Green Fund Project
Final Report

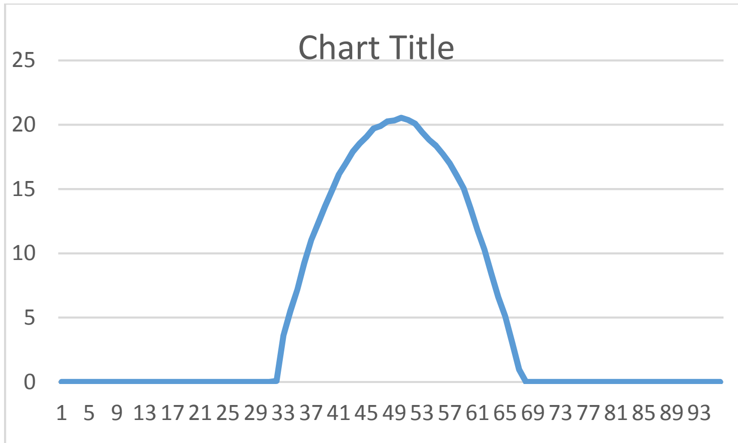
Project Title: *Revamping Campus Solar Array Utilization for Research, Education, Outreach, And Energy Production, Phase I: Efficiency Improvement and Monitoring*
Project ID #: 15SP101
Award Date: 2/25/2015
Completion Award: 08/15/2016
Total Funds Used: $25,000

1. Please provide a write up of your project/project experience. (This may be used on the SIU sustainability website.)

   The first phase of the project dealt with developing measures to monitor operation of the campus solar array and to use the resulting data for analysis of the efficiency of the system and subsequently devising a plan to improve the efficiency and increase its net energy production. This project was the first phase of a more comprehensive plan to (a) promote and facilitate the exploitation of the campus solar array for research, educational, and outreach activities by faculties, students, and community partners (b) increase the visibility of the SIUC campus efforts for adoption of renewable and sustainable energy resources (c) provide a long lasting economic benefit to the campus energy expenditure and (d) stablish collaborative links within the campus and Carbondale community among the interested entities in renewable and sustainable energy.

   Upon start of the project, the first task for the team was to implement a supervisory system using the available on-site equipment to report the real time power generation level of the array. By generating comprehensive data about instantaneous net energy generation, correlated to environmental conditions such as temperature and level of clouds in the sky, this would provide a means to the main goal of the project i.e. devising a plan to improve energy production. Typically, measuring and recording the net energy production of a PV array requires dedicated equipment and hardware, however, upon inspection of the main PV inverter used for the campus array, the project team realized that the inverter automatically measures and records the generation data internally. The challenge at this point was to access the recorded data for the analysis phase and to somehow devise a way to stream the data in real-time to a website to be used for on-line reposting of net energy generation. Through working with the Plant and Services Operations (PSO) personnel, a radio link was successfully established to the "PV hut" and we were able to extract a few years of generation data from the inverter.

   The extracted data was used by the project team to analyze and identify net energy generation patterns that are correlated to various solar irradiance levels and environmental and ambient conditions. Several daily generation profiles were generated and compared against the theoretical generation capacity of the PV array. The following graphs illustrate some example profiles generated using the extracted data,



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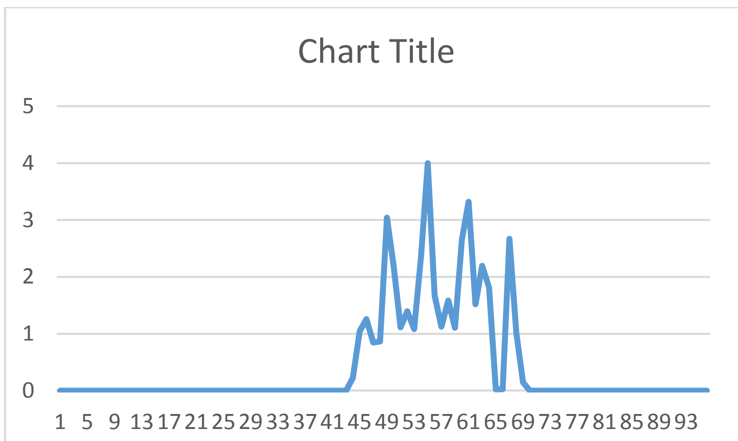

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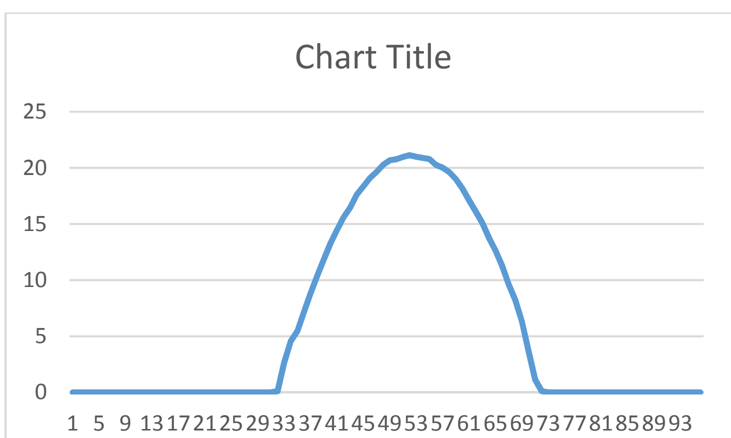

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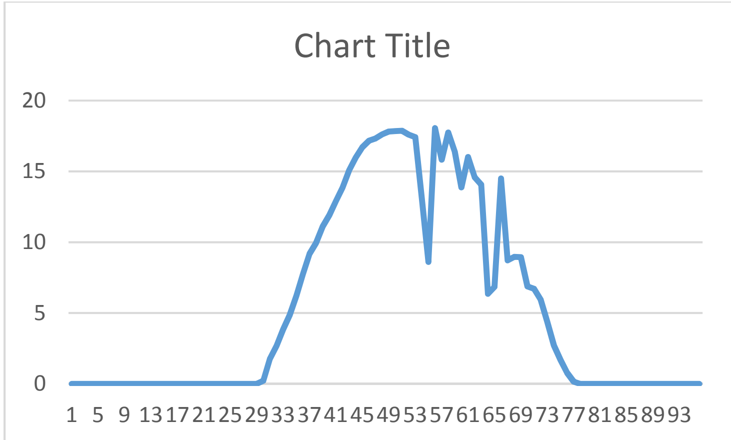

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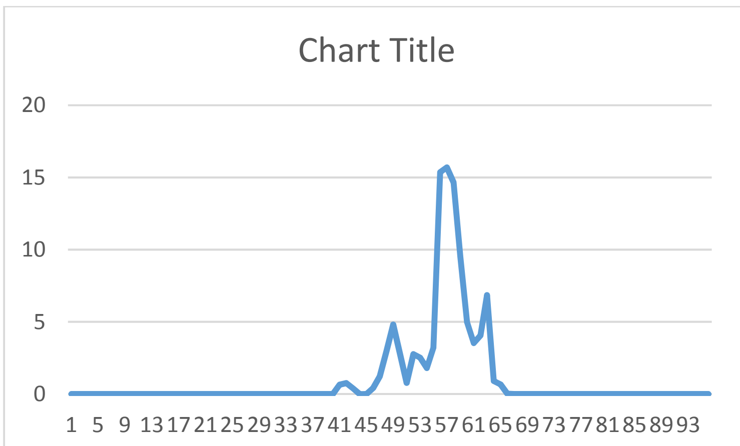
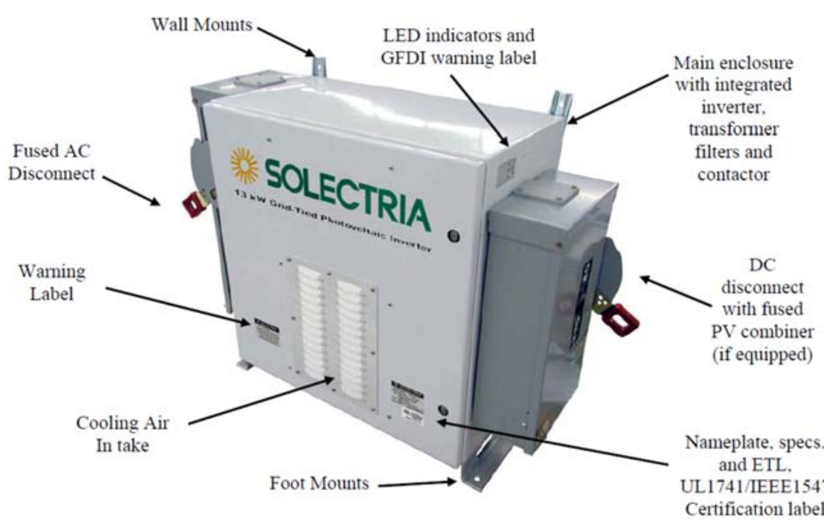


07/01/2015

Analyzing the extracted data provided the research team with an understanding of overall capability of the PV system and specifically it provided a means to evaluate the practical generation capacity. As illustrated in the above graphs, the maximum generation that happened over the recorded history of PV array was just over 20 KW. Working off this number the project team tried to justify and compare the maximum generation to the theoretical maximum generation by the PV array. According to the PSO personnel, the PV array is comprised of 165 PV modules of the type "BP Solar 3160B" and 11 PV modules of the type "BP Solar 175B". Based on the calculations performed by the project team, according to the type and number of PV modules, the PV array should be able to generate close to 30 KW at maximum. However, in this calculation the effect of a drop in solar insolation because of the geographical and environmental conditions has not been considered. Considering those effects, the theoretical value of power generation will be less than 30 KW. Yet, the PV array will be capable of generating substantially more than the 20 KW maximum that is currently generating.

Based on our understanding of the practical vs ideal operation of the PV array, the project team looked at the avenues for improving the efficiency and net generation of the PV array. The amount of electrical energy harvested from the Photovoltaic (PV) systems are typically influenced by: the efficiency of the PV cell which is usually between 15-20% for residential applications according to National Renewable Energy Laboratory (NREL), the efficiency of the power electronics converter which is in the range of 90-98%, and the efficacy of the Maximum Power Point Tracking (MPPT) controller which is in the range of 95-97%. Improved fabrication technology and advance PV cell design method is required to increase the efficiency of the cell which is usually costly. This improvement is typically performed by large PV cell manufacturer. Improvement of the power electronics converter topology can increase the amount of power harvested from the PV cell, similarly the performance improvement of the MPPT controller can be easily implemented in already existing PV system power plants at a minimum cost.

To evaluate the possible improvement in the power converter topology and MPPT controller the project team looked at the current string converter used for harvesting energy from the PV array and injecting it into the grid. The grid-tied PV inverter used is a PVI 13KW/15KW from Solectria Renewables. Feeding power into the grid involves conversion of the DC-voltage from the PV-array to grid compatible AC-voltage by inverting DC to AC. This unit feeds power into a standard 208V AC, 3-phase commercial, industrial or institutional facility's electrical system which is connected to the electrical grid. If the PV system and inverter are providing the same amount of electrical power that the facility is using, then no power is taken from or fed into the utility grid. If the facility is using more power than the PV system is providing, then the utility grid provides the balance of power. If the facility is using less power than the PV system is generating, then the excess is fed into the utility grid.



According to the provided information the project team concluded that there is room for significant improvements regarding this PV inverter due to the fact that firstly this string type inverter does not compensate the effects of mismatching and partial shading of the PV panels in a string, and secondly, based on the provided documentation this inverter does not feature any type of MPPT algorithm. Both issues are very significant and the topic of a myriad of research and technology development in the past few years. Several new solutions have been proposed in academia and produced commercially that can solve the issues. The project team performed a survey of all commercially available solutions to improve the power generation of the PV array and concluded that using distributed individual micro-inverters in place of the current central string inverter is the best solution.

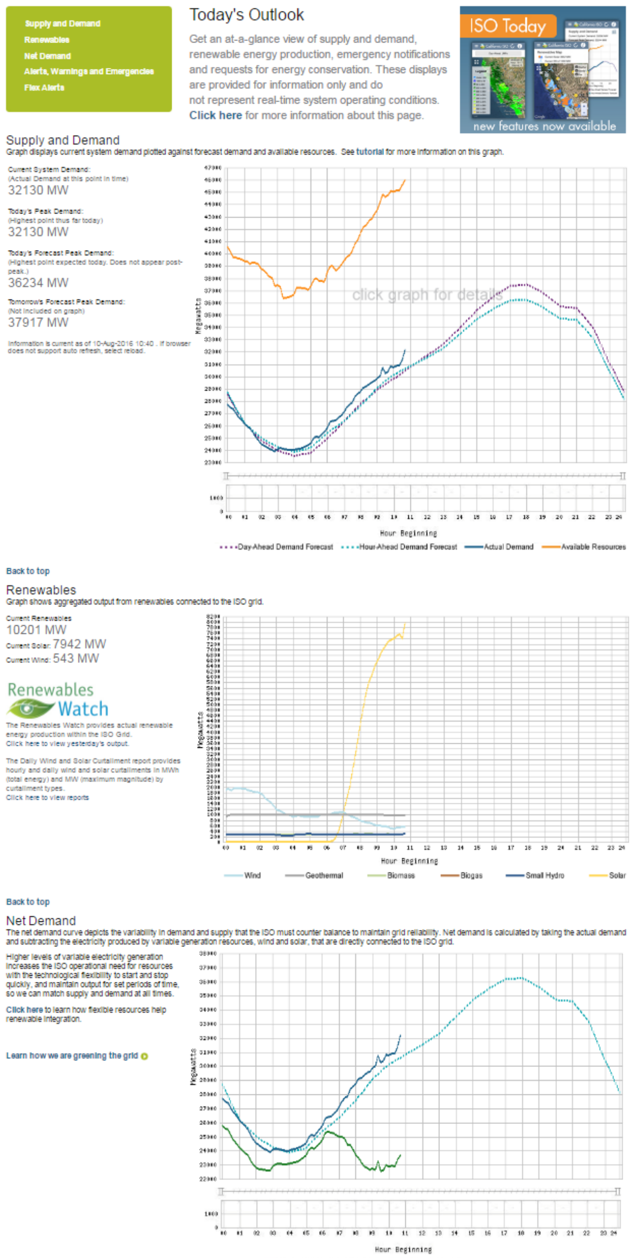
Micro-inverters are rapidly gaining popularity, particularly for residential solar systems. Micro-inverters convert the DC electricity from the solar panels into AC at the panel level (i.e. on the roof), with no need for a separate central inverter. If the PV system uses micro-inverters, there will be one micro-inverter installed at each panel. In many cases the micro-inverters are integrated into the solar panel itself, but they may also be mounted next to the panel on the system's mounting system. One of the major advantages of micro-inverters is that they mitigate the negative impacts of partial or complete shading and mismatch between the panels. Because the DC-AC electricity conversion takes place at each panel, there is no 'bottleneck' when one panel produces less or no electricity. The other major advantage of micro-inverters is that nearly all micro-inverter manufacturers include sophisticated MPPT capabilities into their products, and since the MPPT algorithm is executed in the module level, it is significantly more effective than MPPT that is run in the string level. Micro-inverters also allow for monitoring the performance of individual solar panels.

The project team surveyed many products from many micro-inverter manufacturers to find a suitable product that fits the campus PV array. The ideal solution identified by the project team is the M215 Microinverter family from Enphase. The Enphase M215 Microinverter with integrated ground delivers increased energy harvest and reduces design and installation complexity with its all-AC approach. With the advanced M215, the DC circuit is isolated and insulated from ground, so no Ground Electrode Conductor (GEC) is required for the micro-inverter. This further simplifies installation, enhances safety, and saves on labor and materials costs. The Enphase M215 integrates seamlessly with the Engage Cable, the Envoy Communications Gateway, and Enphase Enlighten monitoring and analysis software.

Another goal of the project from the start was to report the net generation of PV array on the fly over webpage. An example of what was intended is already done by the California ISO and its accessible to public here,

http://www.caiso.com/outlook/outlook.html

an screenshot of the webpage is as follows,



As mentioned earlier, the connection to the monitoring system on the PV inverter has been established successfully. This means the data could be read from the inverter in 15 minute intervals and recorded on a Microsoft access database. Then a dashboard can be made using Excel that reads the data online and displays it on an interactive website. The project team is well capable of making the dashboard and linking it to the measurement data. However, the PSO personnel had a broader idea to get the whole campus energy data, including the PV system and show it on the PSO website in a live fashion. This would be very similar to the California ISO example provided above. Therefore, at this point the project team is waiting on the PSO to get their energy data.

2. Please provide a summary of your results (environmental, social, and/or economic) including quantifiable data as appropriate (ex. # of individuals reached, lbs. diverted from landfill, energy saved, etc.).

   As mentioned above, the PV monitoring system has been established, the PV system operation has been analyzed and a solution for improving the PV array generation system has been provided, the live monitoring and reporting of the PV array generation is also almost complete.

3. Summarize how your project promoted the Green Fee/Sustainability on campus including, but not limited to, flyers created, screenshots of website, signage, etc. Please include website links, if applicable.

   The online monitoring website that is under the work by PSO will increases the visibility of the feasibility of the sustainable energy utilization among campus or community members. This can potentially lead to several social movements towards adoption of sustainable energy sources on or off campus. This will have several social, economic, and cultural implications. The second and third phase of this project involve outreach activities that can result in positive social impacts in the community level. High school students, teachers, and general public will be reached through organizing workshops, seminars and field trips to promote the social acceptance of the renewable energy use.

4. Is there anything you would do differently if you were to do a similar project in the future? If so, please describe.

   Given the availability of the funds it is preferred to buy a few micro-inverters and test them in the field before commissioning them on the whole PV array.

5. Please attach a minimum of 5 digital images –these will be images used to promote interest in sustainability projects on campus. These can be photos of the progress of the project or the completed project.

   This project involved mostly of theoretical analysis, various surveys, and some technological work. The pictures of these activities are not really meaningful to the project. However, when the monitoring webpage is on-line some screenshots will be sent to the green-fund committee to promote interest on campus.