Numerical Analysis of the Impact of Environmental Conditions on BIPV Systems, an Overview of BIPV Modelling in the SOPHIA Project 5AV.2.42

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CONTEXT

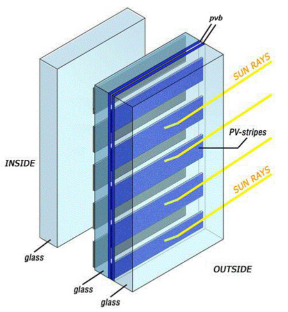
The advantage of BIPV systems is to obtain a multifunctional building envelope by adding functions such as weather impact protection in addition to electro-technical properties. Based on the results of the BIPV task of the SOPHIA research program, the main purpose of this work is to numerically analyze the optical, the thermal and the electrical behavior of BIPV systems according to the environmental conditions. The first step of this project is a critical overview of existing numerical models.

BIPV systems at Hong Kong (Zhou et al, 2007)

OPTICAL MODELLING

The simulation of the irradiance on the BIPV module surface (especially for vertical systems) is more challenging than for conventional PV systems. Many parameters are to consider:

- High incidence angles, albedo impact, shading impact (more frequent due to surrounding objects),
- For complex BIPV structures like **PVSHADE** (see picture), the dependence of the irradiance on the incidence angle, at least for the direct sunlight,
- The spectral influence estimation at vertical orientations, a further problem as the blue-shifted diffuse irradiance fraction is higher,
- For some BIPV applications as sunshading, daylighting, the amount of light reflected or transmitted from the element.

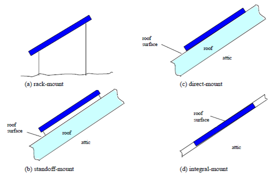


The PVSHADE module. The PV layers of two a-Si:H modules are ablated into stripes with special lasers and then laminated together (Sprenger et al, 2011)

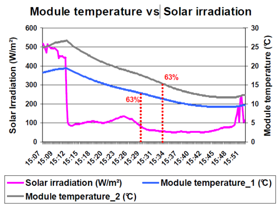
THERMAL MODELLING

The PV-cell temperature of BIPV modules is the main difference compared to standard-PV modules and conventional building products. The aim of these models is to express PV cell temperature as a function of pertinent weather variables and irradiation yields.

Simple	**NOCT, INOCT, NOST**
	• no consideration of variable environmental conditions
Implicit	**Sauer, Sandia, EN61853-2**
	• emperical determined parameters • quite easy and fast, but not accurate • ~locations, environment conditions, module configurations
Explicit	**Thermal equivalent methods**
	• ~heat transport of material, T_{NOCT}, etc • no dynamic behaviours ~heat capacity, surface temperature)



Four typical mounting schemes for PV arrays (Barker et al, 2003)

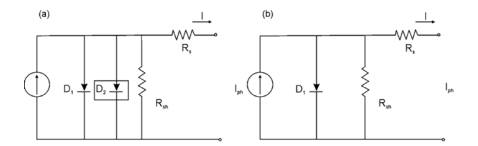


Time-delayed operating temperatures to fluctuated solar irradiation (Misara, 2010)

ELECTRICAL MODELLING

I-V PARAMETERS MODELS

- One diode model seems to be sufficient for PV systems under solar radiation higher than 100W/m².



Equivalent circuit of the model of (left) two diode and (right) one diode. (Hernandez et al, 2011)

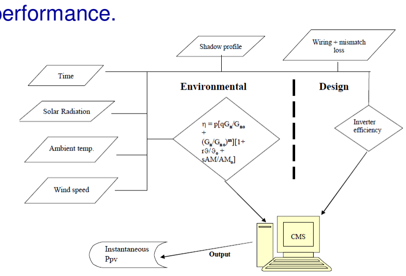
- Main differences between existing models: variables used in the correlations permitting to obtain the IV curve characteristics.

- Some developed models (Zhou et al, 2007) (Hernandez et al, 2011) for BIPV systems show reliability under real conditions.

EFFICIENCY MODEL

- Need to base the electrical balance equations on parameters depending on the PV module technology and environment.

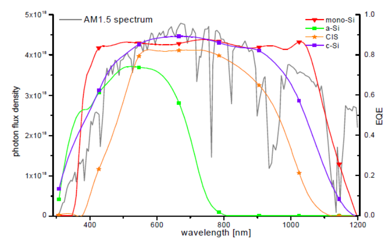
- Lam et al, in 2006: global irradiance is the most critical parameter affecting the BIPV performance.



Schematic diagram of the BIPV dynamic model (Lam et al, 2006)

SPECTRUM RESPONSE

- Module efficiency of each PV technology is different based on its own spectrum response, with respect to variation of air mass and corresponding spectral distribution of solar irradiation.



Spectral response for different PV modules (Krawczynski et al, 2010)

ANALYSIS OF RESULTS

CEA INES developed in TRNSYS software a 2D steady-state model of PV modules integrated into roof. AIT uses different approaches of modelling, for example a stochastic volumetric path tracing of spectral light or 1D and 3D thermal modeling of convective, radiative and conductive cooling. Fraunhofer ISE realized a steady-state temperature model for BIPV systems, including the dependence on the operation mode. A real-time power balance model is developed at Fraunhofer IWES in holistic approach. ENEA takes care of the BIPV configuration and categories of integration. This literature overview will permit to evaluate the accuracy and the relevance of these models by using numerically and experimentally ICT conditions and finally benchmark.