OVERVIEW OF SOLAR POWER INSTALLATION PROJECT FOR LEE COUNTY JUSTICE CENTER

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ABSTRACT: This project consists of installing a 16.6 kW grid-connected solar-powered system that will be used to offset the energy costs of electricity used by Lee County's TK Davis Justice Center located in Opelika, AL, USA. The project will monitor the performance of the system and make the on-going results available to officials and the public. Information gathered through the system's design, installation, and performance monitoring will provide valuable research information concerning practical photovoltaic alternative energy systems design and integration. Its research value will be enhanced by its additional asset as an excellent teaching and demonstration tool. The purpose of this program is to aid in photovoltaic system design by providing accurate and in-depth information on likely system power output and load consumption, necessary backup power during the operation of the system, and the financial impacts of installing the proposed system. The system is vitally important to the overall scope of the alternative energy plan envisioned by the Lee County Commission and Auburn University's SRI. This project hopes to establish a message that local governments need to take an active role in increasing energy-efficiency and being environmentally friendly while reducing operational costs for its citizens over the long-term.
Keywords: Energy Options, PV System, Small Grid-connected PV system

1 PROJECT OVERVIEW

With the inauguration of a new President of The United States of America, it appears the topic of renewable energy has come to the forefront. As President Obama stated, "We will harness the sun and the winds and the soil to fuel our cars and run our factories." This paper will discuss the recent local energy initiative of the state of Alabama in the installation of photovoltaic panels to Lee County's TK Davis Justice Center (LCJC) located in the City of Opelika, AL, USA. This project hopes to establish a message that local governments need to take an active role in increasing energy-efficiency and being environmentally friendly while reducing operational costs for its citizens over the long-term. The new addition to the LCJC is a model of energy efficiency and conservation.

This project consists of installing a 16.6 kW grid-connected solar-powered system that will be used to offset the energy costs of electricity used by the LCJC. The project will monitor the performance of the system and make the on-going results available to officials and the public. Information gathered through the system's design, installation, and performance monitoring will provide valuable research information concerning practical photovoltaic alternative energy systems design and integration. Its research value will be enhanced by its additional asset as an excellent teaching and demonstration tool. The purpose of this program is to aid in photovoltaic system design by providing accurate and in-depth information on likely system power output and load consumption, necessary backup power during the operation of the system, and the financial impacts of installing the proposed system. The 16.6 kW system is vitally important to the overall scope of the alternative energy plan envisioned by the Lee County Commission and Auburn University's SRI. The initial system will serve as the backbone of the expandable system located at the LCJC complex.

Location, sun shading analysis, and mounting options will be reviewed for this paper. Performance projections and lifetime financial analysis will also be presented. The model used at the Space Research Institute is called PV-DesignPro v6.0. This tool is exceptionally versatile. With this project's unique location, ease of replicability and expansion, this project has the potential to be the prototype for other similar undertakings across not only the state but also the country and even worldwide.

2 THE TIME IS NOW

In the last three years, an amazing upsurge has taken place in the use of cost-competitive photovoltaic technologies for terrestrial applications. Because of the existing 30% U.S. Government tax credit for installing photovoltaic (PV) and/or solar hot water systems coupled with tax incentives in a few states, the use of solar technologies on dwellings and facilities is increasing and this is helping reduce the U.S. reliance on foreign oil and also the need for new power plants fueled by coal or oil. The present cost of PV electricity is approximately $0.20/kWh (Fig. 1). Grid parity could be reached by 2012 due to module prices decreasing, the Si supply is recovering, and the cost of electricity is increasing. However, even with these incentives, most

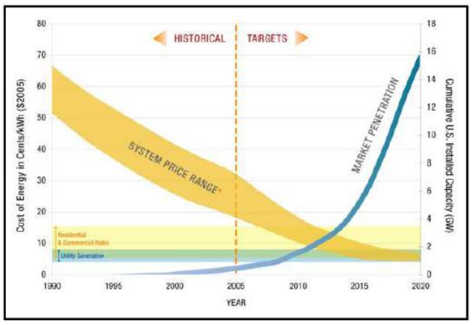

Figure 1: Solar array system costs and market penetration

states in the U.S. lag behind Europe and Asia in implementing solar technologies for new distributed applications and in consumer education.

3 SOLAR ARRAY SYSTEM ANALYSIS

3.1 Load Monitoring

In order to do an in-depth analysis and determine the appropriate system for LCJC it was necessary to know what load would be placed on the solar arrays. Electronic load monitoring and data logging of some load center panels in the Central Utility Plant of the LCJC were made. Figure 2 is an example of one of these

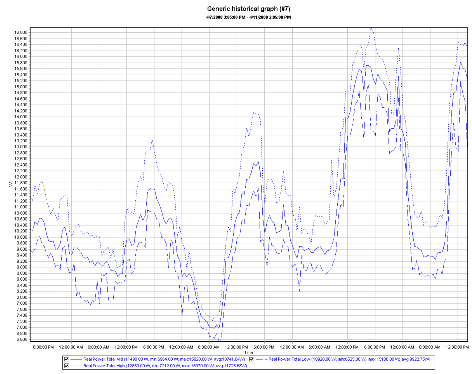

Figure 2: Example of LCJC load profile

load monitor logs. It illustrates the hourly and daily variations in the electrical load demands of this one circuit. Notice that it peaks nominally during daylight hours matching the generation capability of the photovoltaic array very well. It also illustrates that there are days when the LCJC activities result in heavier demands. Using this as an example, the typical, averaged profile (see Fig. 3) can be used as input to a

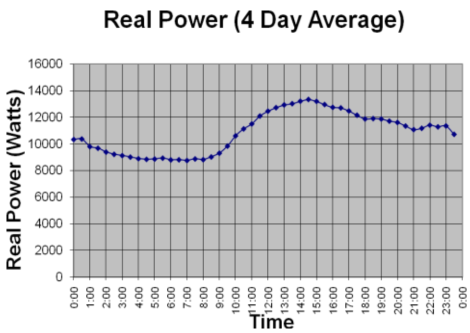

Figure 3: Averaged daily power profile used in the modeling program

solar power modeling program to project system performance, help optimize design, and compare to predicted performance. Using such load data, the electrical inverter specifications can also be determined.

3.2 PV Module Comparisons

An in depth study has been done of the types and performance of photovoltaic modules that are currently available in the market. A comparison of PV modules ratio to highest power can be seen in Fig. 4. The cost to power ratio was also calculated as shown in Fig. 5. From these initial calculations several of the more promising photovoltaic modules were selected and run in the modeling program. When choosing the photovoltaic panels it is a decision of efficiency versus cost.

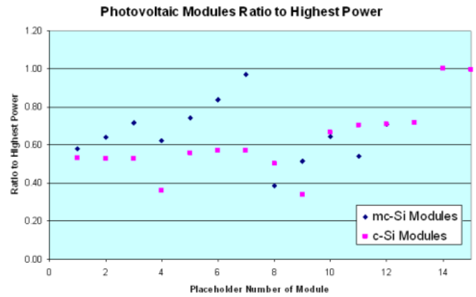

Figure 4: Ratio of module power to highest power module

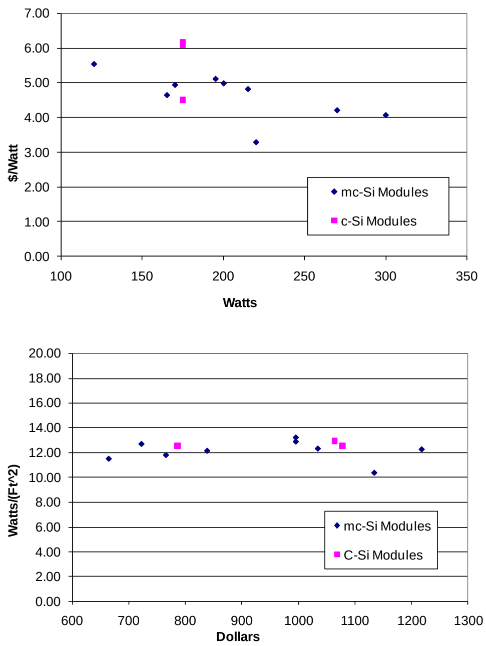

Figure 5: Cost per watt analysis

3.3 PV Design Pro G Modeling

For the first modeling case we used 220W SunPower panels in the data base of PV DesignPro–G. Similarly, the database contains inverters that will be used to convert the direct current (DC) of the solar arrays into the 480 VAC. The 30-year weather profile database for Montgomery, Ala., was used. Figure 6 shows that 35.5 percent of the annual load is produced by photovoltaic energy for an east-west tracking system at fixed tilt of 30 degrees or an annual total of energy provided to the load of 34,047 kWh. Of course the system cannot supply 100 percent of the load because the power that is needed at night and when the sun isn't shining has to come from the power grid. In addition, the fraction supplied by the solar array varies by month due to the change in weather over the year. The load also varies by day and month, but we have not included that variation in this calculation. Electronic load monitoring was only done at

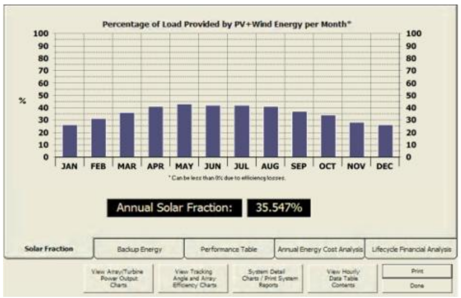

Figure 6: Solar percentage for a fixed tilt, east-west tracking 20 kW array, for the LCJC

one time of year so we kept the load the same each month. It is important to note, however, that all of the energy generated by the system cannot be used by this load. Sometimes the array will produce more energy than the load requires – for example, in the morning. In this analysis, the array produced an additional annual excess energy of 6,587 kWh (for a total of 40,634 kWh). In this installation, the system will automatically shift the excess power to another circuit so all the power generated by the array will be used within the facility. The same calculations were run for several other PV modules for comparison purposes. The above is just one example of the systems run. It was determined later that a tracking system was not the optimal choice for the LCJC; the increased power did not offset the higher price.

3.4 Financial Analysis

A photovoltaic energy system lifetime financial analysis can be calculated by PV Design Pro-G. It calculates the cost per PV produced kWh, payback years, and internal rate of return (IRR) over the alternative. This is based on the system cost, the sales tax rate, any tax credits available, the life of the system, and the cost of alternative energy. If excess power is produced, the cost of the sold energy is also taken into account. For the example given above, the payback is 16 years and the IRR is 5.6%. One of the current disadvantages of installing solar power in Alabama is there are no state tax incentives. This is a huge hurdle to overcome when other states, such as Louisiana, offer up to a 50% tax credit. The 30% federal tax credit was taken into account. Alabama also has a lower cost of electricity than many other states causing the payback time for a solar system to be longer.

3.5 Shadowing Studies

Shadowing studies were completed on two different potential mounting locations for morning and afternoon sun position taking into account summer and winter solstice. One such view is seen in Fig. 7. Through the use of these models it allows for the optimal system based on cost and performance to be chosen for installation at LCJC. Clearly the design shown in Fig. 7 must be modified due to shadowing effects. Due to this study another roof location was selected for installation.

3.6 Fixed vs. Tracking Arrays

When choosing between a fixed verses a tracking array there are several considerations. A one and two axis PV solar tracker system will have higher energy due to optimal solar alignment. However, for a system of this scale, the balance of system costs start to equal or exceed the cost benefits from increased energy production. Trade studies were made of this system including consideration of available space, the costs, and there is more potential for failure and maintenance due to the moving parts. A stationary pole mount is easy, inexpensive, and looks good. A low profile ground mount is easy to install but is a bit more difficult for grounds maintenance so a gravel base bed would need to be added. The footprint with a fixed system is smaller which can also be important depending on the location size allotted.

3.7 Roof vs. Ground Mounting

The roofing material at the LCJC is a Firestone EPDM rubber-based composite. Therefore it is vital that the manufacturer roofing warranty for this rubber membrane be conserved. After review of Firestone's Roofing compatibility requirement it was determined that there is only one roof mount system endorsed, the SunPower T-10 roof system. The array itself needs to be non-penetrating and flat unobstructed roof space is available. Mechanical loading (lbs/ft^2) allowable for the roof must all be observed along with the minimizing the distance to the power circuits. Roof arrays are easy to install allowing quick deployment. However, they are not visible from the ground. The ground mounting option is easily visible and can be used as an example for other facilities, but it takes up needed ground area for expansion of the facility. Public visibility is critical to this installation and is an essential part of the design. Future expansion on the roof may also lead to shadowing issues. A combination of both options was a good settlement for this project.

3.8 Angle of Elevation

An analysis was performed to determine the optimal elevation angle for both fixed and tracking arrays based on the location and time of year. With completion of the LCJC, these calculations are being compared to actual performance to determine their accuracy.

3.9 Inverter Selection

One of the interesting aspects of this small installation is that it will deliver its power to a both a 480 VAC, 3 phase circuit and a 208 VAC circuit requiring the use of two different inverters. The inverters selected must have capability for easy

Figure 7: Shadowing effects for roof mounted array at LCJC

integration into a web site that is being prepared for the system. This system will have real-time reporting on electricity production and usage as well as other system and environmental reports. Environmental data being collected include: solar irradiance, module temperature, ambient air temperature, and wind speed. As noted before, this system will not power any circuits that are essential to security or safety of the center. Selected inverters are described next.

Figure 8: T-10 system on roof of LCJC

Figure 9: Pole mounted array at LCJC

4 INSTALLATION

After careful consideration of all factors of the analysis, the installation consists of a roof-mounted array using 64 SunPower 230W high efficiency modules in T-10 mounts angled at 13º for a total power of 14.7 kW (Fig. 8). The remainder of the array is pole-mounted and consists of 8 of the same modules (1.84 kW) mounted at a fixed, latitude angle (Fig. 9). The output of the roof array passes through a Solectria 13 kW grid-tied inverter delivering 480 VAC, 3-phase. This inverter has 94.5% overall efficiency. The pole mount array is connected to the building through a SunPower SPR3000m inverter (made by SMA) delivering 208 VAC. Total power for the system is 16.6 kW. Inverter performance monitoring is through the use of an SMA Sunny WebBox and Solectria's SolrenView Web Monitor. The environmental monitoring utilizes SMA Sunny SensorBox with temperature sensors, irradiance cell, and wind anemometer.

By using different mounting options and tilt angles the project will be a learning tool and showcase for potential solar array installations at other facilities. To verify the power performance of our chosen arrays an analysis was done using both the PV Watts and PV Design Pro-G software. The numbers were consistent with that of the solar array installer and are compared to experimental data later on in this paper.

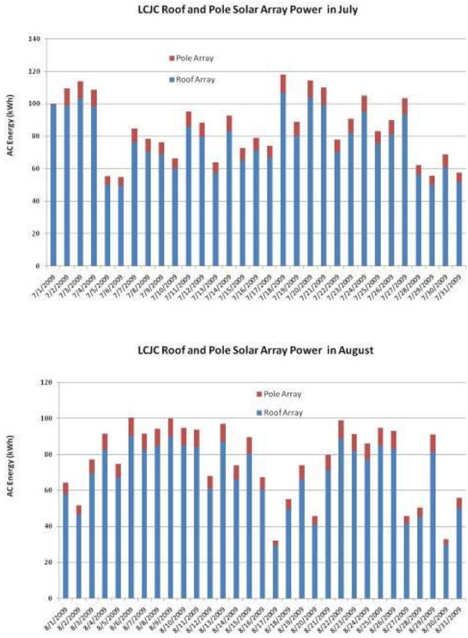

Figure 10: AC Energy produced by day in kWh for July and August

5 DATA COLLECTION

Sensors have been installed to measure the solar irradiance, wind speed (for roof system), ambient temperature, and module temperature in addition to the primary power, voltage, and performance information. Data collection for the roof and pole system show that from June 29 thru September 14, 2009 the total AC energy provided to the LCJC was 6231 kWh. The offset CO_2 emissions are 9863 lbs or 4474 kg. The AC Energy produced by day in kWh for July and August can be seen in Fig. 10. The week of July12-18th was studied in detail. It demonstrates all different types of weather patterns as shown in Fig. 11. Power profiles vary due to cloud cover and storm fronts.

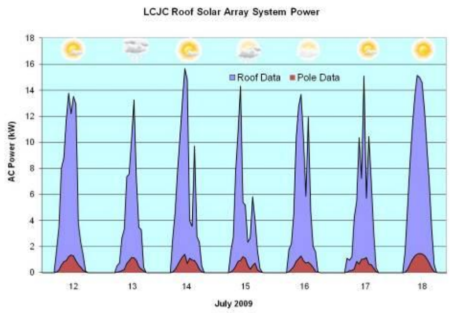

Figure 11: AC power produced compared to weather data from the same week

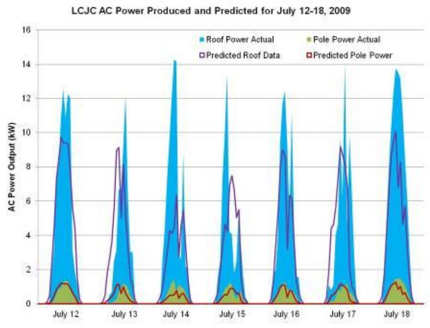

Figure 12: Power produced vs. power predicted

PV Design Pro-G modeling predicted 2,100 kWh for all of July. The current power production surpasses predictions even with the recent stormy weather. The power produced vs. predictions can be seen in Fig. 12. For July the pole produced 101% of predicted and the roof was 116%. For August the pole produced 96% of predicted and the roof was 105%.

Figure 13 shows the relationship of the power and solar irradiance for the roof and pole array. It is a linear relationship as expected. Roof scatter is due to the difference in how the data is acquired and averaged not to mention it is not corrected for temperature. From this information the overall system efficiency of the panels including the inverters and wiring ohmic losses is 18%. These graphs are just part of a first order analysis of the solar system. Data collection and analysis will be continued over the next year.

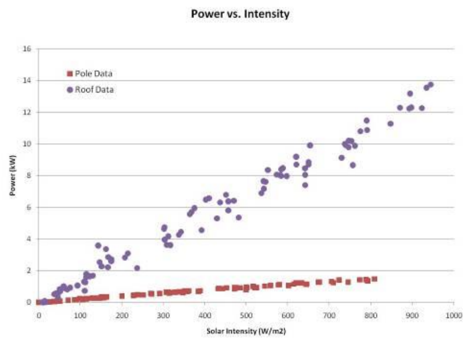

Figure 13: Solar array power vs. insolation

6 FUTURE EXPANSION

This initial system can serve as the backbone of an expandable, renewable power system at this complex.

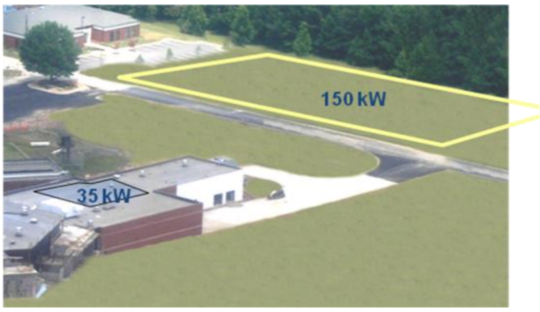

Figure 14: Future expansion sites at LCJC

Future expansion sites have already been evaluated. There is the opportunity to place 35 kW more on the roof and a 150 kW system to the back of the complex using low-profile ground mounts (see Fig. 14). With the current oversupply of PV modules, installed system costs are dropping. In 2010 $4/W is expected. This will help create new business opportunities in Alabama.

7 SUMMARY

Alabama's first State Government sponsored PV energy project was successfully completed on schedule and is fully operational. This project supports the energy-efficiency design approach used in the addition to the T.K. Davis Justice Center. It can serve as a model of how local governments can be an example of how to increase energy-efficiency, be environmentally friendly, and reduce operational costs over the long-term. With this project's unique location, ease of being replicated and expansion, this project has the potential to be the prototype for other similar undertakings across not only the state but also the country. It allows wide access to agencies, businesses, and individuals to inspire them along with providing an excellent teaching and demonstration tool for all sectors. Please visit our website at http://www.leeco.us/solar_project/index.html.

8 ACKNOWLEDGEMENTS

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