Modelling Solar Potential for Energy Generation in Cold Regions

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INTRODUCTION

The application of renewable power systems is particularly relevant to remote locations such as Antarctic stations, where traditional fossil fuel based systems incur relatively high costs of fuel transportation, in conjunction with an increased risk of environmental damage. Traditionally the potential for solar power systems at high latitudes has been viewed as low and thus neglected. However, recent pilot projects at the Australian Antarctic station at Davis (68° 34' S, 77° 58' E) have demonstrated the capabilities of both Photovoltaic and solar hot water systems.

A solar energy model, SEMAS (Solar Energy Modelling for Antarctic Stations), is currently being developed by Latitude Technologies Pty. Ltd., in collaboration with the Australian Antarctic Division, to assess the potential for various types of solar power systems. Integrating environmental and operational data collected from the stations with standard meteorological data recorded by the Australian Bureau of Meteorology, SEMAS determines the available solar energy at a site and facilitates the design of potential solar energy systems.

This paper will introduce the basic framework of the SEMAS model and present preliminary estimates of annual solar potential for Australian National Antarctic Research Expedition (A.N.A.R.E.) stations. The future development of the SEMAS model will be discussed with regard to the continuation of the 1999-2000 season.

BACKGROUND

Solar energy modelling focuses upon the level of solar radiation incident at a given location on the Earth's surface. This is simply a function of

- The level of solar intensity reaching the top of the Earth's atmosphere.
- The transmission of radiation through the Earth's atmosphere.
- The location and orientation of collecting surfaces on the Earth's surface with respect to the position of the sun with time.

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METHODOLOGY

The definition of parameters and the development of the mathematical equations necessary to the SEMAS model are detailed in Sayigh (1977). The SEMAS model is being developed in conjunction with observed radiation data currently collected by the Australian Antarctic Division at Davis Station. This data provides benchmark testing of the SEMAS output and subsequent empirical calibration of the model. This data is particularly important when examining the role of observed cloud data and its integration into the model.

Solar Energy System Monitoring at Davis Station 1998-99

In the summer of 1998-99, an experimental Solar Hot Water system was installed and monitored at Davis Station (Guichard, 1999). Global radiation was measured on a horizontal surface between the 5th and 15th of February. This data was analysed with respect to the level of global radiation predicted by the SEMAS model and calibrated against the three hourly observations of total cloud cover (Figure 1).

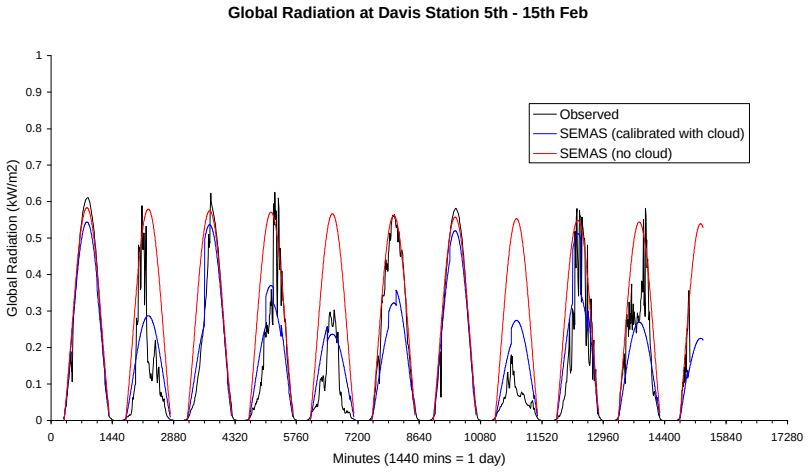

Figure 1: Global Radiation at Davis Station 5th –15th February 1999. Includes a) global radiation observed on a horizontal surface, b) predicted "clear sky" global radiation by the SEMAS model and c) predicted output of SEMAS model calibrated against three hourly observations of total cloud cover.

In conjunction with annual cloud data files collected during 1998, SEMAS generated annual estimates of radiation for each of the A.N.A.R.E. stations and determined the potential of fixed, altitude, azimuth and full tracking systems.

RESULTS

SEMAS Radiation Estimates for A.N.A.R.E. Stations

Table 1: Solar Radiation Estimates for A.N.A.R.E. Stations. Presented are the radiation estimates incident upon a flat horizontal surface using observed cloud data (three-hourly total cloud cover) from each of the stations in 1998.

Station	**Global Radiation**		**Direct Radiation**		**Diffuse Radiation**	
	Daily Average MJ/m^2	**Annual Total** MJ/m^2	**Daily Average** MJ/m^2	**Annual Total** MJ/m^2	**Daily Average** MJ/m^2	**Annual Total** MJ/m^2
Macquarie	9.9	3611	14.8	5398	2.8	1007
Casey	8.2	3008	13.3	4860	2.7	973
Davis	8.4	3002	14.1	5010	2.8	1002
Mawson	8.7	3163	14.3	5209	2.8	1030
	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2
Macquarie	2.8	1003	4.1	1500	0.8	280
Casey	2.3	836	3.7	1350	0.7	270
Davis	2.4	834	3.9	1392	0.8	279
Mawson	2.4	878	4.0	1447	0.8	286

Table 2: Solar Radiation Estimates for Non-Horizontal Panel Tracking Systems. All fixed azimuth systems face north. These estimates are based on the figures shown in Table 1, incident upon the following panel configurations: a) Fixed, b) Altitude Tracking, c) Azimuth Tracking and d) Full Tracking.

Station	**Best Fixed Position**		**Altitude Tracking**		**Azimuth Tracking**		**Full Tracking**	
	Daily Average MJ/m^2	**Annual Total** MJ/m^2	**Daily Average** MJ/m^2	**Annual Total** MJ/m^2	**Daily Average** MJ/m^2	**Annual Total** MJ/m^2	**Daily Average** MJ/m^2	**Annual Total** MJ/m^2
Macquarie	11.9	4353	12.6	4596	16.0	5836	16.7	6082
Casey	10.8	3954	11.9	4350	16.0	5822	16.3	5945
Davis	10.6	3885	11.8	4324	16.1	5870	16.4	5978
Mawson	11.3	4136	12.6	4583	16.9	6162	17.2	6284
	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2	kWh/m^2
Macquarie	3.3	1209	3.5	1276	4.4	1621	4.6	1689
Casey	3.0	1098	3.3	1208	4.4	1617	4.4	1651
Davis	3.0	1079	3.3	1201	4.5	1630	4.7	1662
Mawson	3.2	1148	3.5	1273	4.7	1711	4.8	1745

DISCUSSION

Photovoltaic and Solar Hot Water Potential

Further work is focused on assessing the efficiency of photovoltaic and solar hot water exchange systems in converting the available solar energy shown in Tables 1-2 into useful power for the A.N.A.R.E. stations. Although most manufacturers provide efficiency estimates for their solar conversion units, the extreme operational conditions presented on Antarctic stations require special attention and in situ monitoring of operational output and critical meteorological parameters.

The work plan initiated at Davis Station in the summer of 1998-99 has been expanded for the 1999-2000 season in light of the preliminary SEMAS results. With a view to strategically increasing the available data set, the SEMAS model will be refined to improve solar radiation prediction and post-collection energy utilisation

Future Development of SEMAS model

The initial results of the SEMAS model presented in this report are very promising, but nonetheless preliminary due to the relatively small data set of observed radiation levels limited to one site (i.e. Davis Station). The robustness of SEMAS model output will improve steadily with future development, specifically:

- The resolution of observed three hourly cloud data into a finer scale time grid.
- The incorporation of observed cloud types, i.e. high, middle and low cloud.
- Calibration with observed data collected from sites other than Davis Station.
- Application to non-Antarctic sites of varying latitude around the world.

SEMAS presents an efficient and inexpensive assessment of solar energy potential, invaluable to the planning and management of energy use in remote locations.

REFERENCES

Sayigh, A. A. M., “Solar Energy Availability Prediction from Climatological Data,” Solar Energy Engineering, Edited by Sayigh, A. A. M. Academic Press, New York, 1977.

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