to step down battery charger voltage which is maximum 48 V. This is because voltage that could receive by PIC should be below 5V.

D. Calibration of Voltage Sensor

For voltage divider circuit, values of resistors used must be suitable so that the output will be less or equal to 5V. After some calculation, values of resistors 10W 1KΩ and 10 W 10 KΩ were chosen. Scaling was carried out by connecting both resistors on the breadboard. Then, voltage drop at resistor 1KΩ was measured by using multimeter. The data as shown in Figure 2.

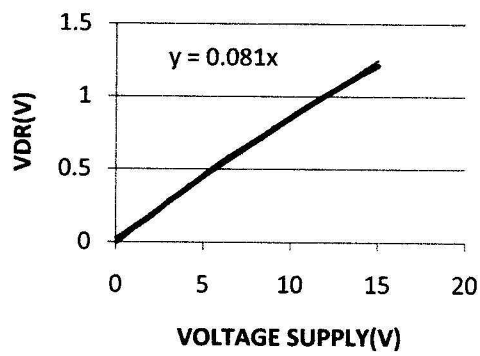

Figure 2: Graph VDR versus voltage supply

In Figure 2, equation for voltage divider was obtained which was y= 0.081x where y stands for output voltage divider (VDR) while x stands for voltage supply. The equation was manipulated and become x=12.5y. This equation would be inserted into C Programming.

E. PIC Microcontroller (SK40C)

Port A was used as input port. Port A is 6 bit wide, bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit (=1) will make the corresponding PORT A pin an input while clearing a TRISA bit (=0) will make the corresponding PORTA pin an output. Therefore, student set bit 0 and bit 1 as 1 because RA0 connect to voltage divider while RA1 connect to current sensor. So, TRISA become **0b000011.**

The analog to digital (A/D) Converter module has eight inputs for the 40/44 pin devices. The conversion of an analog input signal results in a corresponding 10 bit digital number. The A/D module has four registers. These registers are:

- A/D Result High Register(ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1(ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference) or as digital I/O.

ADCON0 was set to 0b10000001| (channel<<3)

Bit 7-6: 10 represent clock conversion Fosc/32.

Bit 5-3: analog Channel select bit 000(channel 0), 001(channel 1), 010(channel 2)

Bit 2: GO/DONE: A/D Conversion status bit when ADON=1;

0: A/D conversion not in progress

Bit 1 : Unimplemented: Read as'0'

Bit 0 : ADON: A/D on bit

1= A/D converter module is powered up

ADCON1 was set to 0b00000001

Bit 7: 0- left justified. Six (6) Most significant bits of ADRESH are read as '0'

Bit 6: <ADCS2>0=0/<ADCS0>=10 represent clock conversion Fosc/32.

Bit 5-4: unimplemented: read as'0'

Bit 3-0: A/D Port Configuration Control Bits

0000-AN7-AN0-analog input.

Both of these registers were stated in function adc_read. Function adc_ read () was used to read analog input in RA0 and RA1. That function would read input one by one. These analog inputs would be converted into digital values.

Conversion always in progress since forever loop was used. So, this program will process the data from battery charging system continuously.

In order to obtain power, equation of power which is product of voltage and current was derived. When program read each ADC input, those datas will be displayed on the LCD.

F. Liquid Crystal Display (LCD)

LCD that has been used in this project was LCD 2x16. It has 16 pins and the pin configuration is shown in Table 1.

Table 1: Description of LCD pin

Pin	Function	Description
1	VSS	Ground
2	VCC	+5V Supply
3	VEE	Contrast
4	RS	Register Select
5	R/W	Read/Write
6	E	Enable
7-14	DB0-DB7	8 Bit Data
15	LED	+ Backlight Supply
16	LED	- Backlight Ground

On the LCD, three parameters which are voltage, current and power need to be displayed simultaneously. Therefore, voltage was represented by V, current by I, and power by P. Program was designed so that values could be displayed in decimal point.

G. Program of PIC16F877A using C programming in MPLAB software.

Before the program was designed, the flowchart as shown in Figure 3 was completed first. This flowchart will summarize all the operations.

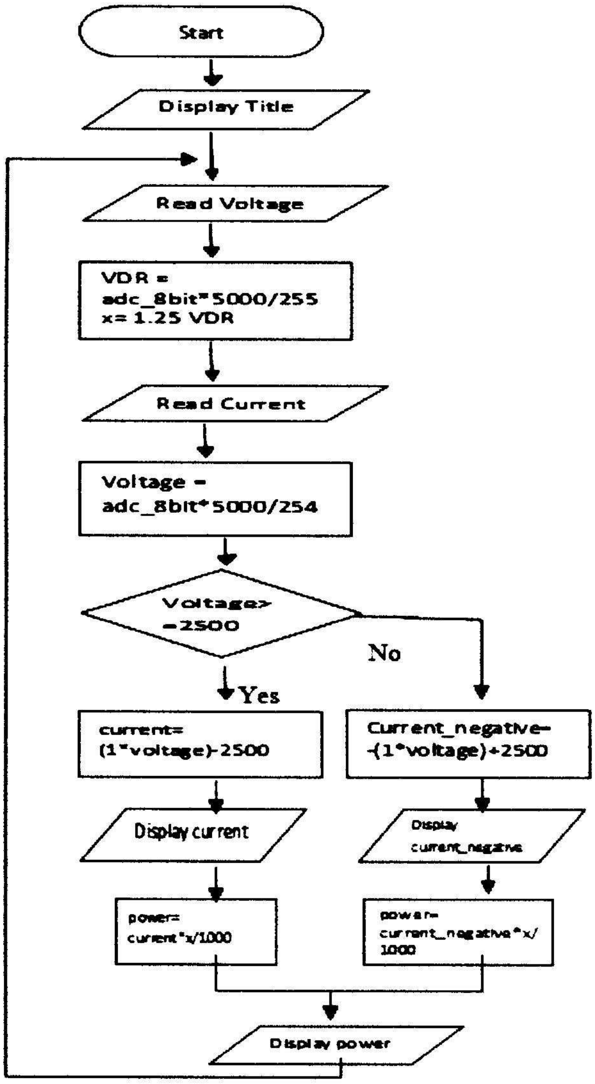

Figure 3: Flowchart of C Programming

1) Reading voltage:

```
While(1){
.......................................................
CCPR1L=adc8_read(0);
adc_8bit=adc8_read(0);
VDR = (unsigned long) adc_8bit*5000/255;
... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ...
}
```

2) Reading Current:

```
While (1){
CCPR1L=adc8_read(1);
adc_8bit=adc8_read(1);
voltage = (unsigned long)adc_8bit*5000/254;
}
```

3) Calculate power:

```
While(1){
..........................................
x= 1.25*VDR;//equation to calculate input voltage
..........................................
current= (1*voltage) - 2500;// equation to calculate positive sensed current
...............................................
power =current*x/1000; // equation to calculate power for positive sensed current
...............................................
current_negative= - (1*voltage) + 2500; // equation to calculate negative sensed current
...............................................
power= current_negative*x/1000;// equation to calculate power for negative sensed current
.................................................
}
```

4) Reading input at port assigned

```
unsigned char adc8_read(unsigned char channel)
{
ADCON1= 0b00000000; //left justify, all analog
ADCON0 = 0b10000001 | (channel<<3) ;
delay_ms(1);
GODONE = 1;
While (GODONE==1);
return ADRESH;
}
```

III. RESULTS

After the program was designed and hardware was installed, several tests were carried out until the best result was obtained. Values displayed on the LCD were compared with actual values from supply in order to calculate the percentage of error. Percentage of error was calculated by using (1)

$$\frac{|power\ actual - power\ display|}{power\ actual}\ 100\ \% \ldots\ldots\ldots(1)$$

The test was done in two conditions which were during positive current supply and negative current supply. For positive current supply, data as shown in Table 2 while for negative current supply data as shown in Table 3. Based on recorded data, display values on the LCD almost similar with actual values from supply. Only small errors could be observed. The percentage of errors about 0% - 10%. Errors might occur because of parallax error or error on the equipment itself.

Table 2: Comparison between display and actual value (Positive current)

I_actual (A)	I_display (A)	V_actual (V)	V_display (V)	P_actual (W)	P_display (W)	Error(%)
0.20	0.19	5.00	5.16	1.0	0.9	10
0.40	0.39	10.00	10.08	4.0	3.9	2.5
0.60	0.59	15.00	15.51	9.0	9.1	1.1
0.80	0.78	20.00	20.41	16.0	15.9	0.625
1.00	0.98	25.00	25.58	25.0	25.0	0
1.20	1.18	30.00	30.50	36.0	35.9	0.278
1.40	1.37	35.00	35.42	49.0	48.5	1.02
1.60	1.57	40.00	40.10	64.0	62.9	1.718
1.80	1.77	45.00	45.51	81.0	80.5	0.617
2.00	1.96	50.00	50.43	100.0	98.8	1.2

Table 3: Comparison between display and actual value (Positive current)

I_actual (A)	I_display (A)	V_actual (A)	V_display (A)	P_actual (A)	P_display (A)	Error(%)
-0.20	-0.20	5.00	5.16	-1.0	-1.0	0
-0.40	-0.40	10.00	10.08	-4.0	-4.0	0
-0.60	-0.60	15.00	15.25	-9.0	-9.1	1.11
-0.80	-0.79	20.00	20.17	-16.0	-15.9	0.625
-1.00	-0.99	25.00	25.58	-25.0	-25.3	1.2
-1.20	-1.19	30.00	30.26	-36.0	-36.0	0
-1.40	-1.38	35.00	35.42	-49.0	-48.8	0.408
-1.60	-1.58	40.00	40.10	-64.0	-63.3	1.093
-1.80	-1.78	45.00	45.27	-81.0	-80.5	0.617
-2.00	-1.97	50.00	50.18	-100.0	-98.8	1.2

In overall, the result is satisfying the desired output. It shows that software and hardware involved in this project function in a right way. This project had achieved its main objective which is to indicate PV output power for battery charging system.

IV. CONCLUSION

In conclusion, this project had achieved its main objectives which were to understand concept of battery charging system, to integrate between sensor, PIC and circuit and to study how to design program using C language to display output power of battery charging system.

By doing a research on each element involved in photovoltaic system such as PV modules, charge controller and battery charger, function of battery charger system and how it relate with other elements would be understood. All the information was gathered from reading materials such as journal or articles.

Besides that, during this project, method to integrate between sensors, PIC and circuit and design program using C language were implemented. This project involved of two sensors which are voltage and current sensor. Voltage divider circuit was used as voltage sensor while ACS 712 was use as current sensor. PIC could only read voltage below 5V and in form of analog. Therefore, to match output of sensor with PIC scaling was carried out so that output voltage of current sensor could change to value of current and output of voltage divider below than 5 V. From the scaling, equations obtained would be used in programming. However, during this process several problems occur such as values keep changing every time doing scaling. As a solution, troubleshoot need to be done and all the devices and equipments used were ensured in their best condition.

Meanwhile, the most important element should be known to design program is how to define PIC and set which port is going to use. Since inputs were in analog form, function ADC should be applied to convert them to digital value. Another element involved in the program design is how to send data to LCD.

V. RECOMMENDATION

Development of PV output power indicator for battery charging system is one of the improvements in photovoltaic monitoring system. Since the demand of photovoltaic system is increasing, this project will help customers to know level of voltage and current of battery charger at anytime. Battery charger is one of the important element in photovoltaic, it will discharge when there is load demand. As we know, battery charger has continuous level of voltage and current. However, it can only discharge until certain level. Usually, maximum depth of discharge (D0Dmax) of Battery charger is between 70% to 80%. Frequent discharge to D0Dmax will reduce the cycle life dramatically. As a recommendation, this project could be improved by install an alarm that will produce sound when the level of voltage in battery charger is full or reach dangerous level. However this project can also be use for any other equipment that have voltage and current rather than use for battery charger system only. Another recommendation is to connect it to data logger. Data logger will record all the data for certain period of time. Customers can observe the performance of battery charging system for example for the whole day.

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