School of Electrical and Information Engineering
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ELEN3017 ELECTRICAL ENGINEERING DESIGN I (PAPER) – 2018

Optimisation of Solar PV Installation

1 Introduction

This project aims to provide the student with some experience in paper design. There is no development of any hardware or software for this project; students are required to use as many software tools to design, simulate and optimise their solution, as may be required, to satisfy the application requirements. Since there is no prototyping development stage, this design process lacks a feedback path normally used for refinement.

This is an individual project, each student is required to derive their own solution and communicate it in an engineering report, the body of which is limited to three pages (excluding appendices) and not to exceed a total page-count of eight pages. Appendices should include a system block diagram, simulation plots, a basic technical drawing, and anything else required to fully present all aspects and components of the proposed solution.

This paper design is only assessed via the written report (hard-copy) using the marking grid provided on Sakai, and counts 25% of the course mark.

2 The Application

Your engineering skills have been hired by an aid agency to assist them with the design of a solar electrification system for their rural containerised community centers, dispersed across southern Africa. Each container comprises a 1.2 kW PV array (panel details below), mounted on the roof, which can be tilted to any angle and orientated in any direction. The panels feed a bank of power electronics and storage batteries, which may be assumed to be a constant load, indefinitely.

The technical services team are at a cross-roads in their decision making, and need your valuable skills and input. Since the sites are often very rural, robustness and simplicity are of prime importance. Their decision requires knowledge of the four uncertainties below:

1. Using a year's worth of solar data for the site in question, what constant load (i.e. fixed resistance) must be directly connected to the PV array* to harness maximum energy over a 1-year period?
2. What corresponding tilt and orientation angle of the array is required to achieve the above?
3. If a Maximum Power Point Tracker (MPPT) with the efficiency below, were to be installed to supply a constant load of 10 Ω, for the same PV array with the same tilt and orientation, how much energy would be harvested for the same 1-year period?
4. Using your engineering judgement, sound reasoning and paying attention to all aspects of the system (such as the costs of power electronics and PV silicon, wiring requirements, a realistic non-constant MPPT efficiency, environmental temperature, etc), which would you advise to the client: fixed load or MPPT, and what other recommendations would you advise?

*The individual panel modules may be connected in series, parallel or any combination thereof.

Table 1: Constraints pertinent to the design.

PARAMETER	VALUE / LIMITS
Solar module:	4 × TSM300PA14
Typical module power output:	300 W (each)
MPPT efficiency (assumed constant at all loads):	90 %

As a guide, the following steps will need to be considered. Firstly, the amount of solar energy available at each site will need to be determined. Estimates of annual irradiance at a location may be obtained from [3] for example, to give a starting point – this may or may not take into account the panel's tilt and orientation and will not be sufficient to successfully achieve the objectives above. Secondly, knowledge of the sun's trajectory through the sky (reference [3] may be useful), relative to the panels' position, is required to then understand the plethora of solar measurements available, from [2], to select the most appropriate data for modelling. Thirdly, understanding the operation of a PV panel is crucial to determine its power output given a certain load; references [4] and [5] present simple approximation models. Several examples of relevant methodologies from a similar project will be available on Sakai.

Commence with a simple model of low resolution and refine it as confidence builds. The optimization may (will) require an iterative process: the use of Matlab or a spreadsheet will be most valuable for this purpose. All aspects of the design should be discussed and all decisions justified in the report. Once an optimised solution has been derived, further recommendations and improvements should be considered and discussed.

References

[1] Sun Earth Tools. www.sunearthtools.com, last accessed 05-02-2018.

[2] Southern African Universities Radiometric Network. www.sauran.net, last accessed 05-02-2018.

[3] Photovoltaic Geographical Information System. re.jrc.ec.europa.eu/pvgis/, last accessed 05-02-2018.

[4] L. Cristaldi, M. Faifer, M. Rossi and S. Toscani, "A Simplified Model of a Photovoltaic Panel", IEEE Xplore, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6229672, last accessed 06-02-2018.

[5] D. Sera and R. Teodorescu, "PV Panel Model Based on Datasheet Values", IEEE Xplore, http://ieeexplore.ieee.org/abstract/document/4374981/?part=1, last accessed 06-02-2018.