Steven J Ransome BP Solar, Sunbury-on-Thames, UK
John H Wohlgemuth BP Solar, Frederick, MD, USA

Predicting kWh / kWp performance for amorphous silicon thin film modules

ABSTRACT

To evaluate the field kWh/kWp performance of tandem junction a-Si modules, a long term test program has been set up with test sites in Africa, Europe, Asia, Australia and the United States.

INTRODUCTION

1. a-Si performance does not depend linearly with insolation, it depends on recent history, solar spectrum, angle of incidence etc.
2. Crystalline Silicon equations do not work with a-Si
3. Empirical equations have been used to model a-Si kWh / kWp performance from real logged data

DEFINITIONS

Specific Yield SY = ΣWh / Pmax / time
e.g. if a 100Wp Pmax module gives 400 Wh / day then the SY = 400 / 100 = 4 / day

PR = Performance Ratio (dimensionless)
PR = ΣWh / Pmax / ΣInsolation
e.g. If the module above has an insolation of 5 kWh / m^2 then the PR = 4/5 = 80 %

MILLENNIA PERFORMANCE

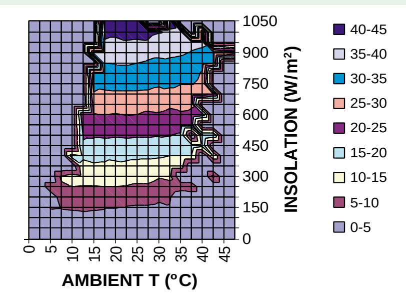

Fig 7. Average dc Pmax vs Temperature and Insolation of a Millennia module in South Africa from a year of hourly measurements. Note the good performance at high temperatures where a Crystalline module would already have reduced due to its higher -dPmax / dT factor.

kWh / kWp PREDICTIONS

	Average Insolation	Average Tambient	Millennia DC	Millennia AC	Saturn DC
Data source	Ref3	Ref3	EDG	NREL	EDG
Bangalore	2064	23.8	1869	1668	1836
Boulder	1993	9.9	1917	1581	1863
Madrid	1706	14.2	1792	1517	1749
Sydney	1802	18.2	1667	1434	1634
Washington	1797	12.7	1698	1421	1659
Hamburg	1082	8.8	1020	812	998
Units	kWh /m^2	°C	kWh/ kWp	kWh/ kWp	kWh/ kWp

TABLE (1) Summary of predicted energy output vs Meteorological data for different sites and technologies

EMPIRICAL SIZING MODEL

PVUSA [ref 2] **Pcalc = ΣIrr * (A + B * ΣIrr + C * avgTamb + D * avgWS)**

This Paper **SYcalcx = ΣIrr * (Ax + Bx * ΣIrr + Cx * avgTamb + Dx * avgWS) - Ex**

x defines the time period (hourly, daily) of the model

FITTING THE EMPIRICAL MODEL

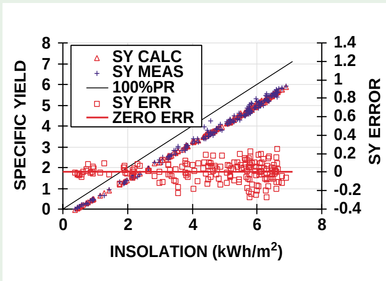

Fig 2 Fitting program with typical daily data. The parameter Ex is used because the SY versus Insolation does not go through the origin. Typical fit is <±4 % for each point (limited by measurement scatter). The overall bias error is near 0

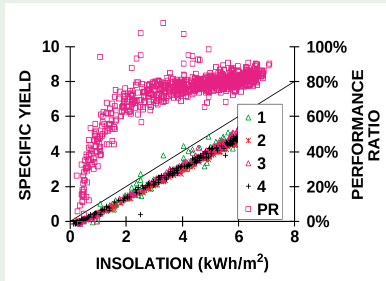

Fig 4 Daily ac PR and SY (each season) vs Insolation (MD). Note the SY for each of the 4 seasons are almost coincident, implying that the 'seasonal change' is just dependent on insolation values. Also the apparent low light level drop in PR is due to a constant power loss.

MODELLING ACCURACY HOURLY AND DAILY

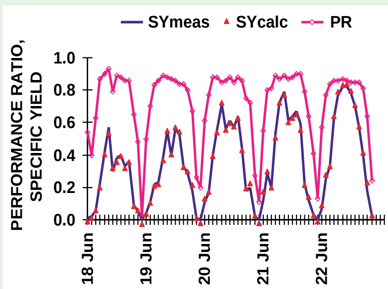

Fig 5. Hourly ac Model fit for TN Millennia Array. The proposed model gives very good fits to Hourly data

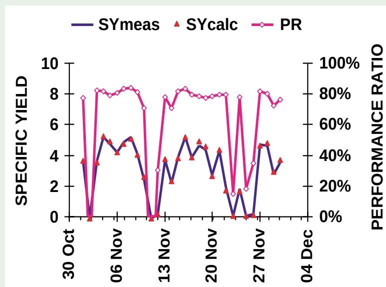

Fig 6. Daily ac Model fit for MD Millennia Array. The proposed model gives very good fits to Daily data

▲ Locations of some of the logged sites

Part of a data logged Millennia array in Germantown, MD ►

CONCLUSIONS

- A new empirical model has been developed which accurately predicts the performance of a-Si arrays and modules
- Hourly or daily data can be modelled equally well
- The model has been used in a Sizing program to predict kWh / kWp values expected from a-Si arrays around the world

REFERENCES • 1. PVG Utility PhotoVoltaic Group, 1800 M Street, N.W., Suite 300, Washington, DC 20036-5802, U.S.A. . eMail: upvg@ttcorp.com • 2. PVUSA R.N.Dows et al "PVUSA Procurement, Acceptance and Rating Practices for Photovoltaic Power Plants", Pacific Gas and Electric Co R&D report #95 30910000.1Sept 95
3. METEONORM Meteotest, Fabrikstr 14, CH-3012 Bern, Switzerland office@meteotest.ch

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