Engineering 1N
THE NATURE OF ENGINEERING

Design Exercise: Photovoltaic System Design

Due 7:00 pm, December 12, 2002 (at the regularly scheduled final exam time)

Goal: The goal of this exercise is to give you an opportunity to develop a design for a small, stand-alone photovoltaic (PV) power system. Such a design is an example of routine design, using readily available components assembled into a cost-effective system. A second goal is to give you the opportunity to learn a little about PV technology, energy engineering, and electrical engineering. The final goal is to encourage you to think carefully about how one communicates engineering design information.

Need: Your client (me) owns a small (3.66 m x 6.40 m) cabin in a remote area of Colorado near Virginia Dale, CO (lat. 40°59'30" N, long. 105°25'21" W, El. 2322 m NGVD). (See Figs. 1 and 2.) The cabin is used almost exclusively in the summer months (May-September), although I do occasionally visit it in the winter. With my current schedule I am there for 3 to 10 days at a time, but I hope to spend more time there in the summers in the future. The site is characterized by high winds at times throughout the year, and grazing cattle in the spring and fall of most years and in the summer during dry years.

When staying at the cabin, I would like to have adequate lighting for preparing meals and reading in the evening, refrigeration for drinks and perishable food, music (I own a small Sony radio/cassette/CD boombox), and the ability to use/recharge my laptop computer (currently an Apple PowerBook G4). I cook with a Coleman stove using small propane bulbs, and do just fine without any heat, hairdryer, microwave, toaster, or any other appliance I can think of. The interior of the cabin is finished with unstained cedar siding on the walls, industrial indoor/outdoor carpeting over plywood on the floor, and a drop ceiling of wallboard painted white. The cabin is wired for standard 120-V alternating current (AC), with four simple, single-lamp ceramic light fixtures on the ceiling, and 5 standard duplex outlets distributed along 3 walls. The ceiling fixtures are on one circuit and the outlet boxes are on the other. There are no circuit breakers or fuses in the circuits. The feed to the interior wiring is through the floor at the southwest corner of the cabin. Currently it has a standard 3-prong male 120-V AC plug on its external end.

The local power utility has estimated the initial cost of connecting the cabin to the local power grid to be at least $10,000. Local energy rates are presently approximately $0.10 per kilowatt-hr (kWh). Since the estimated installation cost is more than the entire initial cost of the cabin ($8600 in 1984), I would like to engage your services to design a stand-alone (i.e., not connected to the utility power system grid) flat-plate PV power system for my cabin, which I hope will be less expensive than hooking up to the grid (and, as importantly, more environmentally friendly). I am seeking a design report which includes:

1) Specification (manufacturer and model) of all necessary components for the system. This should include the PV system, as well as lamps and refrigerator;
2) An estimate of the cost of the system, itemized by component;

Fig. 1. Location map of cabin site. House symbol shows approximate location of the cabin. The red star identifies Virginia Dale, CO.

3) A diagram showing how the system is to be connected;
4) A brief discussion of the rationale for the design, i.e., why particular components are chosen and why they are connected in the way shown; and
5) Any other comments you think would be of assistance to the client.

For convenience and consistency, I would like you to specify all components other than the lamps (light bulbs) from the on-line Solar, Wind & Hydro Catalog of Real Goods Trading Corporation, Real Goods.com. The URL is:

http://www.realgoods.com/renew/index.cfm

(You will find that the Real Goods site has lots of useful information pertaining to PV system design.) The lamps may be from any source.

Fig. 2. Cabin near Virginia Dale, CO, looking approximately southwest (north and east walls of cabin). Photo taken September 2001.

To assure consistency, I would also like to request that any solar radiation data which you use come from *The Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors, 30-yr (1961-1990) Average of Monthly Solar Radiation for Each Month*. These data are provided by the National Renewable Energy Laboratory on their *Solar Radiation Resource Information* web site:

http://rredc.nrel.gov/solar/pubs/redbook/

The nearest stations are Boulder, CO, Rock Springs, WY, and Cheyenne, WY.

Teams: Please work in teams of three (3), as follows:

Team	Members
1	Heather Backman, hbackman@stanford.edu Tina Chen, tinachen@stanford.edu Helen Chen, wei.helen.chen@stanford.edu
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Assistance: Prof. Gil Masters of the Dept. of Civil & Environmental Engineering has agreed to serve as an expert resource to you. Prof. Masters earned a Ph.D. in Electrical Engineering (at Stanford), was a principal in the solar energy design firm, Pacific Sun, and now focuses on renewable energy, energy conservation, and green building in his teaching at Stanford. Prof. Masters has visited my cabin, so he knows both the setting and the technology. I think you will find him very helpful.

Reports: I would like each team to prepare its report in the form of a *poster presentation*. I will provide each team with a cardboard display to which you will attach your design presentations, in the form of appropriate graphics, tables, and text. The closest analogue with which you might be familiar is a science fair presentation. I and some guests will visit each poster to review your designs and to discuss them with you. You should therefore design your poster so that it is visually interesting and can be read from a reasonable distance away (on the order of a meter), and you should be prepared to explain your design and answer any questions we might have about it. When we are not visiting your poster, you will be free to view the posters of the other teams. Your poster will serve as your only design report (I will take them with me at the end of the class for grading).

Logistics and Other Details: You may discuss the project with your classmates (on any team), or anyone else who will listen, ad nauseam. However, each team should develop its own design using its own best judgment, and it should prepare its own design poster. You will find it essential to work as a true team on this project, dividing up responsibility and labor, in order to complete the project efficiently and in a timely manner. I urge you first to plan your efforts carefully, developing a step-by-step process you wish to follow. Then assign tasks and complete your design.