Testing and Commissioning of Malaysian Grid Connected PV System Calculator using Visual Basic 2008

Aizat Bin Noor Azmi
Faculty of Electrical Engineering,
UniversitiTeknologi MARA Malaysia
40450Shah Alam,Selangor, Malaysia
Email: Aizat_1902@yahoo.com

***Abstract*–Nowadays, renewable energy come as one of energy source that really important to our life. Photovoltaic system is one of renewable energy that mostly used and popular among other renewable energy. This system becomes popular and useful because of geographic condition. Besides that, Malaysia is looking another source of energy.Malaysia has located at equatorial sunshine, so Malaysia relatively high solar irradiance on most of the days. A lot of premises and commercial building have installed grid-connected PV system. Before the installed system can be approved, it must pass the test and commissioning (T&C) process. A software calculator is needed during T&C process due to irradiance change very rapidly. The calculator is develop using visual basic 2008 (VB 2008) which the final . exe file can be run at any computer and notepad.**

Keyword: Photovoltaic (PV) system, Visual Basic 2008 (VB 2008).

I.INTRODUCTION

Electricity is most versatile form of energy we have. It is what allows citizen of the developed countries to have nearly universal lighting on demand, refrigeration, hygiene, interior climate control in their homes, businesses and school, and widespread access to various electronic and electromagnetic media [1].

Last few years, the interest in renewable energy for power generation has increasing because of environmental issues and depletion of fossil fuels. The huge technological improvements for photovoltaic cells (PV) along with their decreasing cost seem to justify their use as a possible solution [2]. Photovoltaic systems are the solar energy supply systems, which either supply power directly to electrical equipment or feed energy into the public electricity grid [3].

Photovoltaic (PV) power systems convert sunlight directly into electricity. A residential PV power system enables a home owner to generate some or all of their daily electrical energy demand on their own roof, exchanging daytime excess power for future energy needs (i.e. nighttime usage). The house remains connected to the electric utility at all times, so any power needed above what the solar system can produce is simply drawn from the utility. PV systems can also include battery backup or uninterruptible power supply(UPS) capability to operate selected circuits in the residence for hours or days during a utility outage.

Typically, system owners have specific goals in mind for their PV system. These might include reducing electric bills by a certain percentage, maximizing the power output from available roof space or maximizing return on their PV investment. The PVsystem designers then devise a strategy to meet these requirements. This strategy, including documents describing the intended system components and calculated expected performance output, which should help guide the PV testing and commissioning process.

The purpose of testing and commissioning on PV system is to ensure that the system is high performing and to ensure that the system is safety.Besides that, to verify that applicable equipment and systems areinstalled according to the contract documents, manufacturer's recommendations and industry accepted minimum standards. Furthermore, other purpose of testing and commissioning is to verify that installing contractors perform adequate operation checkout and prepare document proper performance ofequipment and systems. It's also to ensure that the operations and maintenance (O&M) documentation left on-site is complete and to ensure that the owner's operating personnel areadequately trained.

Testing and commissioning process especially for larger projects, during the design phase commissioning should be incorporated into the specifications and bid documents. Include required documentation, checklists, testing procedures, expected performance and basis ofdesign. It is also important to specify requirements for the commissioning timeline and give guidance on what person or entity will be responsible for the commissioning.

Timeline or particular about time is one of the most important parts in testing and commissioning process. It should be planned for during the design phase, built into the system cost, actively carried out at the end of construction and repeated as desired after project completion. However,most of the commissioning work will occur just after the PVinstallation is complete and the system is ready to be turned on for the first time. Ideally, this commissioning event occurs after all permits are signed off, the utility has given permission to operate the system and the monitoring system. If one or more of these milestones is delayed, you may want to start up and test the system regardless.

Be sure to schedule the commissioningas soon as possible after PV system construction is complete, but within a suitable window of weather. It does notmake sense, for example, to commission when there is irradiance of less than400 W/m2 in the array plane. Not only must the weather

be good, but the time of day must also be appropriate. Probably the most difficult and the most important aspect of commissioning a PV system is evaluating whether it is performing as well as it should be. First, the expected performance needs to be determined. Then, the actual performance needs to be measured and collect the data as soon as possible.

II. Scope Of Study

Scopes of study that involved in this project as follows:

- Study about PV system basic operation and Installation of the PV system.
- Learn the guidelines about testing and commissioning for PV system.
- Learn how to use Visual Basic 2008 (VB 2008) Software in order to complete this project.
- Create program for this project based knowledge in VB 2008.
- Run the program and observe the results.
- Detects any problems and try to find a overcome of that problems.
- Analyzed the outcomes.

III. Methodology

A. Visual Basic 2008 (VB 2008)

Visual Basic (VB) is a programming environment from Microsoft in which a programmer uses a graphical user interface (GUI) to choose and modify preselected sections of code written in the BASIC programming language [4]. This project used Visual Basic 2008 (VB 2008) software. This software can design and evaluate virtual form of testing and commissioning procedures. Using this software, the testing and commissioning become easier and can produce accurate result. Besides that, the program language of VB 2008 quiet similar to the program language of program C or program C++.

This software consists of two parts that can be considered which is design and program forms.To using VB 2008, firstly choose type of templates that installed at VB 2008. There are several types of templates that installed in this software such as window form application, class library, WPF application, WPF browser application and console application. For this project, the template that chosen was window form application. After choose the template, name the project and save the project. Next, there are two form appear at VB 2008 which is design form and program form. The purpose of design form is to design for user interfaces *andretains the drag-and-drop developers' interfaces.*

Rapid Application Development (RAD) is the technique of designing, coding, and testing applications in a constantly repeating sequence.RAD developers design and code interactively, producing results in a surprisingly short time [5]. To create or design a form that want to use, refer to Toolbox window. In there, its provides all the tools need to write and test applicationsVisual controls for creating user interfaces in Windows applications.

In this project form, there are several components that have been used and apply. This is representing design form. It includes Label component, Textbox component, Button component and RadioButton component. For each component there have own purposes. Label component function as to identify the data that want to insert while doing testing and commissioning process. Next is Textbox component which is function to insert data that reading from site.Button component function as to apply the mathematical formula using by data collection on site project. Last component that used in this program is RadioButton component which purpose to tell the info and mathematical equation that involve. All these components have to program it so that it will run smooth and follow the standard of testing and commissioning procedures.

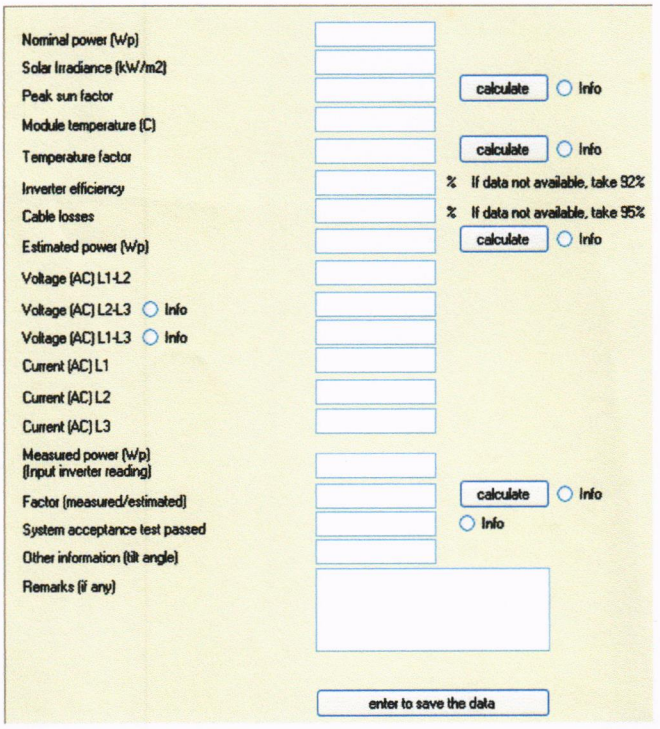

Figure 1: shows the virtual form created in VB 2008

Figure 1 shows the components that used in this program. Label components represent names of the data example nominal power, solar irradiance and etc. the blank box is representing textbox component. Data values must insert at these blank box. Button component represent calculation boxes. These boxes function to apply mathematical formula with related to some data that involve in the system. The last one component that involve is RadioButton who representing the info. Info functions as to tell information and formula that use in this project.

Program form will be appear in this project if some design components need to program it and need to make *mathematical equations. The program start with* "Public Class Form1" while to end the program type "End Class".

In Visual Basic, the source code is Spartan because Visual Basic is what was once called arapid application development (RAD) environment. The idea at the core of Visual Basic is theability to develop an application as quickly as possible without the esoteric details of the language [6]. To make the application do something, user need to add user interface elements or addsome code. Adding code without adding user interface elements will make the program dosomething, but it's not as exciting.

In this program, Codes were created and apply to the calculation box. Calculation box have different program

because when user click at calculation box, the program already calculated due to input data and display the result to user based on the equation that created.

Besides that, program also existence at Radio Button also known as "info" in this program because when Radio button is click, there will be appear some information. The information is already codes and ready to apply when user click the Radio Button.

After create a program is done, now time to run the application. To run the application, select Debug ➤ Start Debugging. Alternatively, use the keyboardshortcut F5. You'll see a window representing the Windows Application [6].

B. Flow Chart for this the program.

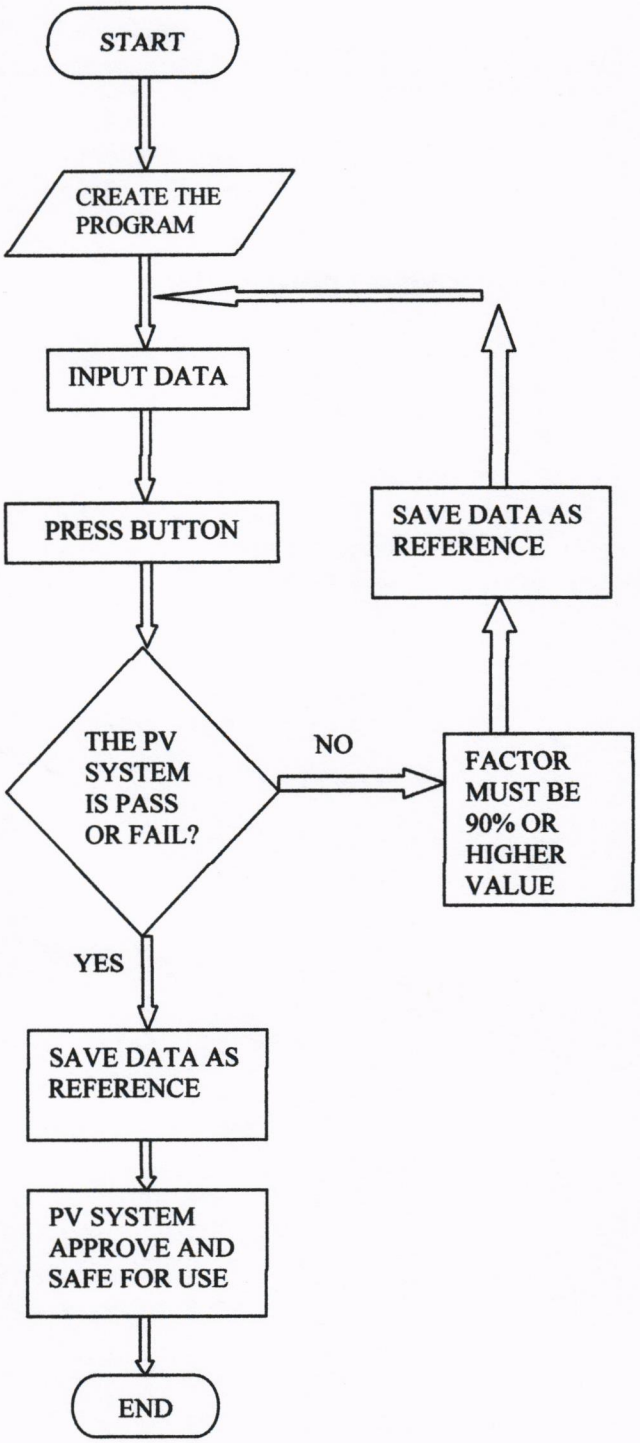

Figure 2: flow chart of programming in VB 2008

C. Data

This project will start by collecting all the data need in order to start design and create program. The data comes from Photovoltaic Monitoring Centre Universiti Teknologi MARA (PVMC). The data includes system testing and commissioning report, values, detail of equipment use and also the resources of the project.

Before begin this project, study the data that obtain and where that the data comes from. Firstly, before making testing and commissioning process and collect the data, check to make sure that PV system is in full sun with no shading what so ever. If it is impossible to find a time during the day when the whole array is in full sun, only that portion that is in full sun will be able to be accepted. After that condition is consider, disconnect all inverter circuit breakers which are not relevant and connect the relevant ones for the test.

The data that should have in this project are firstly nominal power in watt peak (Wp). Nominal power is the total of output power produce by PV arrays. Next data that consider is solar irradiance which means that solar radiance is an instantaneous power density in units of kW/m^2.The solar radiance is strongly dependant on location and local weather. Peak sun factor is mathematical equation that involved data of solar irradiance divide by 1000. Then, record data of module temperature. The cell of temperature of PV array will vary drastically due to ambient condition such as sun intensity, air temperature, wind speed, and other factor. Module construction and how array is mounted can also impact the module's cell temperature. This value can take at PV modules that use in the system. Usually the value of module temperature is around 40 degree to 60 degree. Next after get the value of module temperature, obtain the temperature factor. By using calculation, temperature factor can be defined. The formula using data of module temperature, standard test condition which is the value is 25 degree, temperature coefficient of the PV module used. Data of temperature coefficient of PV module depend on type of module that install at the system. If data is not available, use 0.50 for mono/poly – crystalline modules and 0.25 for amorphous silicon module (thin film module).

Inverter efficiency is depending to what type of inverter that has been installed in the PV system. If data not available, take 0.92 as the data of inverter efficiency. Cable losses are the power losses due to resistance of the wiring of the system. Cable losses data usually take from direct current (DC) wiring of the system. If the data is not available, use 0.95 as the value of the data. After that, calculate the estimate alternating current (AC) of output power in watt peak (W) by using the formula.

The data that involve in that formula are sum of total of the module ratings multiply by peak sun factor multiply by temperature factor multiply by inverter efficiency multiply by cable losses. After done calculate the estimated AC power, then record the voltage at L1 – L2 (line voltage 1 toline voltage 2), voltage L2 - L3 (line voltage 2 to line voltage 3), voltage L1 – L3 (line voltage 1 to line voltage 3). If the system is single phase, only voltage at L1 – L2 will be record.Record the current output at line 1, line 2 and line 3. If the system is single phase, only current at line 1 has value. After that, record value of power at inverter. The power depends on type of inverter.

The most important procedure for testing and commissioning system acceptance or not is factor of power which means that measuredpower divide with estimated power.

Measure AC power must be higher than estimated AC power. The factor must be 90% or higher value. If it is less than 90%, the PV system is shaded, dirty, miswired, fuses are blown, or the modules or inveter are not operating properly.There are equations that involve in the testing and commissioning for PV system:

$$Peak\ sun\ factor = \frac{solar\ irradiance}{1000} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

$$Temperature\ factor$$

$$= \frac{(100 - \{(Temp\ module - 25) \times Temp\ coeff\ of\ PV\ module)\}}{100} \quad \ldots\ldots\ldots\ldots (2)$$

$$Estimated\ AC\ power\ =$$

$$Nominal\ power \times Peak\ sun\ factor \times Temperature\ factor \times Inverter\ efficiency \times Cable\ losses \quad \ldots\ldots\ldots\ldots\ (3)$$

$$Factor = \frac{Measured\ power}{Estimated\ power} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

IV. Result And Discussion

To test whether this project is fully function or not, let take one sample of successful testing and commissioning that have done by PVMC. Usually while making the testing and commissioning for PV system, there have to consider some factor that affecting the output such as temperature, miss match and wiring losses, angle of sunlight emission to the PV module surface, DC to AC converting losses and dirt and dust on the solar module surface. There are committees who involve which are PVMC, PTM, TNB, supplier and owners.

For this sample, the installation was located at No1, Jalan Kelana, Ipoh Perak. The PV capacity is 3.78 KWp. The PV system was installed on august 2007 and date commissioned on September 2007.

From this sample, data were collected [8] and recorded into the form that provided by PVMC.

PV array	1st run	2nd run
Nominal power (Wp)	3780	3780
Solar irradiance (W/m2)	315	319
Peak sun factor	0.315	0.319
Module temperature (C)	35 C	35 C
Temperature factor	0.95	0.95
Inverter efficiency	0.92	0.92
Cable losses	0.95	0.95
Estimated power (W)	**988.6**	**1001**
Voltage L1-L2	240	240
Voltage L2-L3	-	-
Voltage L1-L3	-	-
Current L1	3.7	3.8
Current L2	-	-
Current L3	-	-
Measured power (W) (Inverter reading)	**888 890**	**912 950**
Factor (Measured/estimated)	0.89	0.91
System acceptance test passed	Yes	Yes

Figure 3: shows the table of data for testing and commissioning.

Figure 3 shows that the data that have been taken and recorded. The data were fillin into the table. According to the line voltage in this system, this PV system was installed in single phase because data was recorded only at voltage line1 to voltage line 2. From this table, all the calculation have made by using calculator. The calculations were done manually.So it's take time to get the result whether system is acceptance or not.

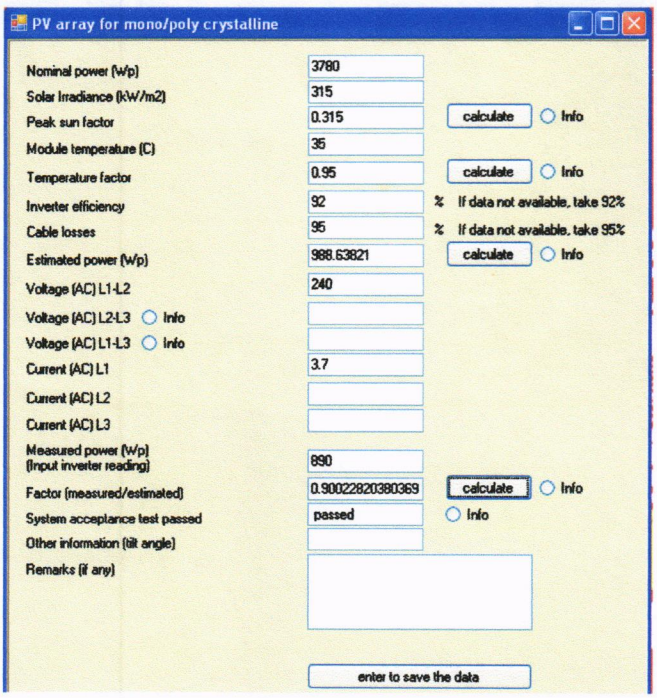

Figure 4: the virtual table of data created in VB 2008 for testing and commissioning.

Figure 3 shows that the same data was recorded but different form. This virtual form created based on the same as previous form. The different of this form is the calculation is ready and can apply any time. This is because this form was programmed and the calculation has already inserted in the program.

From these two forms, the data is exactly same and the result quiet close, but there have comparison between it. For manual form, the column that given is not enough to record data more than two. Besides that, the data must write down in this form, the data should take faster and accurate because the data that measured is changed rapidly. So, if wrong data are inserting into wrong column, it will delay the result and probability to do error is higher. Moreover, this manual form takes time because calculation part needs to do manually by using calculator. The user needs to refer data at manual form then insert data into calculator to get the result. So it will take time to search what equation that wants to use and what data should put into the formula. So it will affect the result of testing and commissioning.

For this project form, user can record data as much as user want because this form can save the previous data by click the button save that provided. Besides that, this form are friendly user and easier to use. By using this form, percentage to do error is smaller. By using this project form, the user doesn't have to bring different manual form because with this project form, it already inserted two forms in one program which is mono/poly crystalline and amorphous silicon (thin film) module. By clicking in first interface that appear, just select type of module and it will be appear. This project will quickly display the result whether the system is past or not.It also can save a lot of time especially on calculation part because this project is already programmed with equation for the calculation.User just inserts the data then press calculation button to see the result.This will make user easier to do testing and commissioning process.

V.CONCLUSION

Testing and commissioning is very important to PV system installation. These procedures are to ensure that the system is safety and to determine whether the PV system is acceptance or not. Besides that, these procedures are to check the performance of the PV system. The performance of the system is depending on data taken. So, for making testing and commissioning more efficient to produce the result, the software has created on VB 2008. After study and made some research about PV system especially in testing and commissioningand VB 2008 software, the conclusion from the research can be drawn as followings:

- Understand about the concept and guidelines of testing and commissioning for photovoltaic (PV) system.
- Learn and understand Visual Basic 2008 (VB 2008) and able to do program and mathematical formula based on the testing and commissioning guidelines.
- Able to create program by using codes of VB 2008, run the program, compile the program and change the program file to an application file by using VB 2008. This application can be open at any computer without access VB 2008.
- By using this application, it will help the person who incharge to produce faster result and can determine whether result is pass or not in short time of period. This application is easy and friendly user.

VI.FUTURE DEVELOPMENT

Future development for this application is by applying the program of this application into hardware so that this application can run with hardware. The hardware can record the data that necessary then link to this application so that this application can do calculation automatically. Otherwise, upgrade this application so that it can be use in cell phone. For future, just bring only cell phone that consists of this application so that it will make easier to do testing and commissioning at side.

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