ELG4126: Case Study 2
Hybrid System Design and Installation

Diesel Driven Generator

Life Cycle Costing

Photovoltaic Cells, Modules, and Arrays

Possibility of Integrating Fuel Cells and Wind Turbines

Environmental Factors

Economics Considerations

Hybrid Distributed Generation System

- Conduct a feasibility study for initiating a profitable hybrid (photovoltaic [40 kW) + diesel (40 kW)] Standalone/Grid-connected distributed generation system. You may add fuel cells, wind turbines, and electricity storage to your project to benefit from the peak premium! Generally the development and operation of a hybrid generation system can be subdivided into the following four steps:

- **Initiation and Feasibility (concluded by go/no-go)**
  - Municipal consultation.
  - Site selection and solar assessment (proposed site; available solar energy)
  - **Technical feasibility:** Description of candidate technologies!
  - Main risk assessment: Obstacles and impacts.
  - Planning requirements of local authorities.
  - Economics based on annual energy production: Revenue, costs, economic indicators.
- **Prebuilding (concluded by go/no-go)**
  - Hybrid farm design including energy yield predictions (intensity, estimated snowfall, grid losses; availability)
  - Planning procedures (environmental issues; noise; visual impact; safety)
  - Grid connection
  - Basic mounting options and tracking considerations.
  - Selection of suppliers
  - Project financing.
- **Building**
  - Overview of the building process
  - Quality control during production and construction
  - Commissioning and handover.
- **Operation and Maintenance**
  - Daily operation
  - Warranties and insurance
  - Maintenance and repair.

Charge Controller

- One of the main tasks of this project is to design an efficient charge controller. This meant implementing the microcontroller, sensors, and electronics necessary to monitor and adjust the power while consuming as little of the power as possible.
- Efficiency is an objective in component selection for the charge controller circuit. This results in an overall low powered charge controller system, which means that more of the solar panel energy is transferred to the battery.
- Size and portability are primary objectives, which make the system very easy to setup in an outdoor environment such as a remote location without any access to electricity.
- Usually, the charge controller incorporates a LCD screen which constantly allows the user to monitor important operational variables such as input voltage, output voltage, input current, output current, battery and solar panel temperature.
- **Write the specifications of the charge controller!**

Wireless Connectivity

- The Photovoltaic MPPT Charge Controller (PMCC) should be able to wirelessly transmit data from the charge controller, located with the solar panels and battery bank, to a computer where the data is processed and displayed in an easy-to-read format.
- The wireless transceivers provide remote monitoring and data logging functionality. This is incredibly useful when a user is not physically at the system itself and wanted to be able to know the performance and whether any anomalies occur.
- **Write the specifications of the wireless protocol!**

Solar Panels

- The solar panel is the most expensive part needed to test and implement the project. Therefore finding an inexpensive module with an optimal power rating is going to be imperative to the entire project's performance and cost.
- Solar panel efficiency and power output needs to surpass the battery charging requirements during normal operating conditions, in order for the charge controller system to be fully tested.
- The panel should also be powerful enough to provide a quick charge, in order to shorten the battery charging time in various operational states and weather conditions. Power output depends on panel efficiency, so efficiency is the main objective in selecting a PV panel.
- **Write the specifications of the panels!**

Panel Performance

- There are a several techniques to increase solar panel performance to make up for lower levels of solar irradiance. These include direct methods like solar tracking and light concentration or indirect method such as the use of an MPPT charge controller.
- Solar tracking is used to minimize the angle of incidence between the sunlight and the panels. In other words, this method ensures that the solar panels face the sun at any given point of the day. This is achieved by mounting the solar panels on a single or double axis mounting mechanism that is controlled by the intensity of the sunlight.
- Light concentration is achieved with the use of mirrors or lenses above or around the solar panel in order to intensify the amount of sunlight that hits the panel.
- MPPT is an indirect method of maximizing the efficiency at which the solar panels deliver electricity to an on-grid or off-grid scenario like charging a bank of batteries.
- **Propose and write the specifications of the applied techniques.**

Microcontroller

- The microcontroller is responsible for all input and output processing of the photovoltaic system. The tasks includes reading sensor values, controlling battery-charging circuitry, monitoring system performance and anomalies, in addition to transmitting data wirelessly and outputting data to an LCD.
- The microcontroller needed to be low-power and contain enough programming space for all project objectives. The device needs to run at a relatively fast processor clock speed in order to be able to multitask between the various peripheral devices and provide useful data in a short amount of time.
- The controller should have adequate digital I/O and analog input pins to be able to handle all peripherals used in PMCC. Multiple TTL serial ports are desirable, as well as Inter-Integrated Circuit communication in order to interface with the devices that use these digital communication protocols.
- A robust programming language and programming software (IDE) associated with the microcontroller are preferred.
- **Write the specifications of the controller!**

Sensors

- The sensors in the PMCC are the devices that are going to be in charge of monitoring and communicating everything that was happening in the system to the microcontroller.
- Two of the sensors that are needed in the design are a voltage and current sensor. Both of these sensors play a significant role in one of the main goals of the project which is achieving maximum power point tracking.
- Sensors keep the microcontroller updated with the voltage and current values being provided by the panel so that it can react to it accordingly. Aside from keeping track of the solar panel's energy output, these sensors also take part in determining the status of the batteries.
- In addition to these sensors, a temperature and irradiance sensor are also needed in the system. A temperature sensor helps keep track of the temperature in the solar panel as well as in the batteries. The irradiance sensor helps keep track of the light intensity the PV panels are receiving.
- **Design and write the specifications of the sensors!**
-

Batteries

- The battery bank should provide a large energy capacity, run at 12V, and provide a large output current to handle high power loads. The battery bank should have a long lifetime and be as low cost as possible.
- There are four possible states that the battery can be in that will determine what charging mechanism:
  - **Off State:** When there is little or no power coming from the solar panel, the device should go into an off state to protect the battery from leaking back into the solar panel.
  - **On State:** When there is minimal power coming from the solar panel, enough to power the system but not enough to move to the next state, the system turns on and attempts to deliver all of the power.
  - **Bulk State:** This is the main charging state where the MPPT algorithms are most relevant. Here the maximum power point is determined and the battery is charged accordingly.
  - **Float State:** Once the battery reached a high enough voltage and is close to fully charged, the controller then moved into the float state.
- **Write the specifications of the battery bank!**

Inverter

- The inverter is the final stage of the system. The main functionality of the inverter is to take the DC voltage stored in the batteries and transform it into AC voltage that can be used by small household appliances.
- It is important that the inverter can deliver a decent amount of power so that multiple devices can be powered simultaneously and the user is not stuck powering a single device.
- It is also important that the inverter has a user interface that is easy to use and that no extensive knowledge of the equipment is needed to operate it safely.
- Finally, the unit should be power efficient so that the energy generated in the system is utilized to the fullest in the most efficient way possible.
- **Write the specifications of the inverter!**

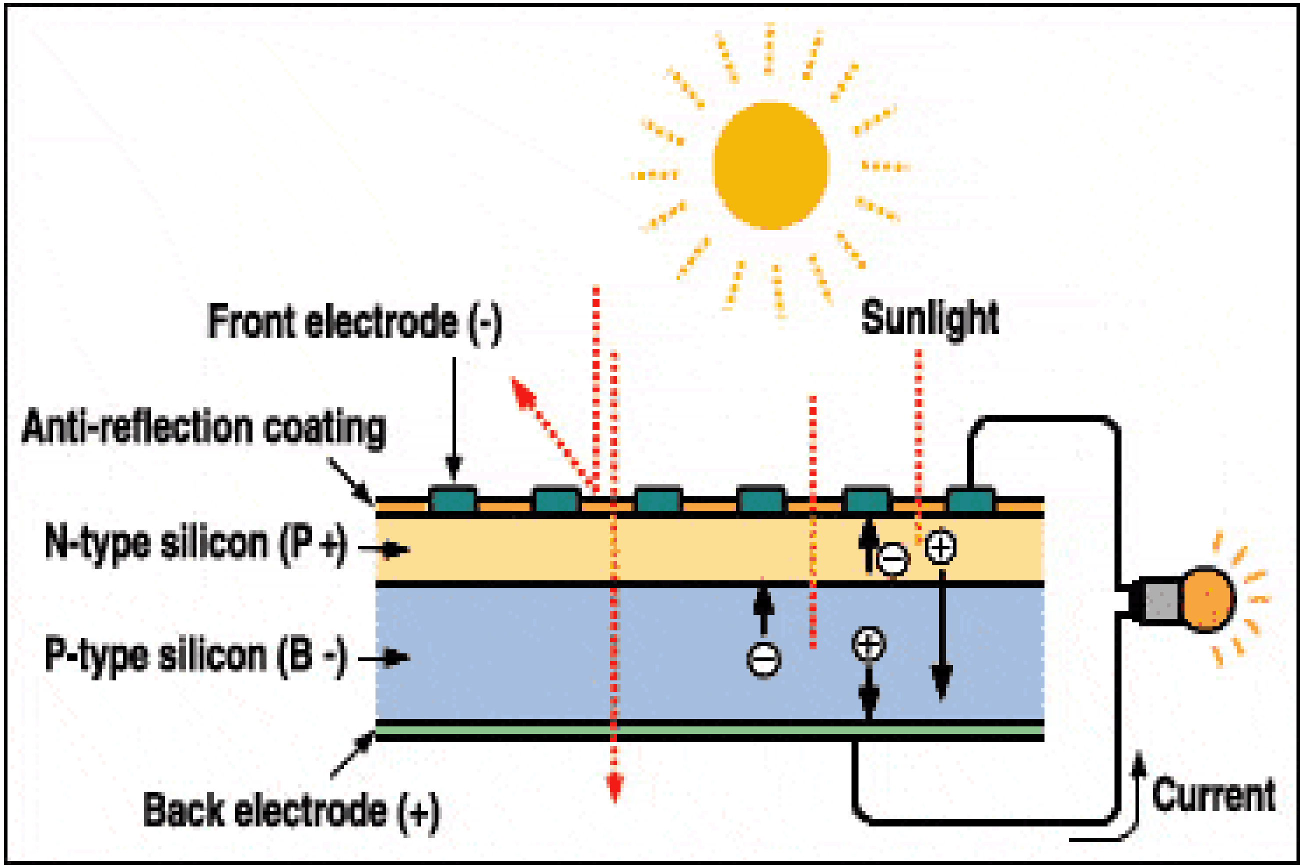
Power Supply

- Power from the panels is needed to power the current, voltage and temperature sensing circuit. Power is also needed to power the MOSFET gate drivers, LCD, wireless transmitters and microcontroller. In order to achieve this, a simple step-down or switching regulator should be connected to the input voltage from the panel.
- **Design a proper power supply!**

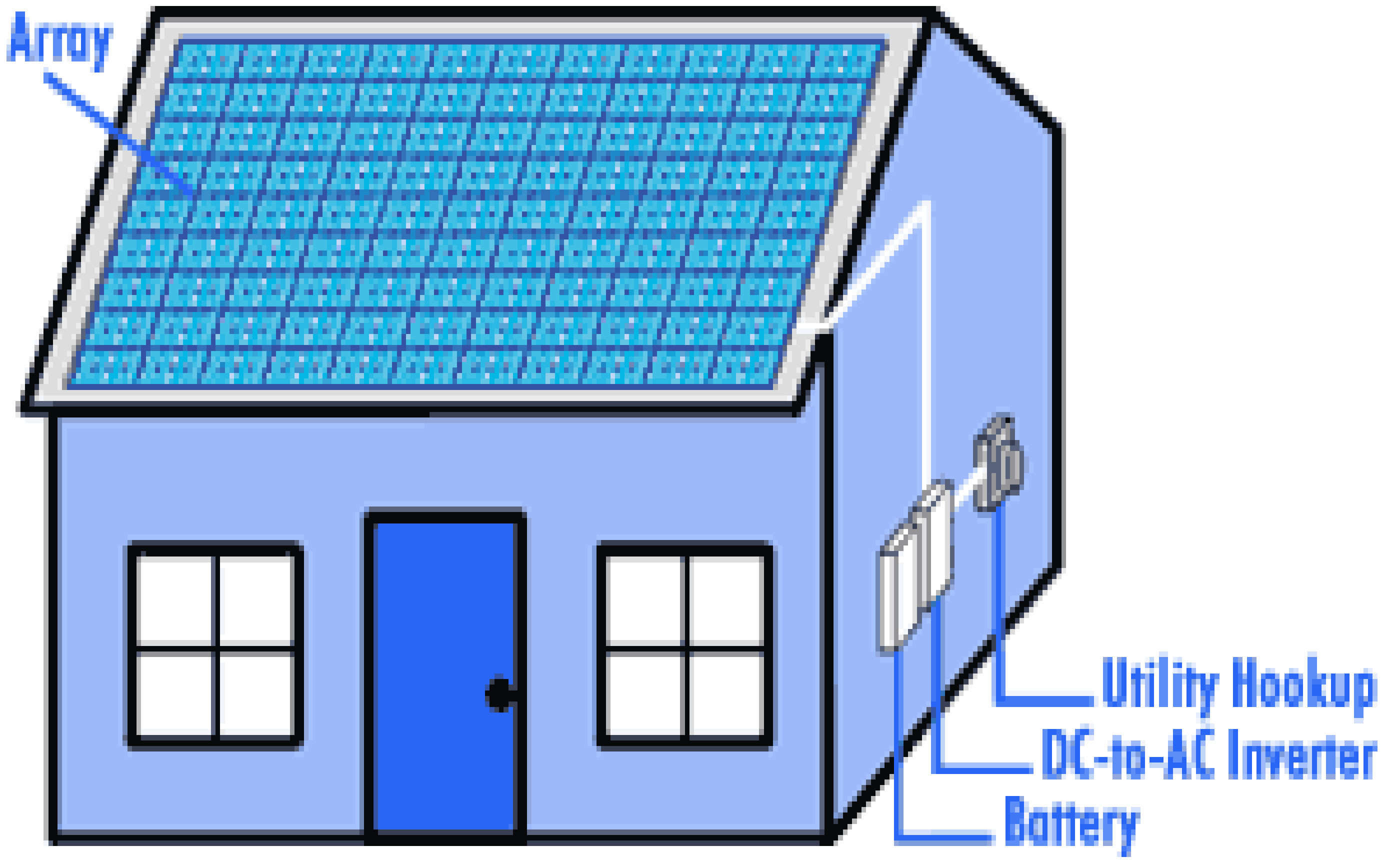
Solar Electricity: The Next Step

- Solid state device that converts incident solar energy directly into electrical energy
- Efficiencies from 7% up to 15% or more
- No moving parts and no maintenance
- No noise
- Lifetimes of 30 years or more
- Both a retrofit and new house technology
- Many new types of PV are beginning to be manufactured in large quantities.

Cross Section of Solar Cell



Net Metering can be Implemented with or without a Battery Backup



Pole Mounted PV

Solar Roofing Shingles

Roof Integrated Photovoltaics in Misawi, Japan

PV Installation in Planned Community in Germany

Solar Carport
Navy Installation: San Diego, California

BP Installation on Gas Station

Solar Cells Installed in Building Facade