FESC
Florida Energy Systems Consortium

University of Central Florida

Buoy Array for Ocean Wave Power Generation

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Description: The objective of this project is to develop a novel design that can extract ocean wave energy for commercial consumption. The design detailed herein is unique in that it is a wave point energy harvester that is small in size and contains all of the mechanical components directly within the buoy. The project focuses mainly on the mechanical system within the buoy as well as methods to control the electrical load on the system. Different mechanical systems have been developed and tested on a motion platform to simulate a vertical wave motion—these systems have been analyzed and compared in order to provide an ever-increasingly effective design. The Harris Corp. have acted as new collaborators with the project since October 1st 2010, funding four UCF senior design teams in the development of a buoy for wave power generation.

Budget: $150,000
Universities: UCF

Executive Summary

This project involves an innovative design, development, laboratory prototype testing, and optimization of a wave power generation system which includes a set of mechanical devices and a permanent magnetic generator. The objective of this project is to build a wave power generation system that is light-weight, low-cost, small size, and easy to deploy. For this project, two laboratory prototypes have been built using machine components. The prototypes were mounted onto a 6-DOF motion platform that can oscillate vertically to simulate wave motion, which drives a shaft to produce electricity using a permanent magnetic generator.

The project began with a literature review, a Matlab/Simulink simulation, a 3-dimensinal viscous CFD (computational fluid dynamics) simulation, and mechanical Pro-E design. Such preparation work was essential to the study of ocean wave generation. Next, two prototypes were developed and tested. The first prototype shows that a simulated wave moving up and down with an amplitude of 15-cm, can generate between 35 to 40 watts electricity. The experiences gained in testing of this prototype helped design and build the second prototype. The second prototype uses two sprockets and a longer chain giving more mechanical advantages. In addition, a more efficient generator that requires less torque reduces frictional losses imposed on the shaft. Test results have shown that the power output increases from 37.34 to 206 watts. Afterwards, two alternative prototypes were tested. One uses a light-weight but large size aluminum flywheel to increase flywheel inertia; the other is specially designed to make it possible for the system to generate power in both directions.

In order to make the generator run more continuously and, thus, generate more power for a given wave input, a load control mechanism was designed to dynamically control the electric load based on the shaft RPM. This requirement is needed when there is no pulling force of the wave at the down-stroke and the load is not applied so that the flywheel runs continuously. Tests of the second prototype were done for a number of different configurations – a combination of different wave amplitude and frequency.

To improve the efficiency of the system, an updated mathematical simulation model was designed for system optimization. The optimization was to study how to choose the radius of sprocket, the inertia of

the flywheel(s), the ratio of the gear set, and the controlled electrical load such that maximum power can be generated, given a fixed wave amplitude and frequency. This allows for different design parameters to be varied to optimize design.

In addition to the prototype tests, the buoyancy force of the waves on a small buoy has been studied. For these experiments, the output of the force is recorded by a computer based data acquisition system and the results help verify the computation fluid dynamics model used in the mathematical simulation.

Due to the nature of wave motion, the electrical power output is not stable in voltage output and frequency. For this reason, a Wave Energy Conversion (WEC) simulation model was built for stabilizing the variable frequency, variable voltage output and for satisfying the grid requirements of constant voltage, frequency, and power. Using experimental three-phrase AC voltage data of the generator, a three-phase breaker is turned on and off by the control system to output DC voltage. The simulation is helpful to the design of a micro-controller to be used in load-control and power stabilization for future preparation once the buoy power system is deployed in the ocean.

Based on the finding of the experimental and analytical results of the mechanical design it was found that a different design concept would have more success in the field. Similar to the team's research in that bi-directional buoy motion is converted to uni-directional rotor rotation, a bi-directional impulse turbine was proposed. The bi-directional impulse turbine can be used in oscillating wave columns as it is able to convert bi-directional flow into uni-directional rotation.

The measured power output, RPM, torque, and the overall optimized system parameters such as the radius of sprocket, the inertia of the flywheel(s), the ratio of the gear set and the controlled electrical load added to the generator, are helpful to the design and optimization of a functional prototype running in the ocean. For the power output, the current laboratory prototype is capable of generating an average of 136W under the movement of a motion platform with 12cm in amplitude, 0.3Hz frequency, and 0.10kg-m^2 moment of inertia, and 206W with 10cm in amplitude, 0.3Hz frequency, and 0.25kg-m^2 moment of inertia.

The research group spent much efforts trying to leverage research funding. A joint proposal with Rostech, Inc. Oviedo, FL, was submitted to the U.S. Department of Energy for applying funding for Phase I SBIR, in an effort to continue the research and commercialize the laboratory prototype. And because of this project, the University of Central Florida has cooperation with the Harris Corporation for the powering of a far offshore buoy system named OceanNet. The company is very interested in developing a clean energy supply local to these far offshore buoys which drastically lowers the expenses involved in traveling out the buoys and refueling. For this reason they have funded the work of 7 senior design teams in the process of two years and are continuing support with the research project to obtain a commercially viable design and the construction of an offshore wave energy converter.

In addition, the research group attended various national and international conferences to attract attention to the work wave energy research in the state of Florida. Several presentations were made. Two conference papers were published and a journal paper based on the load control optimization scheme is revised and resubmitted to *IEEE Journal for Oceanic Engineering* for publication.

Florida has a long costal line and good power delivering infrastructure. The success of this system could provide clean, scalable, and supplementary electric power to Florida coastal communities with lower costs in the long term, and lessen burden from main power grids and fulfill responsibilities of environmental protection.

Florida Energy Systems Consortium

Goals and Objectives

The objective of this project is to analyze, design, and demonstrate a novel wave power generation system that can extract ocean wave energy for commercial consumption. The design detailed herein is unique in that it is a wave point energy harvester that is small in size and contains all of the mechanical components directly within the buoy. As such, the buoy would simply need to be moored to the ocean floor and have cables to transport power to the shore, making it ideal for use in a multiple-unit wave farm. The project focuses mainly on the mechanical system within the buoy as well as methods to control the electrical load on the system. Different mechanical systems have been developed and tested on a motion platform to simulate use within a buoy in vertical heave—these systems have been analyzed and compared in order to provide an ever-increasingly effective design. Mathematical simulations have been developed to help optimize design parameters for use in subsequent prototype designs that will be able to be implemented in a wave pool or saltwater environment.

The ultimate goal is to deploy an array of buoys floating on the ocean and tethered to the floor. Each of them has one or multiple devices inside that can convert the kinetic energy of the motion of the waves into electrical energy. The electricity generated is then transmitted through the cable that goes along or inside the tether to the ocean floor, expending to an energy processing/storage station on the ocean shore.

Project Activities, Results and Accomplishments

Introduction

Nature offers a tremendous source of renewable energy in the kinematic motion of ocean waves. It is estimated that if 0.2% of the ocean's untapped energy could be harvested, it could provide power sufficient for the entire world. Compared with other forms of generation of electricity such as wind and hydro power, research on wave energy is still in its infancy because wave energy development is a field that requires multi-discipline cooperative efforts including technologies in hydro-dynamics, mechanical engineering, control, and power system. There is much room to be improved such as, efficiency, cost of system, reliability, scalability, to name a few, such that wave energy is made affordable to consumers. The project began with a literature review, a Matlab/Simulink simulation, and mechanical Pro-E design. Then, laboratory prototypes were built and tested on a motion table. Figure 1 is an overview of the laboratory prototype.

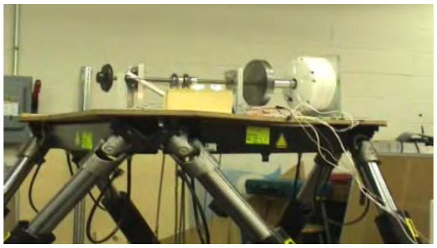

Fig. 1: An overview of laboratory prototype

Simulation and Pro-E mechanical design

A Matlab/Simulink Model shown in Fig. 2 was created to simulate wave movement and power output. This model was based on the differential equations which include all forces dynamically applied to the buoy. Fig. 3 is the simulation results for mechanical and electrical power outputs.

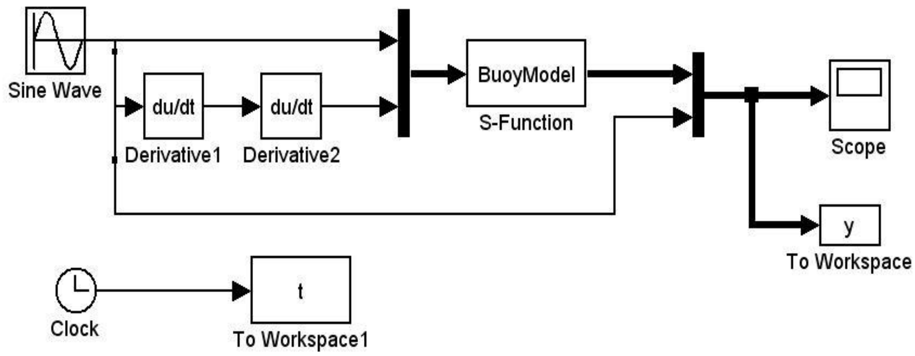

Fig. 2: Matlab/Simulink Model

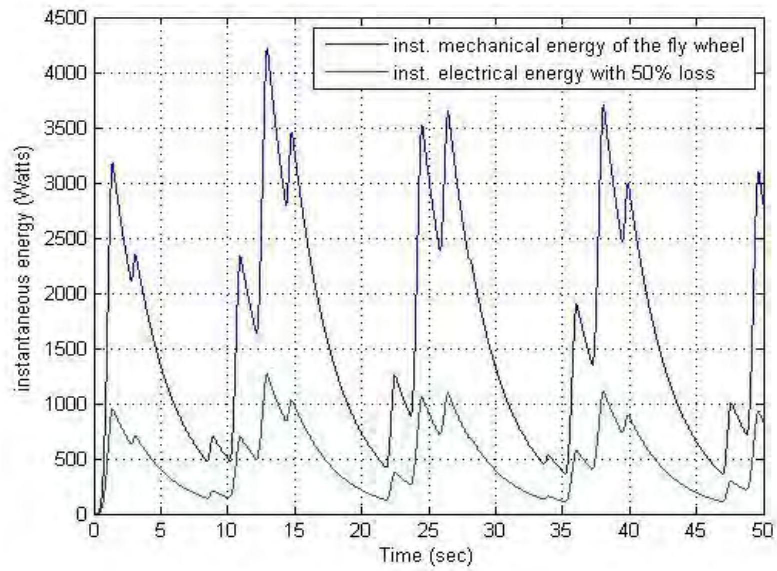

Fig. 3: Simulation results

Before building the prototypes, the mechanical components in the wave power generation system was designed and simulated in Fig. 4 using Pro-E, a professional mechanical engineering tool. This significantly decreased time to build the lab prototype by making development changes and modifications using the software.

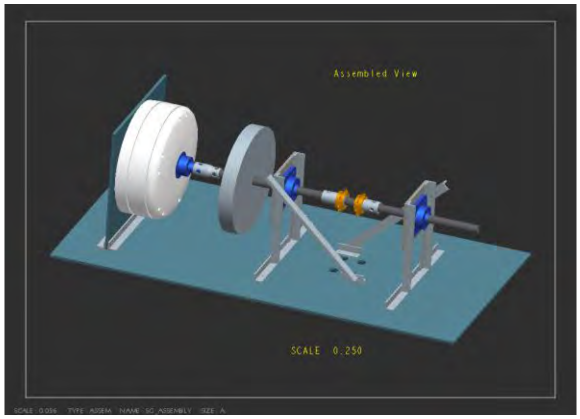

Fig. 4: Pro-e design of the vertical wave system prototype

Laboratory prototypes

Two laboratory prototypes were developed and tested. The first prototype (Figure 5) shows that a simulated wave moving up and down with an amplitude of 15-cm, can generate between 35 to 40 watts electricity. The experiences gained in testing of this prototype helped design and build the second prototype (Figure 6). The second prototype uses two sprockets and a longer chain giving more mechanical advantages. In addition, a more efficient generator that requires less torque reduces frictional losses imposed on the shaft. Test results have shown that the power output increases from 37.34 to 206 watts.

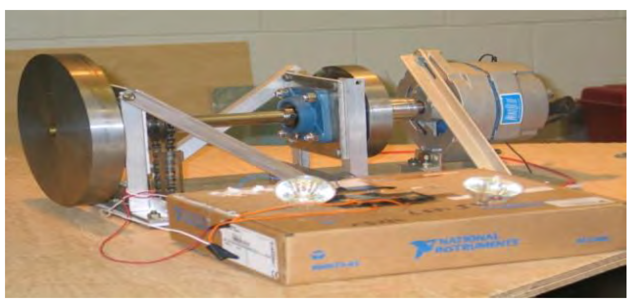

Fig. 5: First generation of prototype

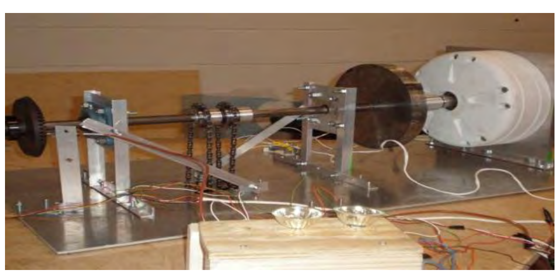

Fig. 6: Second generation of prototype

In order to make the generator run more continuously and, thus, generate more power for a given wave input, a load control mechanism was designed to dynamically control the electric load based on the shaft RPM. This requirement is needed when there is no pulling force of the wave at the down-stroke and the load is not applied so that the flywheel runs continuously. Figure 7 is the electrical components of the generation system.

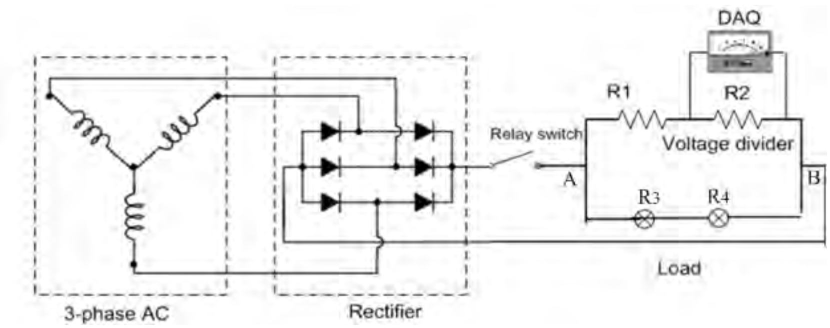

Fig. 7: Electrical components of the generation system

Tests of the second prototype were done for a number of different configurations – a combination of wave frequency and amplitude using a 6-DOF motion platform.

In addition to the current prototype, the following two alternative prototypes were built and tested:

Alternative prototype 1

This first alternative prototype (Fig. 8) was built with the following main characteristics: (1) A cable is used instead of a chain to improve reliability (2) A large size aluminum flywheel to increase flywheel inertia (3) A 4:1 gear set for increasing RPM. The only drawback of this design is that although adding a gear set increases RPM, it also increases the torque.

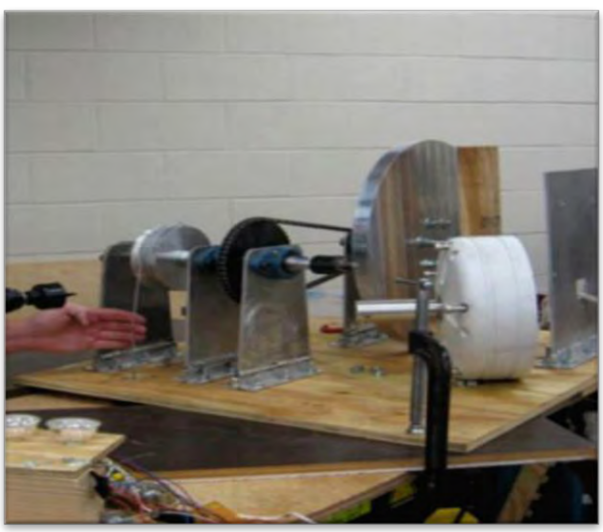

Fig. 8: Alternative Prototype 1

Alternative prototype 2

This second alternative prototype (Fig.9) was built in order to generate consistent power in both directions (up and down). The rack has teeth on both sides which mesh with two gears on two separate shafts. When the motion platform moves up, one shaft runs clockwise; when moving down, the other shaft runs counter-clockwise. The movements of both shafts rotate the generator in the same direction, thus developing consistent power in both directions. Each shaft has one gear set installed to increase RPM. The drawback of this prototype is that it is difficult to fix the top of the rack in the ocean, and it is possible for the rack and gears to become unmeshed.

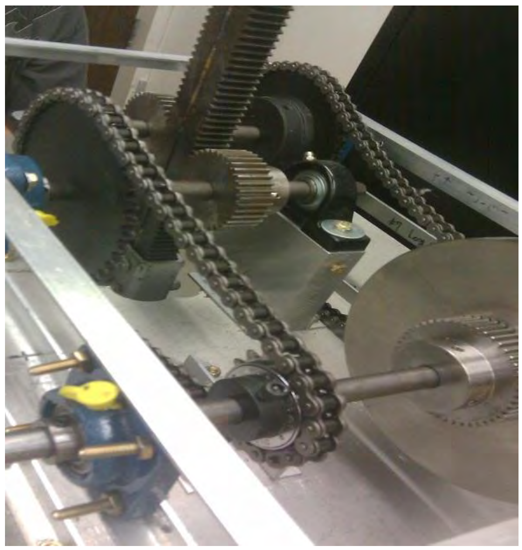

Fig. 9: Alternative Prototype 2

In addition to the prototype tests, the buoyancy force of the waves on a small buoy has been studied. For these experiments, the output of the force is recorded by a computer based data acquisition system and the

results help verify the computation fluid dynamics model used in the mathematical simulation and optimization model.

Wave Energy Conversion (WEC) system

A Wave Energy Conversion (WEC) simulation model (shown in Fig. 10) was built for stabilizing the variable frequency, variable voltage output and for satisfying the grid requirements of constant voltage, frequency, and power. Using experimental three-phrase AC voltage data of the generator, a three-phase breaker is turned on and off by the control system to output DC voltage shown in Fig. 11. The simulation is a stepping-stone to build a micro-controller that can run the buoy control system in the future. This work is for future preparation once the buoy power system is deployed in the ocean.

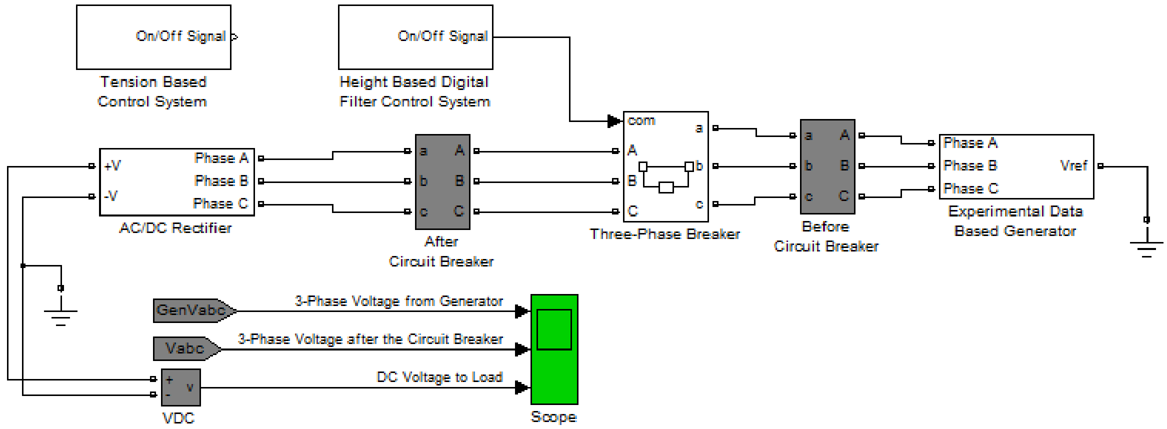

Fig. 10: Schematic for Wave Energy Conversion (WEC) system

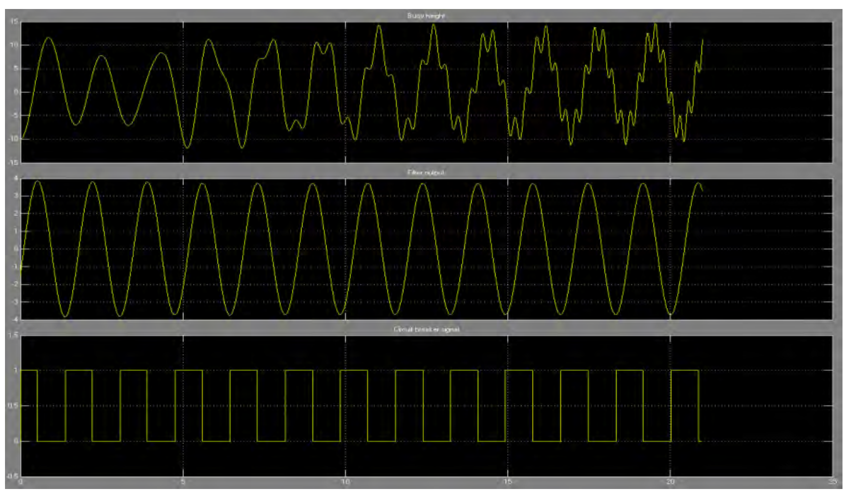

Fig. 11: Height-based control system output

System optimization

The power output of the system is dependent on several factors such as the radius of sprocket, the inertia of the flywheel(s), the ratio of the gear set, and the controlled electrical load added to the generator. An updated mathematical model was designed to optimize the system. The objective is to choose values for these parameters from their feasible ranges in an optimal way in order to get maximum power output. The power optimization model is designed based on the following criteria:

Flywheel inertia optimization: Without enough inertia on the shaft, the flywheel may not continuously spin throughout the wave cycle. With excessive inertia, on the other hand, the angular acceleration of the shaft will suffer as a result of increased chain tension. As such, the inertia of the shaft should be optimized so that the motion of the shaft is continuous while limiting the effect on the buoy motion.

Gear ratio optimization: A gear set can convert excess input torque into a greater RPM of the shaft, or yield a larger torque applied to the generator by sacrificing RPM. Both torque and shaft speed influence the power output for the system, and thus an optimum gear ratio should be found to balance these two inversely-proportional variables.

Electrical load control optimization: Keeping the electric load constantly applied will drastically slow the rotational speed of the shaft while no forcing input is applied. Intuition suggests that the load should be applied while the shaft RPM is high above some threshold, and it should be disconnected while it becomes low.

Optimization of the radius of sprocket: The radius of sprocket is directly related to the shaft RPM. The smaller the radius, the greater the RPM, but also the higher the cable tension.

This optimization method can be applied to a host of wave energy designs and obtain the most suitable parameters for higher efficiency and offer coupled optimization between a host of design parameters.

Bi-Directional Turbine Concept

Based on the finding of the experimental and analytical results of the mechanical design it was found that a different design concept would have more success in the field. Although the control systems were the main focus of this research a design to drive the generator was still lacking. Based on literature reviews the research decided that a turbine driven system would be best for successful wave energy extraction with least maintenance. The design chosen was a bi-directional impulse turbine which is commonly used in oscillating wave columns as it is able to convert bi-directional flow into uni-directional rotation. This is similar to the team's research in that bi-directional buoy motion is converted to uni-directional rotor rotation. The turbine design concept start when the research team began a new set of projects in collaboration with Harris Corp. Harris Company funded the work of four senior design teams involved in offshore structure projects. Two of these projects involved the design and testing of a uni-directional impulse turbine. An illustration of the turbine is shown below in Fig.12.

The research team began with CFD simulation to determine the major losses associated with the turbine design and began CFD and CAD optimization schemes to obtain the best design for increased efficiency. The simulation based results were in good agreement with the experimental results obtained by the senior design teams.

Currently, Harris Corporation is funding a second year of projects with an additional 10K support. This year three teams are sponsored to complete a phase II of the first years project with commercial involvement from local offshore companies.

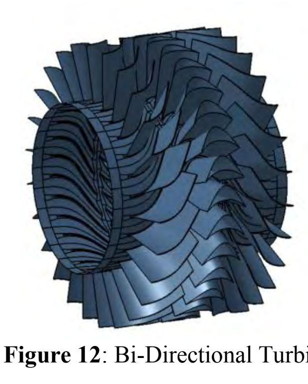

Figure 12: Bi-Directional Turbine

Experimental results
Experiment results show that the current laboratory prototype is capable of generating an average of 136W under the movement of a motion platform with 12cm in amplitude, 0.3Hz frequency, and 0.10kg-m^2 moment of inertia, and 206W with 10cm in amplitude, 0.3Hz frequency, and 0.25kg-m^2 moment of inertia.

The optimal power output depends on several factors. The radius of sprocket, the inertia of the flywheel(s), the ratio of the gear set used, and the controlled electrical load added to the generator, given a fixed wave amplitude and frequency. The overall optimized system parameters are as follows:

Inertia: 0.18 kg-m^2
Gear Ratio: 2.2
Load Control: 190 RPM

Figure 13 is the LabView measurement output when the electric load control is applied.

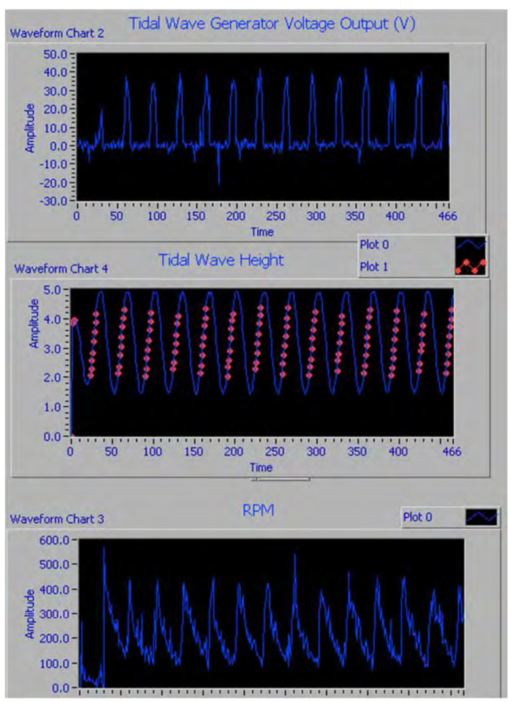

Figure 13: Voltage, RPM, and load control

Accomplishments
The research group spends great time and efforts in improving the research results, leveraging the funding, and commercializing the lab prototype, such as:

Cooperated with the Harris Corporation for the powering of a far offshore buoy system named OceanNet. The company is very interested in developing a clean energy supply local to these far offshore buoys which drastically lowers the expenses involved in traveling out the buoys and refueling. For this reason they have funded the work of 7 senior design teams in the process of two years and are continuing support with the research project to obtain a commercially viable design and the construction of an offshore wave energy converter.

Submitted a proposal with Rostech, Inc. Oviedo, FL, to apply for funding from the U.S. Department of Energy Phase I SBIR.

Designed built and tested 4 different wave energy extraction designs.

Developed analytical models, CFD simulations and experimental techniques pertinent to wave energy research.

Attended various national and international conferences to attract attention to the wave energy research work in the state of Florida.

Published two conference papers and submitted a journal paper based on the load control optimization scheme developed in this research.

Concluding Remarks

This project involves an innovative design, development, and laboratory prototype testing of a light-weight, low-cost, small size wave power generation system which includes a buoy, a set of mechanical devices, and a permanent magnetic generator. Prior to prototype setup, a hydrodynamic model, buoy model, and a generator model are analyzed and a Matlab simulation were conducted. The flywheel inertia, shaft rotation speed, and electrical load are optimized to maximize electricity production. The optimization method and results are helpful to the building of a functional prototype running in the ocean. The proposed bi-directional impulse turbine can be applied in oscillating wave columns to convert bi-directional flow into uni-directional rotation. Because of this project, a number of research projects involved by seven senior design teams at UCF have been funded by Harris Corporation, such as OceanNet, the powering of a far offshore buoy system in the process of two years. In addition, we believe our presentations and publications at national and international conferences have attracted attentions to the wave energy research in the state of Florida. The success of this system could provide clean, scalable, and supplementary electric power to Florida coastal communities with lower costs in the long term.

This project has been completed.

University of Central Florida

Concentrating Solar Power Program

PIs: Charles Cromer, Robert Reedy
Post Doc: Pablo Izuierdo, Ph.D.

Description: The objective of this effort is to produce a detailed map of Florida that shows the monthly solar direct beam and global resource available for the past eleven years. This solar resource map will give potential users or designers of solar systems, the solar input values for their location latitude and longitude and they will receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept employed to determine these solar values is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar resource that gets through to the ground below.

Budget: $50,000
Universities: UCF/FSEC

Progress Summary

The objective of this effort is to produce a detailed map of Florida that shows the monthly solar direct beam and global resource available for the past eleven years. This solar resource map will give potential users or designers of solar systems, the solar input values for their location latitude and longitude and they will receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept employed to determine these solar values is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar resource that gets through to the ground below.

The process used to determine the solar direct bean and global resource was to first complete a literature search. From the literature and experience, equations were derived and programmed that predict theoretical optimum clear sky daily insolation (Hc). The clearness value (x) of each pixel in satellite photos was used to mediate the clear sky insolation values to produce ground level predicted values (H) for that pixel area (5 miles x 5 miles). The hypothesis was tested by using NOAA weather satellite data from summer and fall of 2010 retrieved, and real irradiance values were measured at FSEC. Correlations (r sq) of predicted vs. real values were found to be above 0.90 at the 95% confidence level. This work validated the concept to provide a “go” for the purchase of archive data.

Daytime satellite photos of the past eleven years were purchased from NOAA archives. The archive photos provide a 200 by 100 pixel area that includes Florida. In each photo, a pixel covers a 5 mile x 5 mile square and there are 10,272 pixels over the Florida area in each photo. Using printed NOAA navigational charts, latitude-longitude values were assigned to each pixel. The 20,075 photos were reviewed and if any anomalies (blank areas or bands across the photo) were found, the photo was corrected. Programs were written to correct photos, determine darkest tones, calculate normalized brightness value and, finally, the output the theoretical clear sky direct beam solar energy available for each day of the year for each Florida location (value Hc in the general equation above).

Using the NOAA historical data sets now developed and actual ground measured data taken at FSEC, new correlations were developed that calculate the ground measured direct beam and direct diffuse solar daily insolation. Using these correlations, solar direct beam and direct diffuse radiation values were calculated for each day of the eleven year data base for each of the 10,272 Florida locations (each pixel). Each daily value for each location was averaged across the 11 years of data to produce an average value representative of each day of the year. Daily values for each month were then averaged to produce direct beam and direct diffuse monthly averages for each of the Florida locations. These monthly data were also averaged to produce an annual average data set. Monthly averages and annual average data were formulated into a master table and loaded into an excel spread sheet. An excel program was written that when given a Florida latitude and longitude as input, it retrieves the specific table of the expected monthly direct beam and direct diffuse averages for that Florida location in both W/sq m. and Btu/sq ft. formats.

The excel algorithms were incorporated into a web page format and a Google based map was provided to allow a user to select a physical geographical location in Florida and by clicking on that location, the latitude and longitude of the location is determined and the appropriate table representing that location of monthly averages and annual averages is provided the user. This web page is provided as a link titled "Solar Resource Calculator" on the "Customer" page of the Florida Solar Energy Center web site. The direct link is http://livewire.fsec.ucf.edu/src/

Thus, derived from historical weather satellite data, direct beam and direct global solar resource data are now available for any latitude-longitude location in Florida., These data are especially critical for evaluation of concentrating collectors which use only direct beam sunlight.

2011 Annual Report

The objective of this effort is to produce a detailed map of Florida that shows the monthly solar direct beam and global resource available for the past eleven years. This solar resource map will give potential users or designers of solar systems, the solar input values for their location latitude and longitude and they will receive a table of solar energy monthly averages for that specific site as derived from the past eleven years of data. The concept employed to determine these solar values is to use NOAA satellite photos and utilize the brightness of the cloud cover as a clearness factor predictor of the solar resource that gets through to the ground below.

A literature search was completed and the equations to predict theoretical optimum clear sky daily insolation (Hc) were programmed. The clearness value (x) of each pixel in satellite photos was used to mediate the clear sky insolation values to produce ground level predicted values (H) for that pixel area (5 miles x 5 miles) by the general equation:

$$H = Hc\,(a + b\,EXP(-x/c))$$

Where a , b, and c are correlation coefficients. The hypothesis was tested by using NOAA weather satellite data from summer and fall of 2010 retrieved over the internet, and real irradiance values measured at FSEC. Correlations (r sq) of predicted vs. real values were found to be above 0.90 at the 95% confidence level. This work validated the concept to provide a "go" for the purchase of archive data.

Daytime satellite photos of the past eleven years were purchased from NOAA archives. The archive photos provide a 200 by 100 pixel area that includes Florida. These photos were cropped to generate a photo approximately 100 by 100 pixels that includes Florida. In each photo, a pixel covers a 5 mile x 5 mile square and there are 10,272 pixels over the Florida area in each photo. Using printed NOAA navigational charts, latitude-longitude values were assigned to each pixel. The 20,075 photos were reviewed and if any anomalies (blank areas or bands across the photo) were found, the photo was corrected. Because the gray scale map varied among photos, a program was written to correct all photos to represent a standard gray scale map and all photos' pixels were adjusted to this gray scale base with this program. A program was written that searched the pixel files to determine the darkest tone recorded for each location and these were determined. A program was written that calculated the normalized brightness value (value x in the equation above) for each pixel of each photo and these were loaded into master "clearness" files. A program was written that calculated and output the theoretical clear sky direct beam solar energy available for each day of the year for each Florida location (value Hc in the equation above).

Using the NOAA historical data sets now developed and actual ground measured data taken at FSEC, new correlations were developed that calculate the ground measured direct beam and direct diffuse solar daily insolation. Using these correlations, solar direct beam and direct diffuse radiation values were calculated for each day of the eleven year data base for each of the 10,272 Florida locations (each pixel). Each daily value for each location was averaged across the 11 years of data to produce an average value representative of each day of the year. Daily values for each month were then averaged to produce direct beam and direct diffuse monthly averages for each of the Florida locations. These monthly data were also averaged to produce an annual average data set. Monthly averages and annual average data were formulated into a master table and loaded into an excel spread sheet. An excel program was written that when given a Florida latitude and longitude as input, it retrieves the specific table of the expected monthly direct beam and direct diffuse averages for that Florida location in both W/sq m. and Btu/sq ft. formats.

The excel algorithms were incorporated into a web page format and a Google based map was provided to allow a user to select a physical geographical location in Florida and by clicking on that location, the latitude and longitude of the location is determined and the appropriate table representing that location of monthly averages and annual averages is provided the user. This web page is provided as a link titled "Solar Resource Calculator" on the "Customer" page of the Florida Solar Energy Center web site. The direct link is http://livewire.fsec.ucf.edu/src/

Thus, derived from the last eleven years of historical weather satellite data, direct beam and direct global solar resource data are now available for any latitude-longitude location in Florida., These data are especially critical for evaluation of concentrating collectors which use only direct beam sunlight. With these data and given a potential site for a solar installation in Florida, calculations can be made to make viable comparisons of the various solar configurations, concentrating collectors vs. photovoltaic for example, and the data is now available to calculate a particular solar installation sizing to meet a given load.

University of Central Florida

Development of High Throughput CIGS Manufacturing Process

PI: Neelkanth G. Dhere
Students: Ashwani Kaul (PhD), Eric Schneller (M.S), Narendra Shiradkar (PhD), Sagarnil Das (PhD)

Description: A reduction in the cost of CIGS and other thin film PV modules is required for broad PV applications. The project objective is to develop a high-rate deposition process for synthesis of CIGS absorbers and other layers by employing in-line and batch deposition techniques. The goal is finally to attract a PV manufacturing company to Florida by developing a high-rate manufacturing process for $CuIn_xGa_{1-x}Se_2$ (CIGS) solar cells.

Budget: $141,620
Universities: UCF/FSEC

Progress Summary

The back contact for the CIGS thin film solar cells comprises of molybdenum film that is approximately 1um thick. Typically the film is deposited in a stacking sequence to form a composite structure that has good adhesion and at the same time low resistivity. A thorough study has been carried out recently to understand the effect of processing parameters on the properties of molybdenum back contact. Back contact deposition is a bottleneck in high volume manufacturing due to the current state of art where molybdenum back-contact film consisting of multiple layers must be deposited to achieve the required properties. Experiments were carried out in order to understand and solve this problem.

The effect of working distance (distance between the target and the substrate) on film properties was studied and is being presented here. The main goal in reducing the working distance was to determine the increase in the deposition rate that would be very essential in order to reduce the deposition time and eventually the manufacturing cost. Earlier work carried out on molybdenum films reflected on the effect of the sputtering power and working gas pressure on the film properties. This work is a continuation of that effort in understanding effects of various sputtering parameters and determining the route to develop a composite molybdenum film that possess the required properties of near zero stress, low resistivity and good adhesion to substrate. Further effort has also been made on the development of CIGS solar cells with higher efficiencies.

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The effect of varying the sputtering power on the residual stress in the films deposited at working gas pressure of 1 mTorr was studied. Also, the effect of working gas pressure on the residual stress in the films deposited while keeping sputtering power constant at 200 W was also investigated. It was found that lower sputtering power of 200 W yielded tensile stresses in the molybdenum films. At higher sputtering power of 275 W some compressive stresses were developed in the molybdenum film.

Variation of residual stress with varying working gas pressure suggests an inverted U shaped curve where the tensile stress reaches maximum and then the tensile stress is reduced with the increase of working pressure. Beyond a certain higher pressure, the residual stress crosses into the compressive stress regime. As compared to earlier work, at working distance of 6.5 cm, the dependence of residual stress on the processing conditions is significantly different. It is noted that the properties of the plasma change with varying working distance. Moreover, the discharge voltage required to achieve the same sputtering conditions of power and pressure for working distance of 6.5 cm was higher as compared to that required for working distance of 9 cm. This higher discharge voltage results in higher kinetic energy of the sputtered atoms as well as of the back-scattered and neutralized argon atoms. A four point probe technique was used to measure the sheet resistance of the films and the resistivity of the films was calculated. Figure 1 and 2 shows the variation of resistivity with varying sputtering power and working gas pressure respectively.

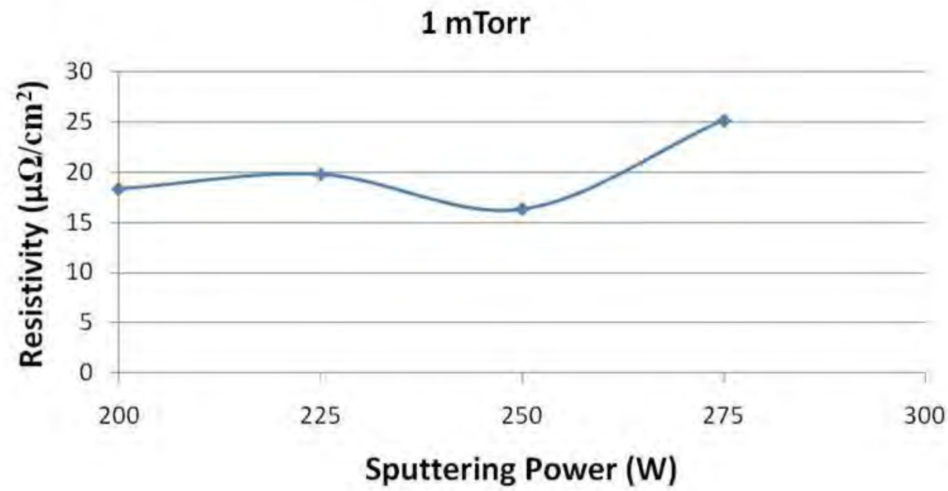

Figure 1: Variation of Resistivity with varying sputtering power for working distance of 6.5 cm

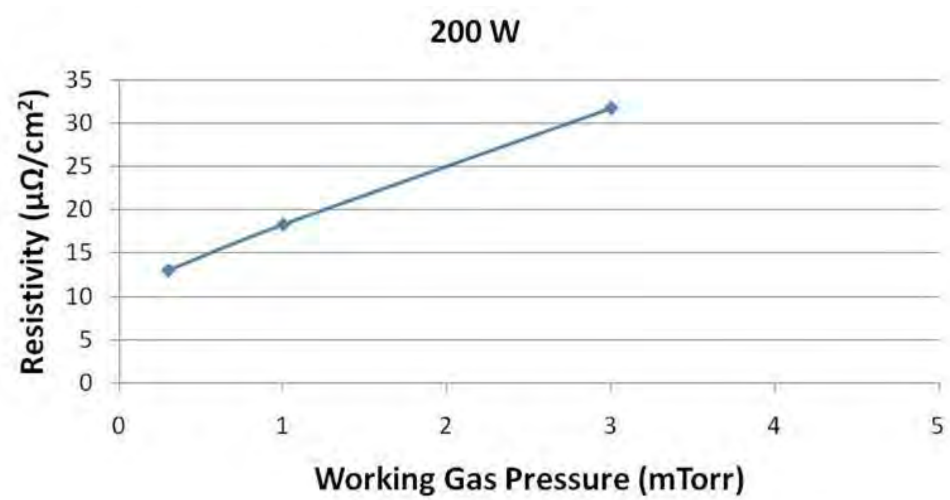

Figure 2: Variation of Resistivity with varying working gas pressure for working distance of 6.5 cm

In Figure 1, the variation in the resistivity of the molybdenum films with sputtering power is not significant. In Figure 2, the resistivity increases with increasing gas pressure because as the pressure increases the scattering of sputtered atoms and the neutralized argon atoms take place. Therefore, the incident kinetic energy of the sputtered atoms and the neutralized argon atoms is reduced which in turn can lead to a slightly more open structure causing an increase in resistivity.

CIGS Solar Cells Development:

Currently research is also being carried out on the development of $CuIn_xGa_{1-x}Se_2$ (CIGS), $CuIn_xGa_{1-x}Se_2S_{2-y}$ (CIGSeS), $CuIn_xGa_{1-x}S_2$ (CIGS2) thin-film solar cells on the soda-lime glass substrate with the molybdenum back contact. The goal is to correlate the processing parameters with materials and electronic properties of solar cells. Efficiencies close to the previously achieved record numbers have been obtained at PV materials lab at FSEC. Official results are pending characterization at the NREL facility.

Human Resources:

Shirish Pethe (PhD in Electrical Engineering) graduated in fall 2010 and Ashwani Kaul (PhD in Material Science) will be graduating in spring 2012. Eric Schneller (M.S in Material Science) will be graduating in fall 2012. Narendra Shiradkar (PhD) and Sagarnil Das (PhD) joined the group during fall 2011.

Publications:

1. S. A. Pethe, A. Kaul and N. G. Dhere, "Effect of working distance on properties of sputtered molybdenum films", submitted for the upcoming MRS- Spring 2011 conference.
2. N. G. Dhere, A. Kaul, S. A. Pethe, and, H.R. Moutinho, "Structural study of CIGS and CIGS2 thin-film solar cells using EBSD technique", 26th European Photovoltaic Solar Energy conference, Hamburg, Germany, September 2011.

University of Central Florida

Energy Efficient Building Technologies and Zero Energy Homes

PI: R. Vieira **Co-PIs:** P. Fairey, J. Sonne

Description: The project consists of two elements: 1) the construction of two flexible research homes at FSEC to conduct research on advanced building energy efficiency technologies under controlled conditions; and 2) a staged, field retrofit study in a small number of unoccupied homes to measure and document the effectiveness of a series of retrofit measures that can be deployed using current technology. The project will also conduct an annual meeting where other FESC participants, other university members and utility, industry, the U.S. Department of Energy, and other stake holders will be briefed on plans and progress. Inputs from meeting participants will be sought.

Budget: $1,224,000
Universities: UCF/FSEC

Progress Summary

A. Staged Retrofit Study of Unoccupied Homes

Technical assistance was provided for government and non-profit residential retrofits. FSEC technical support was largely funded through Building America, and local retrofits were funded by block grants. Key findings:

- 100 Homes Analyzed
  - 73 Retrofits completed
  - 15 Retrofits in progress
  - 12 Lost from study after initial analysis
- Mostly: single family detached, concrete masonry or frame, single story, built 1954 - 2006, 754 – 2408 sq. ft, split-system forced air mechanical systems are the norm.
- Poor HERS results were largely related to duct leakage.
- Ducts were leakier at post-retrofit in 17.5% of the cases.
- Average annual projected whole house energy savings was 25% or $493/year at $0.13/kWh.
- Lack of return air ducts in the bedrooms causing depressurized central rooms was common and provided an opportunity to discuss remedies with contractors.
- 42 homes achieved 30% or more improvement in HERS Index.

B. Flexible Residential Test Structures

Construction of the flexible residential test structures was completed in December 2010. A preliminary measurement of temperature during passive load conditions indicates that the buildings track each other well. A number of DOE staff toured the facility when they visited the Florida Solar Energy Center in January, after FSEC had been awarded a four-year research contract in which the facility will play a significant role. In early 2011, the instrumentation was ordered, and as of September most of the thermocouples were installed. Each building was tightened so that known amount and locations of leakage could be placed in one structure while the other serves as a control. Heat and moisture generation equipment has been installed along with a control system to schedule internal gains.

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- Lack of return air ducts in the bedrooms creating depressurized central rooms was common and provided an opportunity to discuss remedies with contractors.
- 42 homes achieved 30% or more improvement in HERS Index.
- Frequency of including heat pump water heater in retrofits increased towards latter part of study.

A comparison of before and after HERS Index of homes in study is shown in Figures 1 and 2.

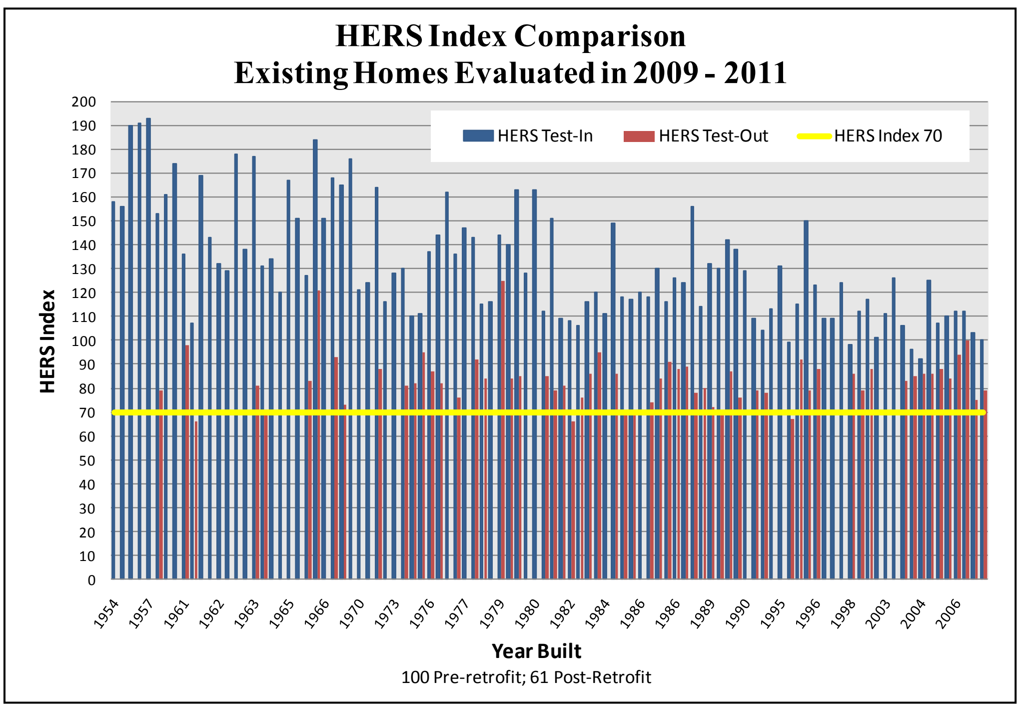

Figure 1: HERS Index (the lower the better) for Before and After Retrofits by Year of Construction

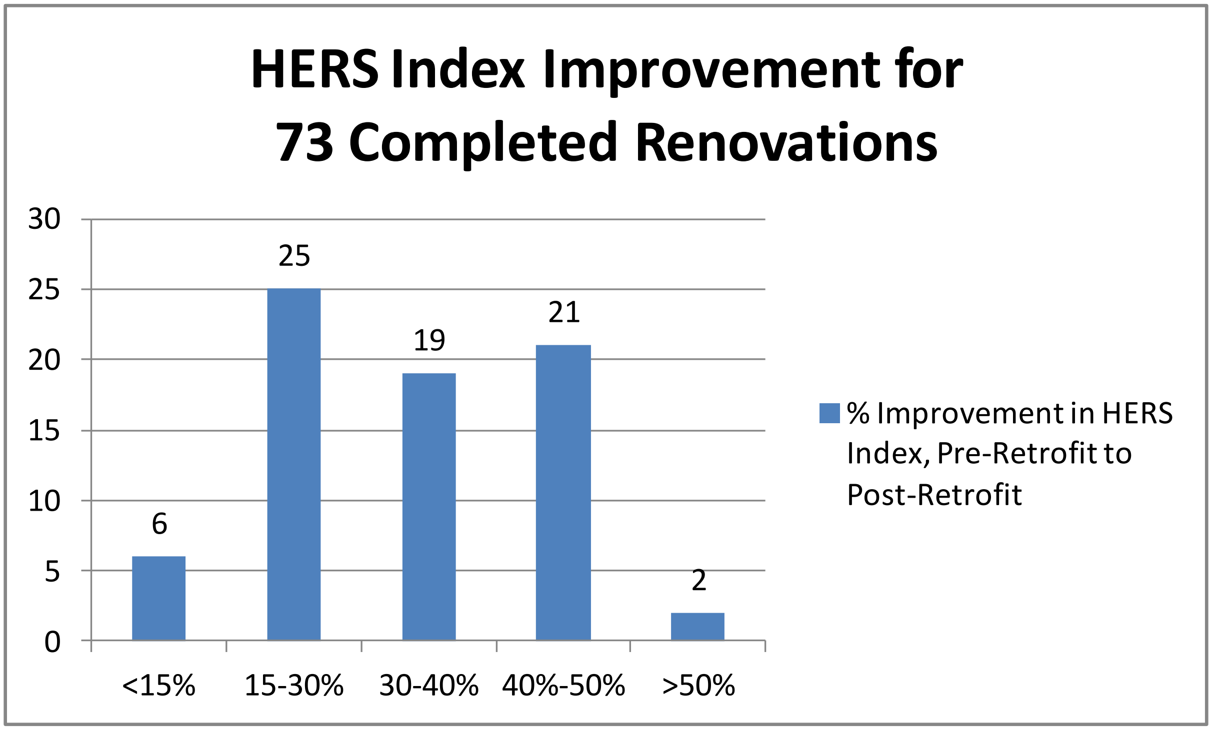

Figure 2: HERS Index Improvement for 73 Complete Renovations

B. Flexible residential test structures:

Construction of the flexible residential test structures was completed in December 2010 (See photos). A preliminary measurement of temperature during passive load conditions indicates that the buildings track each other well. A number of DOE staff toured the facility when they visited the Florida Solar Energy Center in January 2011. Following the DOE visit, FSEC was awarded a four-year research contract in which the residential test facility will play a significant role. In early 2011, the instrumentation was ordered, and as of September most of the thermocouples were installed. Each building was tightened so that known amount and locations of leakage could be placed in one structure while the other serves as a control. Heat and moisture generation equipment has been installed along with a control system to schedule internal gains.

Senior Engineer, John Sherwin, installs wall surface thermocouple.

Project Specialist, David Hoak calibrates schedule controller to use with latent load generator.

FESC Florida Energy Systems Consortium

University of Central Florida

Enhanced and Expanded PV Systems Testing Capabilities at FSEC

PI: Stephen Barkaszi **Co-PI:** Robert Reedy

Description: An important FSEC function is consumer protection from poorly designed and manufactured PV modules and systems. FSEC's test capabilities were established over 10 years ago and were adequate at the time to test PV modules for certification. However, PV costs have fallen and competing electric utility rates have risen. In the last two years, these curves have crossed under some economic scenarios and incentive programs, and the demand for PV module testing and system certification has jumped. Thus, this task will provide for enhanced and expanded PV testing and certification capabilities. The task will also be done in close coordination with FSEC's work with the U.S. Department of Energy's PV program.

Budget: $132,398.00
Universities: UCF/FSEC
External Collaborators: Sandia National Labs and US Department of Energy

Progress Summary

The objective of this project is to provide for enhanced and expanded PV testing and certification capabilities at the Florida Solar Energy Center. Using funding from the Consortium, this project has been used to either purchase or leverage the purchase of photovoltaic test equipment that will be used to expand the research and commercial testing capabilities at FSEC.

Commercial testing capabilities at FSEC have been improved with the equipment purchased under this project. Performance testing times have been reduced and PV modules using newer technologies can be evaluated accurately. Moisture intrusion is a common failure mode in these newer PV module technologies such as thin-film. PV manufacturers are particularly interested in testing new products at FSEC under the rigorous test conditions created by Florida's hot and humid weather.

Research capabilities at FSEC have attracted significant outside funding for applied research. Work with Sandia National Labs has continued in the area of test and reliability of PV equipment. The research involves PV modules and all system components including inverters and balance of system parts. High quality module and weather data is critical to Sandia's PV performance modeling.

FSEC has been recently been selected by the Department of Energy as the location for one of three Regional Test Centers for PV research and development. The FSEC/UCF capabilities and location were critical to the selection. This is a long-term project that involves building on the foundation and recent enhancement of the PV test capabilities that were made possible by this program.

Figure 1: PV module testing with flash simulator

The objective of this project is to provide for enhanced and expanded PV testing and certification capabilities at the Florida Solar Energy Center. Using funding from the Consortium, this project has been used to either purchase or leverage the purchase of photovoltaic test equipment that will be used to expand the research and commercial testing capabilities at FSEC.

A state of the art long-pulse simulator has been purchased that will decrease the turn-around time for commercial testing and will allow more accurate testing of newer thin-film and multi-junction modules. The new solar simulator was installed in the newly enclosed and remodeled PV test facility. The PV test facility improvements have nearly doubled the throughput capabilities.

The outdoor test area for PV module, inverter, and system testing at the FSEC site has also been expanded. Additional module I-V multi-tracers have been installed and have expanded the number of modules that can be tested concurrently. This allows short-term testing of commercial production modules to be conducted concurrently with the long-term testing of different modules for research without conflict or interruption.

Space has been allocated for expanding the fixed module exposure area to increase the available rack space for outdoor testing. This expansion has already been successful in attracting additional contract research for side-by-side module testing of small PV systems. An area is also designated for installation of a dual axis tracker to enhance the existing test capabilities.

Figure 2: PV multi-tracer

Project Description:

The demand for PV products is driven by three major forces: the recent "boom" in green energy awareness, the globalization of the solar industry with many previously uncertified overseas manufacturers and the rapid change in PV cell and module technologies. Thus, these reasons dictate the need for providing enhancement and expansion of FSEC's PV testing and certification capabilities. The testing capacity will implement by the following plans:

- Enclose and outfit a permanent PV Module and Inverter Test Area

- Upgrade and expand test and analysis equipment and software that includes permanent outdoor test stations with I-V curve tracing equipment
- Purchase a long-pulse simulator for indoor PV testing
- Install and instrument a 3-axis tracking platform
- Construct additional fixed rack space for outdoor testing

In addition to these specific equipment improvements, FSEC intends to enhance the general testing infrastructure to include improved instrumentation, documentation and test procedures.

Testing Instrumentation
The instrumentation used for PV testing has been adequate for the previously pace of testing, and the emphasis on research testing. However, for the high-throughput commercial testing now needed, it will be necessary to completely rebuild the wiring and instrumentation setup, with a focus on organization, quick connect/disconnect ability and flexible configurations.

Reporting and Certification
With more automated test data gathering and processing resulting from the upgraded laboratory instrumentation and computational capabilities, PV Test Reports will be more expeditiously completed. In addition, the format of the test reports is to be improved for more accuracy, rapid preparation and ease of use.

Certification Application Documents
Along with reporting and certification tasks, FSEC will also improve the format and content of the Application Forms submitted by the clients. These improvements are geared to both simplify the client's tasks in preparing the Application, aid the client in better defining their products and improving the facilitation of the preparation of the resulting test report.

The instituting of the advancements summarized above will require approximately six months for implementation of the procedural and general infrastructure (non-capital) improvements. It is the Center's goal to aid the PV industry by responding as quickly as possible to the new and growing markets with the essential constraints of reliable and credible high quality testing and certification.

Deliverables:

Expanded Testing Facilities for PV modules and systems, with proven capabilities:

- Long-pulse solar simulator for new multi-junction cell designs
- One 3-axis tracking platforms for maximum exposure and aging testing
- Stationary I-V curve tracers, with flexible connection systems
- Doubling of fixed test rack space
- Improve certification process and minimize time requirements

Industry Support:

This task will be strongly supported by the PV manufacturers. Many such companies have already contracted with FSEC for testing in our uniquely hot, humid and lightning-prone environment. Further, the US DOE is expected to continue support FSEC's PV test program with contract work for accelerated aging, high voltage and generalized testing.

FESC
Florida Energy Systems Consortium

University of Central Florida

Enhanced and Expanded Solar Thermal Test Capabilities

PI: John Del Mar **Co-PI:** Joseph Walters

Description: FSEC believes that independent, third-party testing and certification has extensive value in the marketplace, especially for products that are not widely "proven" with consumers such as solar water heating systems and solar electrical (photovoltaic) systems. In addition, due to the resurgence of the solar industry, FSEC has received a significant increase in demand for solar collector and solar system testing and certification. This occurrence has resulted in requiring the Center to correspondingly amplify its capabilities to respond to the increased demand This project has the objective of increasing FSEC's solar thermal testing and certification activities by the following actions: test and analysis equipment and software upgrades and expansion, integration of the solar collector and system laboratories, enhancing documentation and reporting methods and streamlining and devising more comprehensive client test and certification application documents. Additional test facilities have come on-line internationally in the last two years and the increased testing capacity resulting from the additional tests labs has reduced the industry demand for FSEC's thermal test services. FSEC however, remains the only test facility in the U.S. capable of testing certain types of solar thermal energy equipment and the current testing demand at FSEC still significantly exceeds the demand prior to 2008.

Budget: $809,295
Universities: UCF/FSE
External Collaborators: US Department of Energy, SRCC

Progress Summary

The enhanced and expanded solar thermal test capabilities have shown significant progress. The following is summary of the key aspects of the project.

Measurable Results:

Year	Test Rate	Report Rate	Certification Rate
2008 (before project)	4 collectors/year	4 reports/year	4 per year
2009	14 collectors/year*	22 reports/year*	-
2010	27 collectors/year*	20 reports/year*	195 per year †
2011	15 collectors/year[a]	12 collectors/year[a]	180

* These rates include the interim test and report category which allows collectors to get to market prior to performance testing while still protecting the consumer from poor quality product.

† The certification rate was actually the number of certification for FY2010. Thus the absence of data in year 2009. The rate is expected to increase as the information control system is implemented.

[a] About 15 test facilities have come on-line in the last two years. The increased capacity has significantly reduced the industry demand for FSEC's thermal test services.

Key Elements: Following is a brief project summary of achievements and activities for 2011 with an indicator of % complete.

1. Information Control System – 70%
    - Create application for storage and retrieval of test data in a database. The Test Application Data Analysis (Ta Da) system provides a more efficient method for data review and generation of summary data related to the tests.
    - Provide an information control system that allows customer and user access to determine material status and report on material testing with the ultimate goal of automatically generating the test reports and certifications.
2. MTP Unit 2 – capacity increase – 100 %
    - Update test platform with all the improvements to date with respect to sensors, automation, and wind systems.
    - Modify test platform to add capability to test both glazed and unglazed collectors with only minor adjustments needed based on collector type.
3. Systems Test Lab – 90%
    - A new test facility used to test thermal system components and thermal collectors with integral storage (i.e. thermo-siphon systems) was completed at FSEC. The previous facility was decommissioned and removed providing lab space for other research.
    - Final system validation and start-up procedures are currently underway.
    - The new facility will allow FSEC to be one of only 2 labs in the country capable of performing tests on certain types of solar thermal systems and components, and FSEC will be the only lab capable of conducting a few specific tests related to solar thermal systems.
4. Fixed Stand Configuration - 0%
    - Project cancelled. 15 test facilities have come on-line internationally in the last year. The increased capacity has significantly reduced the industry demand for FSEC's thermal test services.

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Project Impact:

The Florida Solar Energy Center (FSEC) believes that independent, third-party testing and certification has extensive value in the marketplace, especially for products that are not widely "proven" with consumers such as solar water heating systems and solar electrical (photovoltaic) systems. Independent, third-party certification provides not only protection for consumers, but also much needed consumer confidence. Even more important, third-party certification provides protection to reputable manufacturers, ensuring that lower quality products, often from foreign markets, do not compete head-to-head with Florida and U.S. products unless they meet the same standards.

In addition, to be eligible for the 2005 EPAct federal tax credits for solar thermal systems, the consumer must purchase a solar thermal system certified by the Solar Rating and Certification Corporation (SRCC) or FSEC. Since this federal tax credit has been extended through 2016, solar thermal testing and certification will continue to be required. While SRCC or FSEC may accept test results from other testing laboratories for certification, it has only been since July 2009 that other accredited test facilities have been available. Prior to 2010 FSEC was the only accredited thermal test facility in the US. Additional tests labs have significantly reduced the industry demand for FSEC's thermal test services. FSEC however, remains the only test facility in the U.S. capable of testing certain types of solar thermal energy equipment and the current testing demand at FSEC still significantly exceeds the demand prior to 2005.

Solar thermal systems for residential domestic water heating are subject to much variability in quality and performance. An important function of FSEC is consumer protection from poorly designed and manufactured thermal collectors and systems. For many years, the solar water heating industry has experienced very slow and steady growth. FSEC's test capabilities were quite adequate to test and certify the 3-5 new collectors introduced each year. However, in 2005, the demand for testing jumped dramatically, and is now projected at 20-40 new collectors annually, at least for the next 5 years. This increase is driven both by the recent "boom" in green energy awareness and the globalization of the solar industry, resulting in many requests from overseas manufacturers wanting to enter the US market. This project will allow FSEC to meet the new demand for testing and certification of solar thermal collectors and systems.

Project Description:

This project has the objective of increasing FSEC's solar thermal testing and certification activities by the following actions:

- Implement the Interim Certification category to speed product to market
- Upgrade and Expand the Test and Analysis Equipment and Software
- Implement an information control system which encompasses on-line application and payment all the way through to the test report and the certification.

Interim Certification

The interim certification category was introduced in June 2009 to allow quality products to market quickly. Collectors are exposed to outdoor conditions as required by the standard to determine general quality. If they pass these tests they are allowed to market for a limited time until the performance testing is completed. The addition of additional test labs worldwide has resulted in essentially no backlog for collector testing at FSEC in 2011. As a result, very few manufactures of solar energy equipment requiring testing are opting for interim certification. The interim certification program served the purpose it was designed to serve, and will be maintained as an option for FSEC certification.

Testing Instrumentation

Over the years, the instrumentation used in testing solar thermal collectors at FSEC has aged to the extent that an unacceptable level of failures occur that causes negative impacts in the time period required to complete a performance test. For example, problems with sensors, connectors, computers, data cabling and the like often corrupt the test data. These events, the troubleshooting and the repair activity extend the time required to complete the test. Thus, FSEC implemented a modern instrumentation and testing system using advanced but proven hardware and software. Specifically, powerful Compact Field Point (CFP) data loggers, processors and controllers were applied in these instrumentation upgrades.

The advanced hardware and software configuration has been completed and released to production for three test stands as of the time of this writing. A fourth platform, used primarily for equipment calibrations may be updated as well, but that activity is not currently scheduled as part of this project.

The collector test software application created in LabVIEW® offers more flexibility and autonomy in running the performance tests. Features such as automatically adjusting the inlet temperature to compensate for changing air temperature and automatically deciding the orientation of the tracking platform when testing off-angle were introduced to maximize the data collection rate while minimizing user intervention. A Test Application Data Analysis (Ta Da) application was written and released which allows more flexibility and efficiency in reviewing the data and developing the tables and graphs required for the test report.

In addition to performance testing the same automation principles were applied to the temperature sensor calibrations, flow calibrations and pressure tests. These improvements have reduced the test time significantly while improving the data capture integrity.

A parallel equipment and software upgrade has been underway for thermal system component testing at FSEC. System component testing includes testing of solar thermal collector "systems" that include hot water storage in the design. Examples of these collectors include integral collector storage (ICS) and thermosiphon systems. Other components such as heat exchangers, storage tanks, and certain pumps can also be tested in the FSEC thermal system components lab. These tests are also required for equipment certification, but cannot be performed with the same equipment used for typical collector performance testing. In 2011, significant progress was made in the systems component test lab. New equipment was purchased and installed in an on-site lab building, and the old, existing component test facility was decommissioned and dismantled. The new facility is approximately 90% complete with some final assembly and testing needed prior to formal commissioning.

Information Control System

Prior to the recent high demand for thermal collector and system test and certification the document control system at FSEC was sufficient. However, changes in circumstance require a more efficient, traceable information control system. The requirements for an accredited test facility along with the increased work volume demanded a more efficient document control process. Work has been ongoing on a system that encompasses all the aspects required to be a competent provider of testing and certification services.

A system is envisioned where the customer can readily apply and pay on-line for services requested. Additionally they will be able to track the progress of their test from beginning to end. The personnel in the test facility will use it to enter data as the unit progresses through the facility. It will seamlessly communicate with the data collection and analysis software. The test report will be automatically generated and much of the certification process will be automated. Additionally the system will meet the requirements that an ISO 17025 accredited test facility must meet with respect to document control.

Work has begun on the system. The conceptual design is complete with the database design is nearly complete. A separate contract has been entered into between FSEC and the National Renewable Energy Laboratory (NREL), which leverages work already accomplished to pursue information control upgrades further.

Key Results:

The following major projects were identified to attain the project's goals. The following is a summary of key elements up to and including activities in 2011 with an indicator of % complete.

1. Interim Test and Report for Certification – 100%
    - Provide a process that allows collectors to get to market quickly while maintaining consumer protection for quality.
2. Mobile Tracking Platform (MTP) Unit 2 Wind System – 100 %
    - Provide wind source for collector testing to meet wind requirement on demand.
3. MTP Unit 1 Wind System – 100%
    - Provide wind source for collector testing to meet wind requirement on demand.
4. MTP Unit 1 Conversion to Dual Flow – 100 %
    - Provide this test platform the capability to process the predominant collector type like the other platforms.
5. LabVIEW® based Collector Testing – 100%
    - Provide updated data logging automation for improved reliability and data transfer.
6. Sensor Improvement – 100 %
    - Research and implement new sensors and applications of sensors for more reliable and precise data measurement.
7. MTP Unit 4 – capacity increase – 100%
    - Bring into production a new test platform that has all the improvements to date with respect to sensors, automation, and wind systems.
8. Information Control System – 70%
    - Create application for storage and retrieval of test data in a database. The Test Application Data Analysis (Ta Da) system provides a more efficient method for data review and generation of summary data related to the tests.
    - Provide an information control system that allows customer and user access to determine material status and report on material testing with the ultimate goal of automatically generating the test reports and certifications.
9. MTP Unit 2 – capacity increase – 100 %
    - Update test platform with all the improvements to date with respect to sensors, automation, and wind systems.
    - Modify test platform to add capability to test both glazed and unglazed collectors with only minor adjustments needed based on collector type.
10. Systems Test Lab – 90%
    - A new test facility used to test thermal system components and thermal collectors with integral storage (i.e. thermo-siphon systems) was completed at FSEC. The previous facility was decommissioned and removed providing lab space for other research.
    - Final system validation and start-up procedures are currently underway.
    - The new facility will allow FSEC to be one of only 2 labs in the country capable of performing tests on certain types of solar thermal systems and components, and FSEC will be the only lab capable of conducting a few specific tests related to solar thermal systems.
11. Fixed Stand Configuration - 0%
    - Project cancelled. 15 test facilities have come on-line internationally in the last year. The increased capacity has significantly reduced the industry demand for FSEC's thermal test services.

Deliverables:

Expanded solar thermal testing facilities for domestic hot water collectors and systems, with proven capabilities:

- Pursue with all deliberate speed another collector certification mechanism that ensures collector durability and quality, but allows time-limited provisional collector performance ratings such that new collectors and systems can enter the marketplace within three months of application.
- Increase FSEC's collector testing capacity to handle the current and potential future demand for solar thermal hot water systems. Capacity will exceed 15 full performance collector tests per year and 15 - 20 system component tests per year.
- Develop information control system to drastically improve efficiency and accuracy.

Industry Support:

This task will be strongly supported by the solar thermal manufacturers, who must have certification (FSEC within Florida, and FSEC-contracted SRCC nationwide) to effectively sell their products and qualify those products for various state and federal incentives and rebates. The Solar Rating and Certification Corporation (SRCC) has traditionally been operated from the FSEC campus and the SRCC contracted with FSEC for $500,000 of annual work in test and certification. In July of 2011, SRCC moved into a separate independent facility, and now has only limited contracts with FSEC for database and related IT support. Further, the US Department of Energy has funded work at an annual rate of $500,000 to FSEC and SRCC through December of 2011. However, this support is directed to labor and other operating expenses, and will not provide for the capital expansion and enhancements proposed under this task.