AI4PV's ultimate goal is to increase the operational performance of PV plants through the development of Digital Twins combined with Data Analytics of plant signals

AI4PV Validation results

The AI4PV solutions, extensively described in D2.2, D2.3, D3.1, D3.2 and D3.3 have been tested and validated over more than one year using operational data of a real PV park.

AI4PV solutions make up three modules:

- *Descriptive analytics-module:* PV plant Digital Twin (DT) for fault and failure detection and diagnosis.
- *Prescriptive analytics module for O&M:* PV plant data analytics for fault and failure detection and diagnosis.
- *Cost-optimised predictive maintenance module:* PV plant O&M recommendation system.

The **first module** concerns the study of a **DT tool for early fault and failure detection and diagnosis of PV plants components** (PV panels, Inverters, power transformers). Based on electrical data and meteorological data, a DT system will help the supervisor of the plant to detect the most common problems that may happen in solar parks.

The **second module** concerns the study of **Artificial Intelligence (AI), Machine Learning (ML) solutions for early fault detection, and the diagnosis of PV plants**. Based on historical data, AI-ML algorithms will complement DT in the detection of faults and failures in PV farms.

The **third module** envisions the development of a **recommendation system to support the O&M team of PV plants**. The combination of DT and AI is key for the root cause analysis and for the punctual identification of abnormal conditions in the PV park. Based on Root Cause analysis, a recommendation engine based on Reinforcement Learning will **recommend the best intervention to the O&M teams, that leads to the highest Return on Investment.**

In this press release some of the KPIs are presented.

RMSE EMPIRICAL AND REPRODUCED I-V CURVE

This KPI represents the difference between the empirical I-V curve provided in the datasheet of the PV module and the reproduced curve through the DT modelling. Both curves, the one from the datasheet and the one produced by the DT, are reported in Figure 1 for different levels of irradiance.

To evaluate the effectiveness of the proposed DT, the RMSE between the empirical and the reproduced I-V curve is evaluated. The RMSE is calculated as per Equation 1:

$$RMSE = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(I - I_i)^2}}{Isc}$$ **EQUATION 1**

Where:

- $I_i, \hat{I}_i$ are the real and modelled output current of the PV module.
- N is the number of samples of the empirical I-V curve
- Isc it's the short circuit current of the PV module

The RMSE value stands at 0.18, much lower than its target value (0.6).

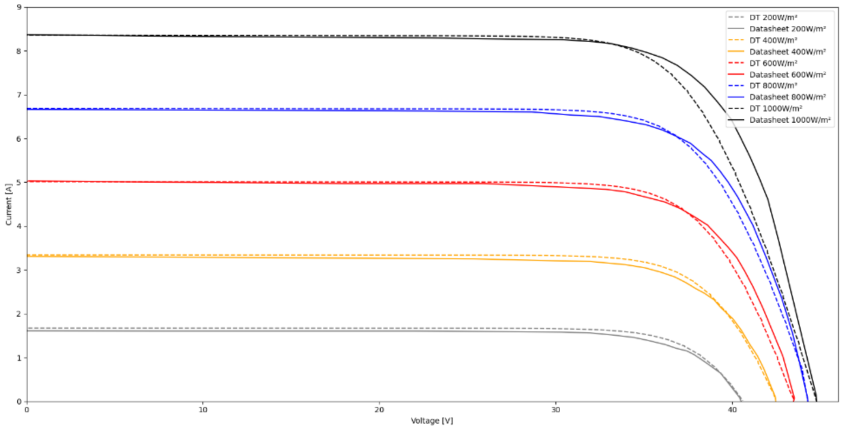

FIGURE 1: REPRODUCED AND EMPIRICAL I-V CURVES

Fault Detection accuracy

This KPI describe the accuracy of the fault detection and classification algorithms developed within the AI4PV project. It is calculated via Equation 2.

$$FDA = \frac{N\_true\_positive\_state}{N\_true\_positive\_state + N\_false\_positive\_state}\%$$ **EQUATION 2**

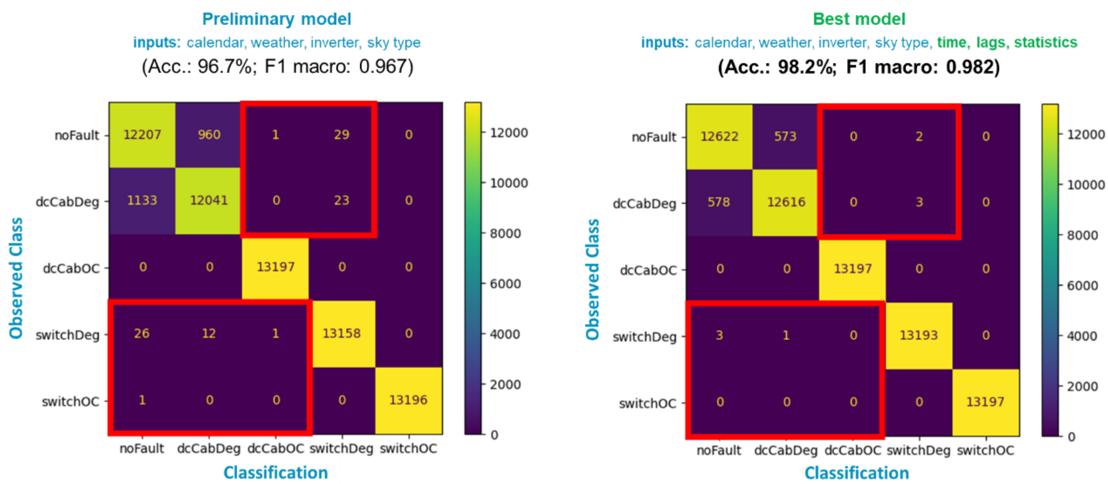

FIGURE 2: FDA ML ALGORITHMS FOR THE INVERTERS

Figure 2 shows the confusion matrix of the ML algorithms for the inverters. As it can be seen, after some feature engineering the AI4PV solutions can achieve an accuracy of 98.2%, much higher than the target value (80%).

Similarly the ML algorithms for fault detection and classification for power transformer, shown an accuracy of almost 97% (Figure 3), still higher than the target value (80%).

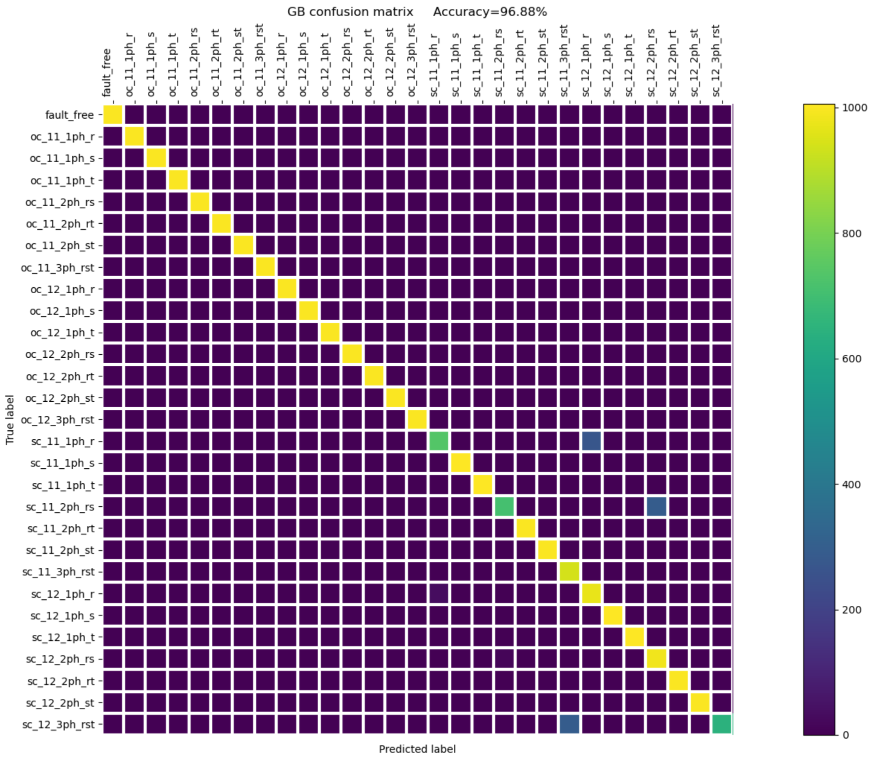

FIGURE 3: FDA ML ALGORITHMS FOR POWER TRANSFORMERS

CBA: SOILING USE CASE

In order to evaluate the effectiveness of the proposed solutions, particularly the cleaning optimiser, a Cost Benefit Analysis is performed to assess potential benefits due to the AI4PV methodology.

The AI4PV cleaning module, its objectives and operations, are extensively described in D3.2 and D3.3.

In order to evaluate and quantify potential benefits, the AI4PV approach is compared against traditional methods. A common strategy is what is called “the threshold-based approach” (hereafter referred as TR-based policy), where PV panels are cleaned whenever the PR is below a certain threshold.

Two options are investigated:

- **Option A**: rain events are not taken into account in the cleaning schedule optimisation.
- **Option B**: rain events are considered and modelled in the optimisation.

AI4PV is an EUROGIA2030 and ITEA4 project part of the EUREKA cluster. This work is financed by the ERDF - European Regional Development Fund - through the Operational Programme for Competitiveness and Internationalisation COMPETE 2020 under the Portugal 2020 Partnership Agreement within project AI4PV, with reference POCI-01-0247-FEDER-111936 – and Spain’s Multi-regional Operational Programme 2014-202, under CDTI Agreement for the project AI4PV, with reference IDI-20201080. International collaborative project EUR 2020058 with the seal of the AI EUREKA CLUSTER

CBA Option A

When performing this option, rain events are not modelled into the optimisation. The cleaning schedule is affected by two main parameters:

1. Cost of cleaning;
2. PR threshold for the TR-based policy.

Having said that, a sensitivity analysis is performed to see the changes in the potential benefits due to these parameters. The results obtained for this option are shown in Figure 4.

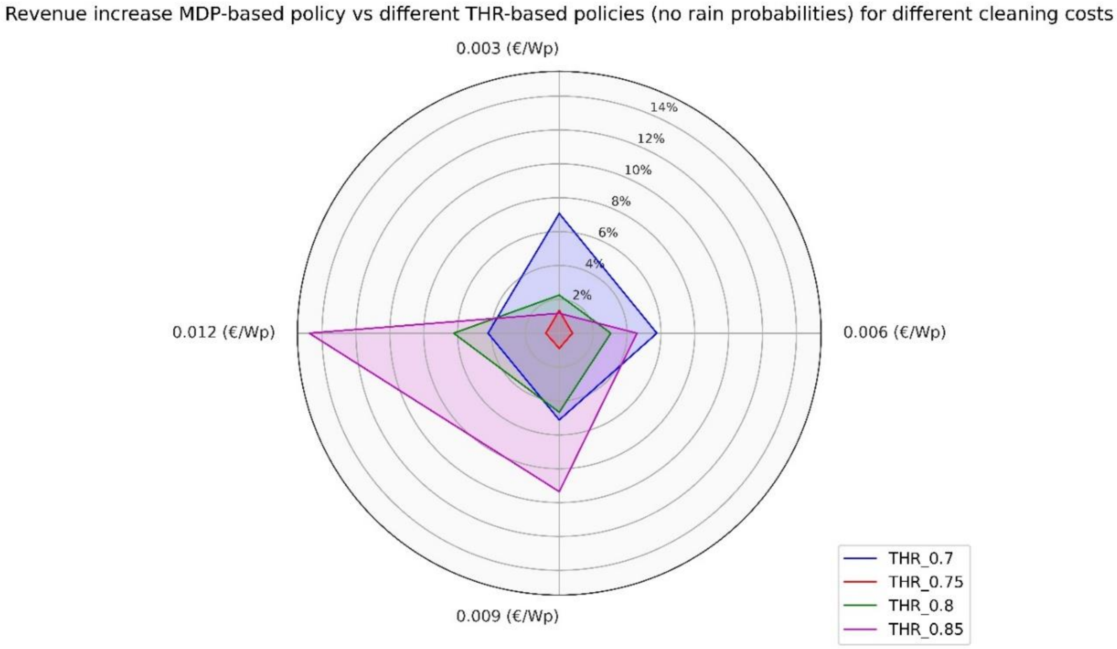

FIGURE 4: OPTION A - CBA AI4PV APPROACH VS TR-BASE POLICY

As it can be seen, **the AI4PV approach brings additional revenues regardless of the cost of cleaning and threshold value, when compared to the TR-based policy**. However, the magnitude of such increase varies according to the level of the cost of cleaning and threshold value. The AI4PV benefits are summarised in Table 1.

TABLE 1: OPTION A CBA SUMMARY

TR value / Cost of Cleaning (€/Wp)	TR=0.7	TR=0.75	TR=0.8	TR=0.85
0.003	7%	1%	2%	1%
0.006	6%	1%	3%	4%
0.009	5%	1%	2%	9%
0.012	2%	1%	6%	14%

CBA Option B

Option B include rain events, and their impact on the PR, into the model. The results obtained for this option are shown in Figure 5.

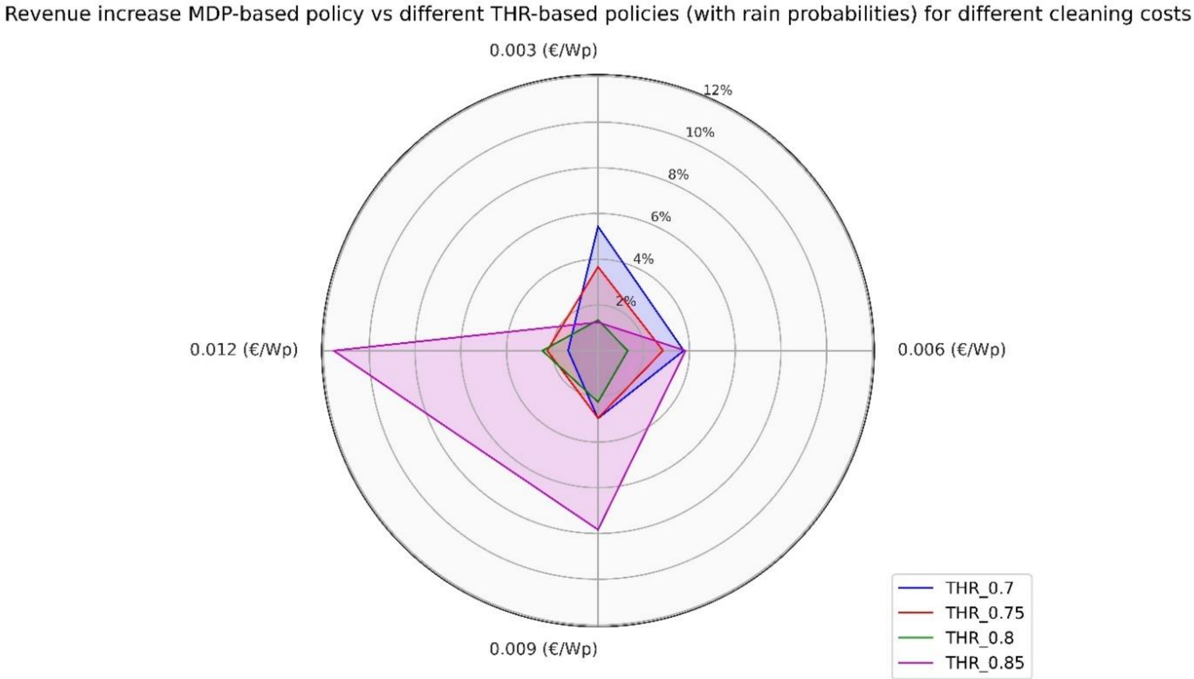

FIGURE 5: OPTION B - CBA AI4PV APPROACH VS TR-BASE POLICY

As it can be seen, even in this case, the AI4PV approach brings additional revenues regardless of the cost of cleaning and threshold value, when compared to the TR-based policy. However, the magnitude of such increase varies according to the level of the cost of cleaning and threshold value. The AI4PV benefits are summarised in Table 2.

TABLE 2: OPTION A CBA SUMMARY

TR value / Cost of Cleaning (€/Wp)	TR=0.7	TR=0.75	TR=0.8	TR=0.85
0.003	5%	4%	2%	2%
0.006	4%	3%	1%	4%
0.009	3%	3%	2%	8%
0.012	1%	2%	2%	12%

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Meet our consortium

EDP NEW

EDP NEW is a subsidiary of the EDP Group with the mission to create value through collaborative R&D in the energy sector. EDP NEW is the coordinator of the project, and will also lead the validation activities, providing both test sites and datasets from existing PV farms for the validation of the AI4PV solutions.

INESC TEC

INESC TEC is an Associate Laboratory with 35 years of experience in R&D and technology transfer. In AI4PV, it contributes with the development of root-cause analysis and intelligent maintenance strategies for PV plants.

ISOTROL

Isotrol is an ICT company specialized on services and solutions for utility-scale renewable energy generation, with over 37 years' experience. In AI4PV Isotrol will lead the conceptual definition of the project as well as the design, implementation and validation of the Digital Twin of photovoltaic plants

AI4PV in a nutshell

Subject	Duration
Development of AI tools to enhance O&M of PV farms	**24 Months (July 2021-June 2023)**
Budget	Funding
813 k€	**ERDF**
Leader	Partnership
EDP NEW	**3 EU partners – 2 Countries**