Energy Loss Due to Irradiance Enhancement

5AO.6.3, 26th EU PVSEC, Hamburg (Germany)
5. September 2011

Mike Zehner, Toni Weigl, Matthias Hartmann, Stefan Thaler, Oliver Schrank, Moritz Czakalla, Bernhard Mayer, Tom Betts, Ralph Gottschalg, Klaus Behrens, Gert König-Langlo, Bodo Giesler, Gerd Becker, Oliver Mayer
Survey on the Talk ‘Energy Loss Due to Irradiance Enhancement’

1) **What is Irradiance Enhancement?**
   Correlations and Profiles of the Effect

2) Improvements of the data base and Internationalisation

3) Relevance for PV-systems

4) **Wrap-up and next steps**
Clear Sky\(^{(1)}\) Conditions on the Reference Day: 27 July 2009 versus Irradiance Enhancement\(^{(2)}\) Conditions on the: 8 July 09

\(\text{CS: Clear Sky}\)  
\(\text{IE: Irradiance Enhancement}\)  
\(\text{(3) Meteorological Institut of the LMU Munich}\)

\(\text{New Munich Trade Fair – global horizontal irradiance (CMP 21 from Kipp & Zonen)}\)
IE-Effect on the Reference Day: 30 May 2009

In black: Measurement data of the New Munich Trade Fair
www.sev-bayern.de

In red: libRadtran calculations
www.libradtran.org

G_{hor \text{ measured}}
G_{hor \text{ Clear Sky calculated}}
Data Mining - Baseline Surface Radiation Network (BSRN), Europe

Climatic Zones, Europe

II-1 Maritime boreal climates
- Lerwick (GBR), SaR\(^2\): 1 min

II-2 Maritime climates with mild winters
- Camborne (GBR), SaR: 1 min

II-3 Submaritime climates
- OT Lindenberg (GER), SaR: 1 min
- Meteo Institute Munich (GER), SaR: 1 min
- New Munich Trade Fair (GER), SaR: 1 sec\(^3\)

II-4 Subcontinental climates
- Toravere (EST), SaR: 1 min

III-1 Mediterranean climates with humid winters and dry summers
- Carpentras (FRA), SaR: 1 min

2) SaR: Sampling rate
3) Analysis of the measured values takes the sampling theorem into account
Gretchen Question: ‘Are we talking about relevant energy content?’
Exemplary BSRN Site OT Lindenberg: IE Energy above CS

Location: Lindenberg (GER), BSRN(1)

(1) Source: [BSRN-2011]
Table 1: Final energy yield and energy due to IE incidents for the year (1995 – 2004, Lindenberg)

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Final Yield in kWh/(m²a)</td>
<td>1061</td>
<td>1016</td>
<td>1132</td>
<td>1044</td>
<td>1114</td>
<td>1048</td>
<td>1029</td>
<td>1024</td>
<td>1191</td>
<td>1075</td>
</tr>
<tr>
<td>IE Energy in kWh/(m²a)</td>
<td>237</td>
<td>254</td>
<td>375</td>
<td>277</td>
<td>278</td>
<td>233</td>
<td>273</td>
<td>229</td>
<td>270</td>
<td>294</td>
</tr>
<tr>
<td>in %</td>
<td>22.3</td>
<td>25.0</td>
<td>33.1</td>
<td>26.5</td>
<td>24.9</td>
<td>22.2</td>
<td>26.6</td>
<td>22.3</td>
<td>22.6</td>
<td>27.3</td>
</tr>
<tr>
<td>IE Energy above CS in kWh/(m²a)</td>
<td>13</td>
<td>16</td>
<td>23</td>
<td>19</td>
<td>17</td>
<td>15</td>
<td>18</td>
<td>15</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>in %</td>
<td>1.26</td>
<td>1.53</td>
<td>2.05</td>
<td>1.81</td>
<td>1.50</td>
<td>1.39</td>
<td>1.74</td>
<td>1.42</td>
<td>1.31</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Exemplary BSRN Site OT Lindenberg: IE Energy above CS

Gretchen Question: ‘Are we talking about relevant energy content?’
Site Assessment - OT Lindenberg: IE Energy in Absolute Values

Location: Lindenberg (GER), 2004, BSRN\(^{(1)}\)


\(^{(1)}\)Source: [BSRN-2011]
Site Assessment - OT Lindenberg: IE Energy in Absolute Values

Location: Lindenberg (GER), 2004, BSRN\(^{(1)}\)

\(\text{Irradiation in } \text{W/(m}^2\text{•a)}\)

Air Temperature in °C

Energy in %

Source: [BSRN-2011]


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Mike Zehner, Munich University of Applied Sciences, Work Group Degree Course Renewable Energies, mike.zehner@hm.edu
Site Assessment - OT Lindenberg: IE Energy in Absolute Values

Location: Lindenberg (GER), 2004, BSRN\(^{(1)}\)


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Site Assessment - 5 Representative European BSRN Locations

Head-to-head comparison averaged 2001-2004\(^{(1)}\)

- Lerwick
- Camborne
- Lindenber
- Toravere
- Carpentras

Final yield in kWh/(m²a) vs. Energy fraction in % of FY vs. IE fraction above CS in % of FY

\(^{(1)}\)Source: [BSRN-2011]
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Modelled Operational Performance - Daily Profiles in Scatter Plots (2)
IE- and CS-Reference Days | Reference Module #1: Monocrystalline

Parameter Definitions
(1) Normalised DC current = \( \frac{I_{DC,MPP}}{I_{nom}} \)
(2) Normalised DC performance = \( \frac{P_{DC,MPP}}{P_{Nom}} \)

Software Modelling with
insel 8 – Release 8.01
Graphical programming language
www.insel.eu

MPP-Operating Points
Modelled Operational Performance - System Considerations

Initial Analysis on the System Response

- Hardware modelling with a Solar Generator Simulator (SGS)
- 30 min IE Test Profile (rich in IE)
- Different modules / inverters - here: thin film modules with a transformerless inverter
- Sizing Ratio variations, here: SR = 0.83 | 1 | 1.11 | 1.25 (IE characteristics, interconnections)

- In dark red: target values of SGS
- In dark blue: inv response, SaR: 10 Hz
- In light red: inv response, SaR: 0.2 Hz
- Dotted line in black: power dissipation curve

(1) SGS: Solar Generator Simulator
(2) Parameter definition: Sizing Ratio: \( SR = \frac{P_{PV-STC}}{P_{INV-NP}} \)
(3) SaR: Sampling rate
Wrap-Up and Next Steps

- CS days in July do not have the highest performance values. STC conditions are visible operating points.
- Lindenberg, energy yield above CS: 1.58% | in total: 25.3%
- Modules: 30% more power than under STC
- Inverter: is current MPPT sufficient?
- System: cue IE-effect and Sizing Ratio (Poster 5BV.2.14)

IE - Effect > Understanding the effect
  » Modelling of the radiative transfer
  » Spatial dispersion and dynamics of enhancements

IE - Sites > Geographical dispersion (North America / Pacific Area)

IE - Systems > Data mining and modelling
  » Adjustment of (site-specific) IE-test profiles
  » Modelling with a solar generator simulator
  » Modelling with the simulation language INSEL
Thanks to All Colleagues Involved in this Project

Toni Weigl, Matthias Hartmann, Stefan Thaler, Oliver Schrank, Moritz Czakalla, Bernhard Mayer, Tom Betts, Ralph Gottschalg, Klaus Behrens, Gert König-Langlo, Bodo Giesler, Gerd Becker, Oliver Mayer

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- Werner Knaupp, PV-Plan
Thank you very much for your time, your interest and your attention.

Kick-Off for Questions ...