Large Scale Evaluation of Photovoltaic Technologies in Different Climates

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ABSTRACT

Photovoltaic systems are typically optimised for performance or cost. In order to evaluate the wider parameter space and extensive measurement campaign has been designed that will provide guidance on future system designs. Four near-identical, grid-connected 200kW PV systems are being installed onto IKEA home furnishings stores in four countries with different climatic classification. The systems are integrated with comprehensive weather and power monitoring systems. This paper reports on the design, installation and scientific objectives of the project.

INTRODUCTION

Many large industrial energy users still see on site renewables as part of their long term sustainability and energy efficiency strategies despite the current economic downturn and lower primary energy costs. However, large urban energy users are restricted in the choice of renewable energy sources they can use on site. Solar photovoltaic (PV) electricity generation is uniquely flexible for building added or integrated power generation due to a wide range of rooftop, façade and ground mounting options for PV arrays. Energy from solar PV has the advantage of being well aligned to commercial electricity demand cycles and having low maintenance requirements.

The key commercial objective in implementing solar PV generating capacity is to achieve a short return on investment. This may be in conflict with assumptions made in the technical community that the key objective is to achieve optimum electrical performance because achieving optimum electrical performance may come at a disproportionate cost.

There have been a number of previous medium to large scale PV comparison projects including:

- The UK “PV-Compare” Project [1].
- Collaboration between groups from Stuttgart, Cyprus and Egypt Universities, with arrays on the 3 sites [1, 2],
- IFSH (Emmerthal) compilation of performance data from 334 grid-connected PV installations (part of IEA PVPS Task 2 project (International Energy Agency: Photovoltaic Power Systems) [3]
- The Japanese Mega-Solar project [4-6].
- The Robert Schulz solar farm [7]

However, these tend to focus on performance alone, which is not the only requirement for PV system design.

THE NEED FOR MULTI-PARAMETER OPTIMISATION

Previous solar PV comparison projects have focused on output as a specific yield (kWh/kWp) or performance ratio (PR). Comparison of kWh/kWp is of limited value to consultants and designers without also showing the relative costs. For example, the more efficient modules also tend to be more expensive, thus performance does not contain all required information for the actual cost of the electricity production by each module type. Nor does it allow a comparison of payback times. Research on costs of PV systems certainly exists, but indepedently of research on performance.

When designing systems for commercial buildings the system requirements are complex. Optimising for maximum efficiency might require leaving excessive areas around the panels to minimise shading. However, this approach might not offer the best value for money. If for example, the one-off costs such as grid connection, and structural approval are essentially constant, then compromising slightly on shading might actually give a lower cost per kWh or shorter financial payback time.

At present there are no models publicly available which consider all these effects together. The current tendency for system designers is to design PV arrays with spacing for maximum energy production, without detailed analysis of the precise effect on the system economics.

The IKEA International Group has a long term goal of using 100% Renewable Energy in all its stores, distribution centres and IKEA owned factories, under the ‘IKEA Goes Renewable Project’. Recently this has been achieved by purchasing ‘bundled’ renewable power, but the company also wants to generate Renewable Energy on-site, using solar, wind, and biomass [8]. Photovoltaic Power is an attractive option for IKEA, due to the large surfaces available on roofs, facades, and above parking lots.

Perpetual Energy Ltd (PE) has been contracted by the IKEA home furnishings retailer, to develop new processes for the design and implementation of commercial solar photovoltaic systems. The Centre for Renewable Energy Systems Technology (CREST) at Loughborough University is the research partner in the project.

Figure 1: Photograph showing micromorph PV modules on the site in Belgium.

This project is unique in taking a systems approach to solar photovoltaics. This means modelling, monitoring and analysing the system as a whole, and incorporating any interdependencies which may be overlooked by looking at individual parameters in a reductionist way.

TECHNOLOGIES

The PV modules of seven different manufacturers are being installed, including:

- poly-crystalline silicon (pSi),
- mono-crystalline (mSi),
- micromorph (µaSi) silicon (as shown in Figure 1),
- triple junction amorphous (aSi) (as shown in Figure 2)
- CIS (Copper Indium Diselenide).

The systems are being installed on IKEA home furnishings stores at Latitudes from 37° to 54° north.

The sites and Koppen climate zones [9] are:

- Brooklyn, USA
  – humid continental, bordering subtropical.
- Gent, Belgium
  – oceanic.
- Rostock, Germany
  – humid continental
- Seville, Spain
  – Mediterranean.

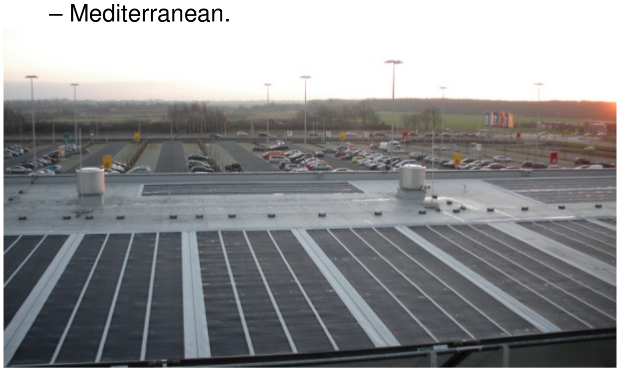

Figure 2: Triple junction amorphous modules on the site in Northern Germany.

The systems will benefit from local feed-in tariffs or other incentives; hence a comparison of 4 different regulatory frameworks and solar incentives schemes will be possible. In particular, the project will compare financial performance between use of building integrated flexible amorphous panels, and the more traditional glass-based modules on elevated frames.

MONITORING SYSTEM

CREST and Perpetual Energy Ltd have developed a new monitoring system to achieve the data accuracy and resolution needed for verifiable research, which cannot be achieved with off the shelf systems.

Data will include:
DC electrical parameters
AC electrical parameters
Environmental variables

Data from each of the four sites in the programme is fed back to CREST in Loughborough using secure daily downloads - Figure 3 below.

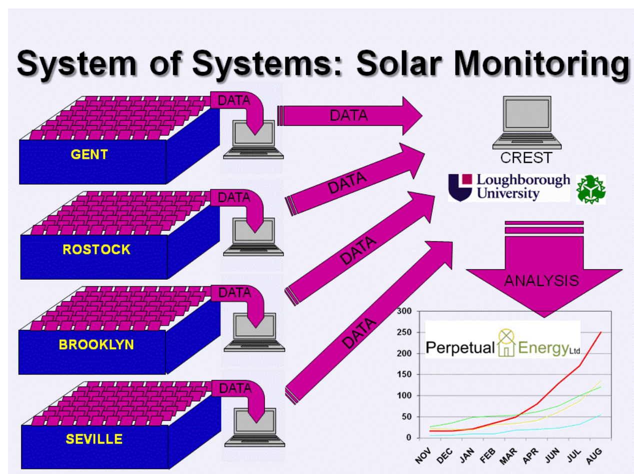

Figure 3: System of Systems (SoS): The CREST/PE worldwide solar PV data management system.

CREST is developing new database algorithms to process the vast amount of raw data and generate regular performance reports.

At each site, data from all the CREST/PE weather and power monitoring units is transmitted to a central site database server via an Ethernet network (Figure 5 below). Battery back-up is provided for the network to provide high data availability.

Figure 4: Sensors measuring horizontal and plane-of-array irradiance and spectral distribution.

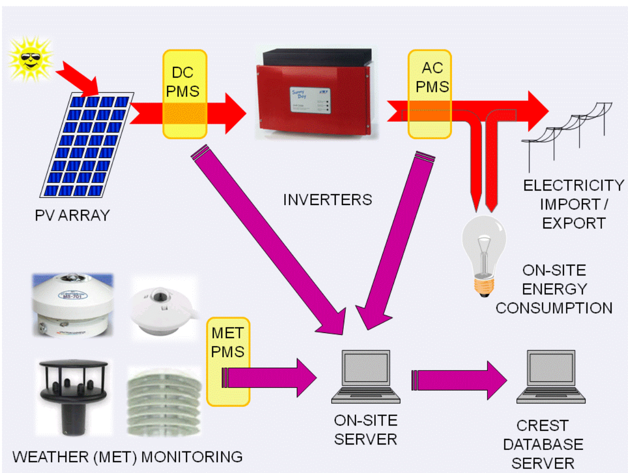

Figure 5: Monitoring system- data flows.

The DC monitoring units record current, voltage and module temperature for every string of PV modules in the ~200kW systems.

The DC monitoring unit incorporates surge protection and fuses or diodes as appropriate, short term data buffering is also provided. The monitoring unit can monitor up to 16 strings and 2 inverters.

AC Power Monitoring Units (Figure 6 below) are installed between the inverters and the AC Distribution Board, these monitor the AC Voltage and current form each inverter. Hence efficiency of the inverter can be analysed with respect to for example module power point or ambient temperature.

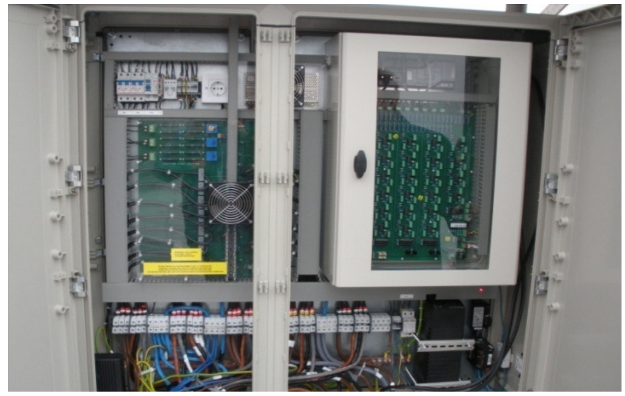

Figure 6: CREST / PE AC Power Monitoring Unit.

In addition to the high accuracy CREST/ PE monitoring system, the inverter manufacturer's off-the- shelf monitoring system is also used for instant access condition monitoring and fault diagnosis. In addition, a detailed real-time display of key parameters is provided at the store front for viewing by store visitors and customers.

The following meteorological variables are also measured:

- High level wind speed & direction
- Array level wind speed & direction
- Ambient temperature
- Relative humidity
- Module temperature (for each string)
- Optical parameters will be measured in plane of array and horizontally:
- Solar spectrum
- Irradiance (Pyranometer and reference cell)

Hence energy production by all the modules can be accurately measured, and used to validate current models for energy production, for the key technologies.

CONCLUSIONS

A system for developing a detailed multi-parameter analysis has been developed. An extensive measurement campaign has been set up and installation is ongoing.

The PV systems at Rostock & Gent have now been generating electricity for use on site for 4 months, with all generated electricity exported to the local electricity network.

Full database operation for all 4 sites is expected to be completed within 6 months. Data will be recorded every 1 second for 24 months. Initial results from the programme will be published later this year, with news reports at www.perpetualenergy.co.uk

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