Program Development for Monitoring and Analyzing the Data from a Solar PV System

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***Abstract* – This paper deals with the process and strategies used in developing a computer program that could be used to monitor and analyze the data from a grid-tied array of solar photovoltaic (PV) panels. The system that was primarily acquired to support a newly developed course on alternative and renewable energy systems also provided an opportunity for demonstrating the use of renewable energy sources to various groups of visitors, ranging from K-12 students to engineering or business professionals. The computer program was developed in Visual Basic primarily by the first author of this paper who was an undergraduate student completing this work as part of the requirements of an independent study on the new lab equipment for renewable energy education. His experience with this project is presented in this paper. The second author who guided and supervised this project adds to the discussions and conclusions the educator's point of view.**

Index Terms – Alternative energy, GUI, solar panel, Visual Basic.

INTRODUCTION

In the fall of 2008 the School of Engineering at Grand Valley State University started offering a technical elective course dealing with alternative and renewable energy systems and applications. In order to make the course content and delivery methods stronger, a laboratory was equipped with solar PV, wind energy, hydrogen energy trainers, an educational fuel cell facility, a grid-tied wind turbine system and a grid-tied solar PV system [1-2]. The latter system consists of twelve solar panels rated at 124 W each (Uni-Solar ES-124 modules). In order to be able to access the raw data from this system and manipulate it so that performance analysis can be carried out, a computer program had to be developed. This program was aimed at providing flexibility to different groups of users. For example, for engineering students taking the above mentioned course it would facilitate daily or multiple-day analysis and performance comparison of the system or comparison of the actual performance with performance predictions based on solar radiation data. For various groups of visitor the primary objective would be to present the data graphically in a way that could be easily interpreted by a non-specialist.

The project of developing the computer program was assigned as part of the requirements of an independent study to an undergraduate student by an advisor, the first and second authors of the paper respectively. In what follows, the paper discusses the various aspects of the development of the program. Discussions from the two authors' perspectives and concluding remarks follow.

PROGRAM SPECIFICATIONS

The program developed accomplishes several tasks:

- Displays near real time data of the solar PV system.
- Converts .csv files to organized .xls files.
- Quickly compares several data files graphically
- Simple user interface for easy demonstrations and access to data.

PROGRAM DEVELOPMENT

The principal objective of this program was to manage and interpret solar data files in an effective and simple manner. The raw data files from the solar PV system were stored as comma separated variables files (.csv), which contained the critical parameter values at a predetermined interval; in this case every fifteen minutes. Each file represented a single day's data and was stored in a dedicated folder for further interpretation.

The program developed uses these files to display the solar PV system data in a useful and efficient way instead of extracting data line by line from unformatted .csv files. The user has the option of selecting one or multiple files to analyze. Once these files are selected they can be saved as a MS Excel friendly file that can be used in reports and analyses that require more advanced methods. Once the appropriate files are selected within the program, the data within them can be graphed for quick comparison using ZedGraph within the Visual Basic .NET framework.

ZedGraph is a set of classes, written in C#, for creating 2D line and bar graphs of arbitrary datasets [3]. In this instance, line graphs were used to compare solar PV parameters. The user could then zoom freely and save each plot created simply by right clicking within the plot area. This allows for quicker comparison of parameters than if the user were simply using MS Excel. Ease of use also makes this form of output appealing in demonstrations to a diverse audience.

The program allows for three types of analysis to take place: single-day, dual-day and multiple-day analysis. Multiple-day analysis allows the user to compare up to seven days of data graphically for all pertinent parameters. The

specific parameters that can be both converted into an MS Excel friendly file as well as displayed graphically include Total Energy (kWh), AC Input frequency (Hz), duration (hrs), AC Output current (mA), DC Input Current (mA), AC output power (W), temperature of the array (°C), AC input voltage (V) and DC input voltage (V).

The program developed needed to interpret data files from the data logger attached to the solar PV system. A Sunny WebBox from SMA America, Inc. was used, which contained an FTP data server that allowed for easier storage of data files.

The Sunny WebBox communicates directly with the Sunny Boy inverter that was connected to the solar panels in the array as can be seen in the schematic in Fig 1. The Sunny Boy inverter also has the capability of transmitting system errors to the Sunny Webbox as well, all of which need to be interpreted accurately by the developed program.

The Sunny WebBox is connected to a local network within the engineering building, where it was given a specific location to store solar data that could be accessed via personal computer.

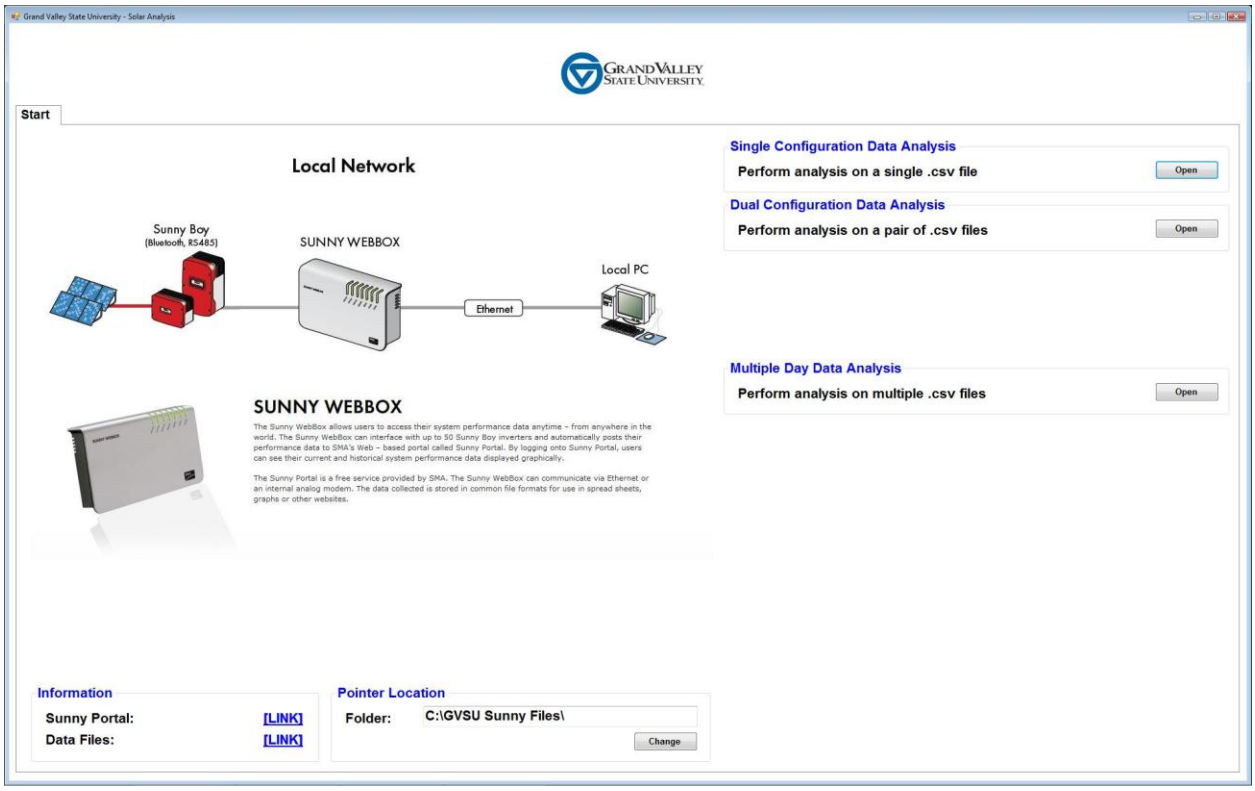

FIGURE 1
START TAB, GRAND VALLEY STATE UNIVERSITY – SOLAR ANALYSIS PROGRAM

The internal memory capacity of the Sunny WebBox is 8MB, which can provide approximately 2 to 30 days of data storage [4]. The data collected by the Sunny WebBox is overwritten once the internal memory has reached capacity, thus making it critical that the solar data be stored externally from the Sunny WebBox itself. To prevent this from occurring, an external file location was selected for the files to be moved.

It was determined that Microsoft Visual Basic 2008 Express Edition would be used as the integrated development environment (IDE) to create the desired program. This IDE can be downloaded free from Microsoft's website. While the Express Edition does not have the breadth and capabilities of Microsoft Visual Studio it was sufficient for the task of developing this program. The general structure of the program consisted of a splash screen, and a main program screen that would consist of a series of tabs the user would navigate through to acquire desired information about the solar PV system.

After a brief splash screen, the program opens to a Start Tab that describes the system components as well as the different data analyses that can be performed. The Start tab is depicted in Figure 1. In the Information section the user can access the Sunny Portal, the SMA packaged internet portal and the folder location of where the data files are being stored on the network. This folder location can be changed by the user to search separate folders for solar data.

The developed program had to be able to retrieve solar data files easily and in an organized manner that is not confusing to the user. It was determined that if the user simply wished to open a single data file, this could be accomplished using a Select File window with a filter that

would only display .csv files located in a particular location. From here the user could easily identify the desired files and select them for analysis. Another consideration for ease of use was how the files were named and were given the format, yyyy-mm-dd.csv allowing the user to identify files quickly by year-month-day.

In the case of Single Configuration Data Analysis, once a file is selected from the appropriate folder, the user is moved to a newly created Spreadsheet tab within the program. The data grid accompanying this tab is populated with the data collected from the raw .csv file. The current data location is also displayed to the user.

The Spreadsheet tab allows the user to change the specific file again if necessary without having to move back to the Start Tab. When a new file is selected the data grid will be automatically cleared of data present from the last file and will be repopulated with the new file once the user confirms to open the file. The user can also highlight specific regions of the data grid for copying as well if a full spreadsheet of data is not desired. With this method, users can quickly compile data in existing MS Excel files to suit their needs.

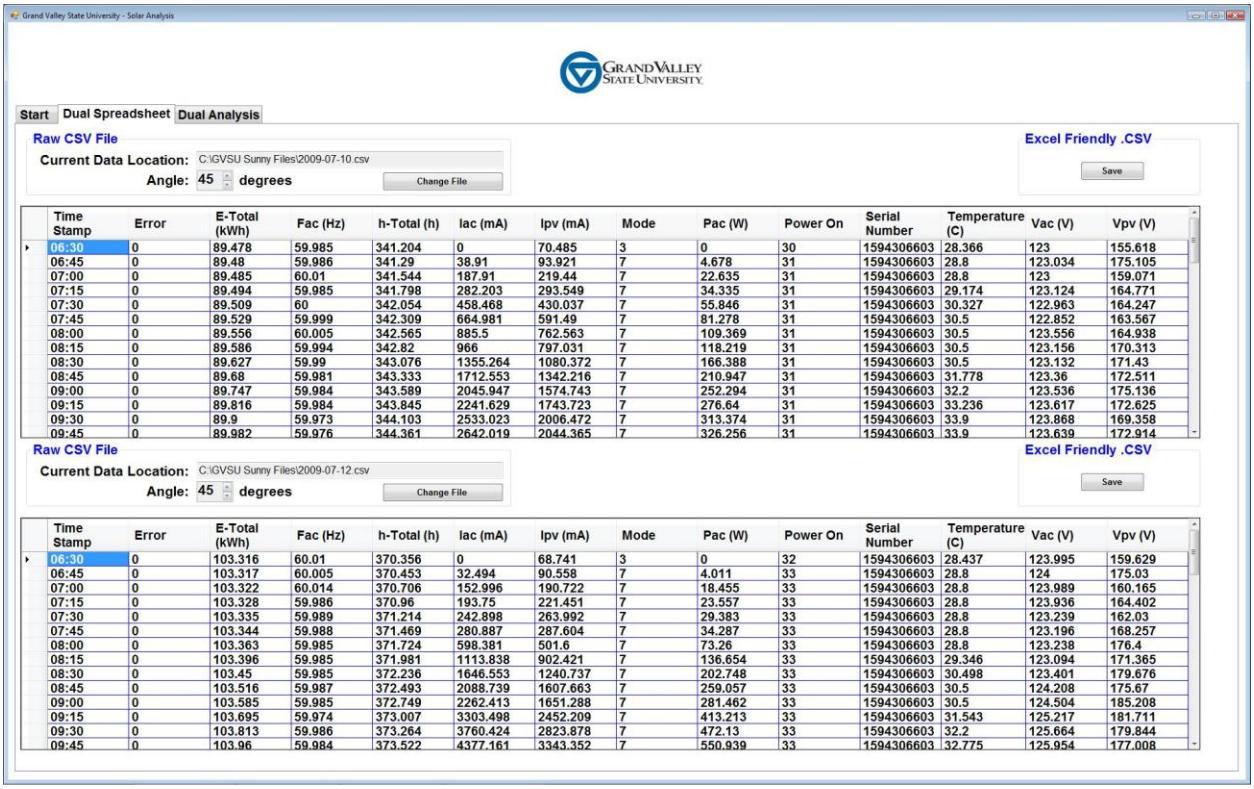

FIGURE 2
DUAL SPREADSHEET TAB, GRAND VALLEY STATE UNIVERSITY – SOLAR ANALYSIS PROGRAM

If the users wish to save the data as shown in the data grid then they can click the Save button in the Excel Friendly .CSV groupbox.

The Day Analysis tab will also be made available to the user once a file has been selected. This tab contains a plot region that the user can populate by selecting the desired parameter from a drop down list. The plot produced can be saved or copied from the right click menu and can be zoomed by clicking and dragging within the plot area. A combination of these features can be used to save zoomed images of the plot.

In order to simplify the user interface tabs are accessed sequentially according to the type of analysis that is being performed. In order to perform another analysis, the user simply clicks back to the Start tab to redefine the type of analysis and the tabs will automatically populate according to the analysis.

If the users wish to open two days of data and compare them side by side then they can select the Dual Configuration Data Analysis from the Start Tab. Here the user can analyze and compare two raw .csv files. From the Start Tab the user can select the Open button located in the Dual Configuration Data Analysis groupbox. Once clicked, an additional groupbox will appear along with a checked listbox. This will list the available .csv files located in the file location selected in the Pointer Location groupbox. From here, the user selects two files to compare and then presses Submit. If two files are not selected and the user attempts to submit, the user will be prompted to select two files before continuing.

Once the program has confirmed that the user has selected two files to compare, the Dual Spreadsheet and Dual Analysis tab will appear as shown in Figure 2. The Dual Spreadsheet tab will appear and show the data grid of both files. Again, the user can save the converted version of the files as a whole or copy specific cells from the data grid.

The array of solar panels is installed on two large stands that can be set to different angles to compare how the angle of inclination affects the energy production of the array. The developed program provides flexibility in comparing different datasets which may have been acquired at different angles of inclination. In order to accomplish this, the user defines what angle each array is stationed in the Dual Spreadsheet tab. This additional data will be added to the converted MS Excel friendly files and will appear in the legend of the graphed data in the Dual Analysis tab.

Along with the Dual Spreadsheet tab, the user has access to the Dual Analysis tab that can plot the various parameters available. For obvious reasons not all characteristics appear in this list (serial number, etc.) because they do not provide additional insight. The user can analyze and compare up to seven .csv files graphically. From the Start Tab the user can select the Open button located in the Multiple Day Data Analysis groupbox. Once clicked, an additional groupbox will appear along with a checked listbox. This will list the available .csv files located in the selected location. From here the user can select one to seven files to compare and then submit these files for analysis. If more than seven files are selected the user will be prompted to select a maximum of seven files before continuing.

Once the program has confirmed that the user has selected an appropriate number of files the Multi Analysis Tab will appear. This tab will allow the user to produce plots of data comparing the multiple .csv file characteristics as shown in Figure 3. The zoom functions of the plot can be used to separate the data sets from one another. Again, these plots can be copied or saved for use in reports and analysis. The Dual Spreadsheet Tab is shown in Fig. 2 for two different days of data.

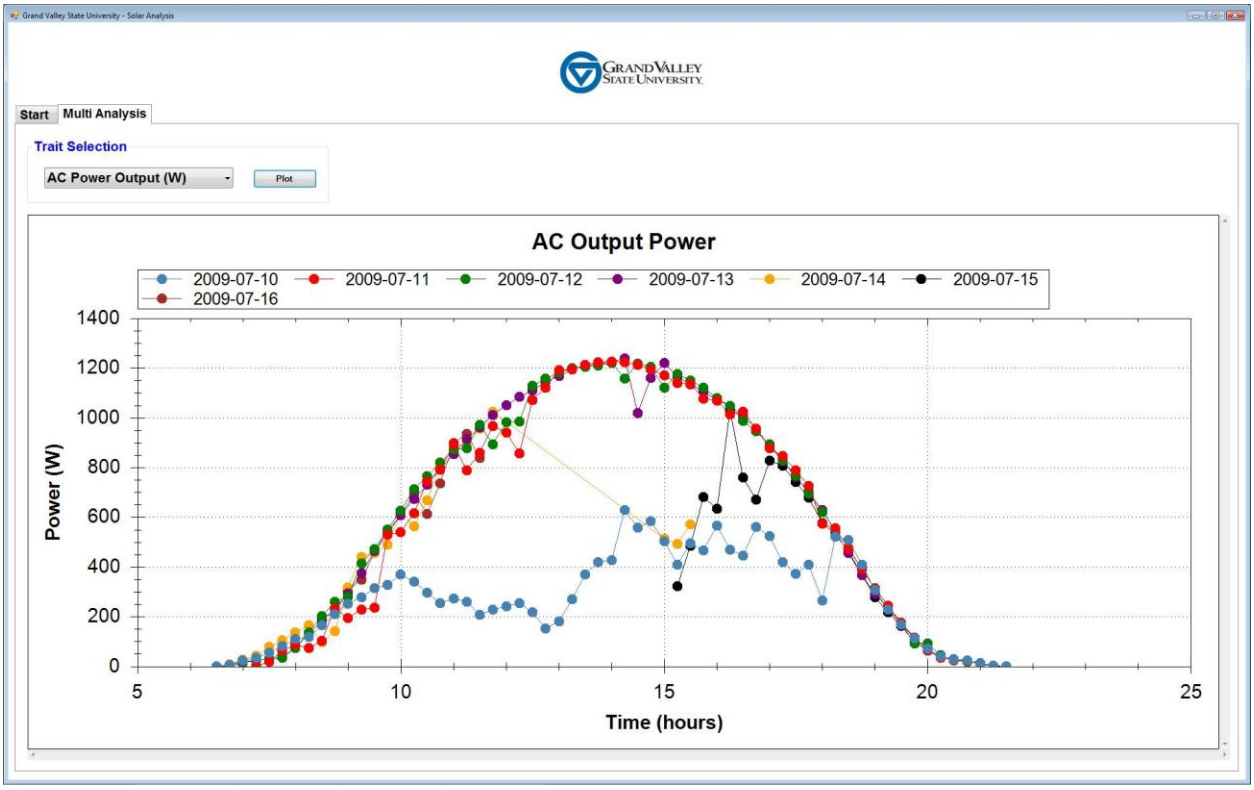

FIGURE 3
MULTI ANALYSIS TAB, GRAND VALLEY STATE UNIVERSITY – SOLAR ANALYSIS PROGRAM

DISCUSSION

The development and implementation of this program could have been achieved in several ways but because a portion of the program's appeal needed to be its ease of use and its aesthetics a unique solution had to be developed for exactly that purpose. An individual could possibly develop a program in either C, FORTRAN or MS Excel to accomplish the same goals achieved in this program's file conversion but the presentations of these programs might not be as appealing to younger student groups who are just beginning to show interest in topics of alternative energy and engineering. With a unique and widely educationally diverse end user it was a priority to make the graphical user interface clean and easy to use.

The first author feels he learned that an engineer must always be aware of who the end user is and to complete his project with this in mind. Because it is the end user that defines the value of the product and how useful it is for their purposes. Developing this program helped him understand that the easiest solution is not necessarily the most effective. In this instance extra effort was placed on the presentation of the data within the program rather than relying on an external program such as MS Excel. This allowed faster analysis and comparison of data. It was critical that the priorities of the end product be clearly defined so these goals could be attained.

While developing the program a deliberate effort was exerted to make it appeal to younger students, it was equally as critical not to narrow the focus of the program too greatly because it still needed to encompass the interests of the engineering students that would be analyzing the data from the solar PV system in greater depth. Here it was necessary to interpret the raw data files and be able to convert them into MS Excel friendly files for further, more detailed investigation. This flexibility allows the finished product, in this case a computer program, to serve the needs of a wide audience.

Since the development and launch of this program several K-12 student groups have visited the School of Engineering and the laboratory housing our monitoring station of the solar PV system as well as our renewable energy equipment that include a monitoring station for a grid-tied wind turbine. Students found the demonstrations conducted using the program developed very interesting and educational that was evident from the inquisitive questions they asked. One other engineering faculty member of the School of Engineering who teaches a freshman level "Introduction to Engineering" course indicated interest in using the monitoring station and accessing the data from the solar PV and wind turbine facilities in order to develop a course module for his aforementioned course. We are currently working with him on this initiative.

CONCLUDING REMARKS

The program that was developed achieved its objective in managing and interpreting solar data files in an environment that could be easily understood by nearly any audience. It is capable of displaying solar data quickly and precisely for presentations and demos while also being capable of converting raw data into easily accessible data that assists engineering students in their study of the solar PV system. It is anticipated that this program will help inspire younger students visiting our facilities to take an interest in renewable energy applications and understand how they function.

This project serves as an excellent example of how to involve undergraduate students in research/development activities that may produce invaluable tools that can be used in the classroom for relevant courses. In predominantly undergraduate engineering programs where the graduate assistance may be scarce or completely absent, faculty members can conveniently involve undergraduates in these types of activities. By doing so, it will not only help in their scholarly activities but also will provide an excellent learning experience for the undergraduate students involved.

REFERENCES

[1] Sözen, M., "Use of Solar, Wind and Hydrogen Technology Trainers in an Alternative and Renewable Energy Course" *Proc. of the 2009 ASEE North Central Section Conference*, Grand Rapids, MI, April 2009

[2] Sözen, M., "From a Traditional Combustion Course to an Alternative and Renewable Energy Course" *Proc. of the ASME International Mechanical Engineering Congress and Exposition 2009*, Lake Buena Vista FL, November 2009

[3] "ZedGraph – Main Page" *ZedGraph*, Feb. 2 2010 http://ZedGraph.org

[4] SMA America, Inc. "Sunny Webbox Web Enabled Data Logger and Controller for Alternative Energy Systems", 2005, pp. 85

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