



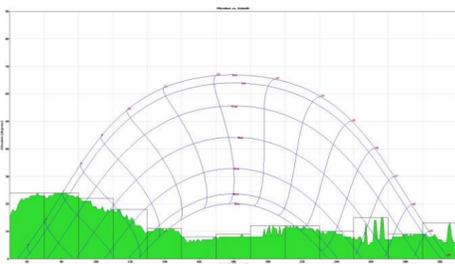
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INTRODUCTION

Photovoltaic system degradation and the improvement of degradation models receives an increasing amount of attention in the last years. The majority of publications focuses on values such as maximum power or performance ratio. Although it is convenient to relate performance losses to these values, the results fail to provide information about the root-causes of PV-system degradation. The study of the correlations between current and irradiation as well as voltage and temperature over time might help to better detect the occurrence, and to evaluate the severity, of specific degradation modes. In this work the impact of the exposure of PV systems of 8 different technologies in operation for more than 7 years under a temperate climate (Bolzano/Italy) is evaluated based on the normalized I_{MPP} and V_{MPP} trends.

PV INSTALLATION

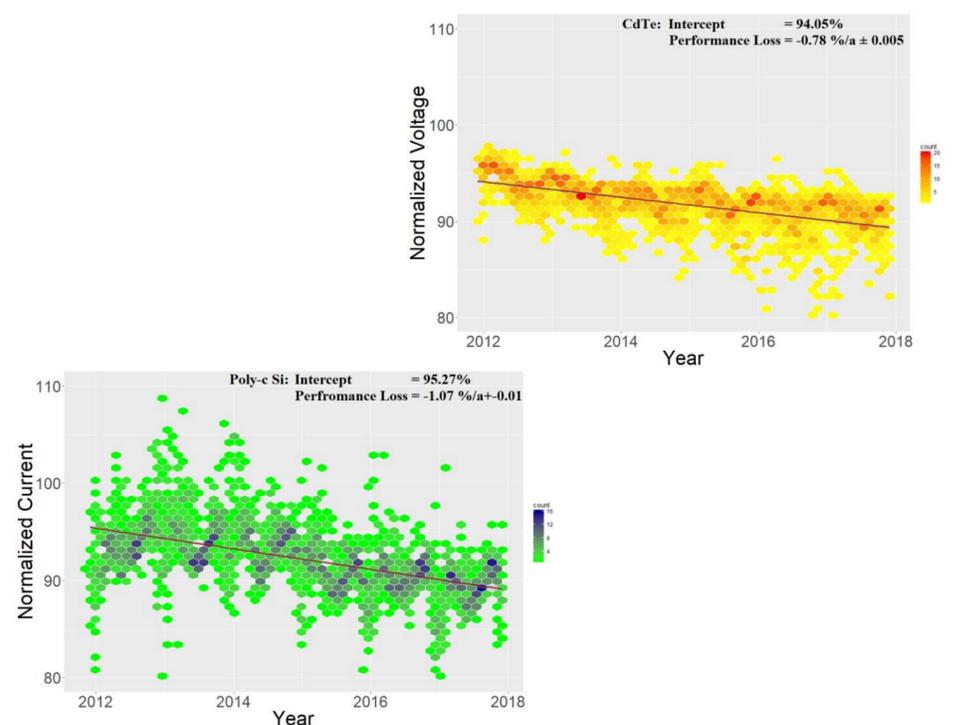
- Climate (Köppen-Geiger):
 ➤ temperate climate
 Mounting position:
 ➤ free standing
 Installation type:
 ➤ Rack
 Azimuth:
 ➤ 188.5° (SSW)
 Installation slope:
 ➤ 30°
 Mountainous surroundings



OVERVIEW PERFORMANCE LOSSES

Technology	I_{PL}	V_{PL}	P_{PL}
mc-Si	-0.82%/a +0.01	0.09%/a +0.002	-0.76%/a +0.01
pc-Si	-1.07%/a +0.01	-0.03%/a +0.003	-1.02%/a +0.01
micromorph	-1.64%/a +0.02	-0.17%/a +0.004	-1.52%/a +0.01
1j-a-Si	-1.18%/a +0.02	-0.24%/a +0.01	-1.31%/a +0.01
3j-a-Si	-1.16%/a +0.02	-0.09%/a +0.003	-1.16%/a +0.02
HIT	-1.30%/a +0.01	-0.13%/a +0.003	-1.36%/a +0.01
CIGS	-1.88%/a +0.02	-0.93%/a +0.02	-2.33%/a +0.02
CdTe	-1.88%/a +0.02	-0.78%/a +0.005	-2.30%/a +0.02

PLOTS CURRENT / VOLTAGE



USED FORMULAS NORMALIZED VALUES

$$I_{NORMALIZED} [\%] = \frac{I_{G,T_{corr}}}{I_{STC} * n_{modules_{parallel}}}$$

$$V_{NORMALIZED} [\%] = \frac{V_{T_{corr}}}{V_{STC} * n_{modules_{series}}}$$

$$P_{NORMALIZED} [\%] = \frac{P_{T,G_{corr}}}{P_{STC} * n_{modules_{series}} * n_{modules_{parallel}}}$$

$$T_{cell} = T_{amb} + (NOCT - T_{NOCT}) * \frac{G}{G_{NOCT}}$$

$$T_{NOCT}=20^{\circ}C, G_{NOCT}=800W/m^2, W=1m/s$$

$$P_{T,G_{corr}} = P_{MEAS} * \frac{G_{STC}}{G} * \frac{1}{[1 + \gamma * (T_{cell} - T_{STC})]}$$

$$V_{T_{corr}} = V_{MEAS} * \frac{1}{[1 + \beta * (T_{cell} - T_{STC})]} \quad I_{G,T_{corr}} = I_{MEAS} * \frac{G_{STC}}{G} * \frac{1}{[1 + \alpha * (T_{cell} - T_{STC})]}$$

[1,2]

PERFORMANCE LOSS CALCULATION

Applying Seasonal-Trend Decomposition using LOESS on normalized data set

Extract trend line: trendnormalized value

Linear regression (trendnormalized value ~ n of days) → $y = Slope_{loss} * x + Intercept$

$$Performance\ loss = 365.25 * Slope_{loss}$$

$$Uncertainty = Standard\ deviation * 365.25\ (Conf.\ interval\ 68\%)$$

REFERENCES

- [1] S. Ransome and J. Sutterlueti, "Using the Loss Factors Model to Improve PV Performance Modelling for Industrial Needs," in *29th EU PVSEC*, Amsterdam, 2014
- [2] G. Belluardo et al., "Novel method for the improvement in the evaluation of outdoor performance loss rate in different PV technologies and comparison with two other methods," *Solar Energy*, vol. 117, pp. 139-152, 2015

CONCLUSIONS

It is visible that a degradation throughout all technologies takes place. For all systems under observation, a decreasing current is the main driver for the performance loss, with current loss rate values between 0.7% and 1.9% per year. The main drivers for the decrease in MPP current and a resulting reduced power output are most probably a degradation in the short circuit current combined with a lowered fill factor.

While analyzing the voltage behavior, a smaller decrease, compared to the current, is visible for most technologies, crystalline silicon systems being an exception.

Further studies including the evaluation of I_{sc} , V_{oc} and FF might lead to a better understanding of the degradation mechanisms taking place.

ACKNOWLEDGMENT

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