

Strategies for Early Fault Detection and Diagnostics

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- Observed system losses
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Introduction



3E timeline



1999

3E foundation
as a spin-off
of IMEC

2010

Launch of our
digital journey

2014

Launch of
Solar Data
Services

2020

Surpassing
10 GW of
connected
assets

2021

Launch of
Wind Analytics
LivLiner
Inside

1999 - 2007

Organic
growth,
international
presence

2012

Launch of our
digital twin
performance
model

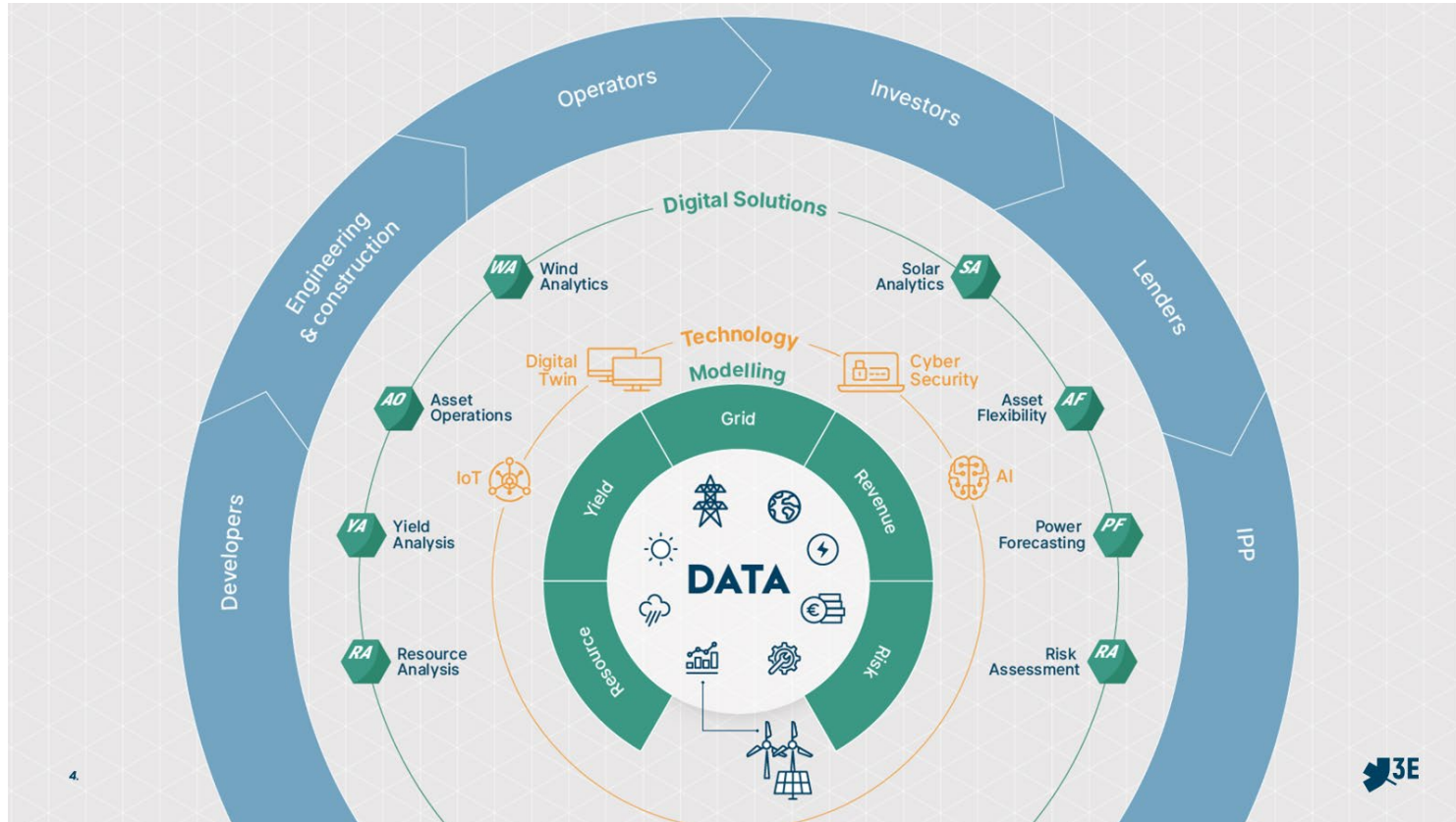
2017

Launch of
Solar Analytics
& Sensor
Check

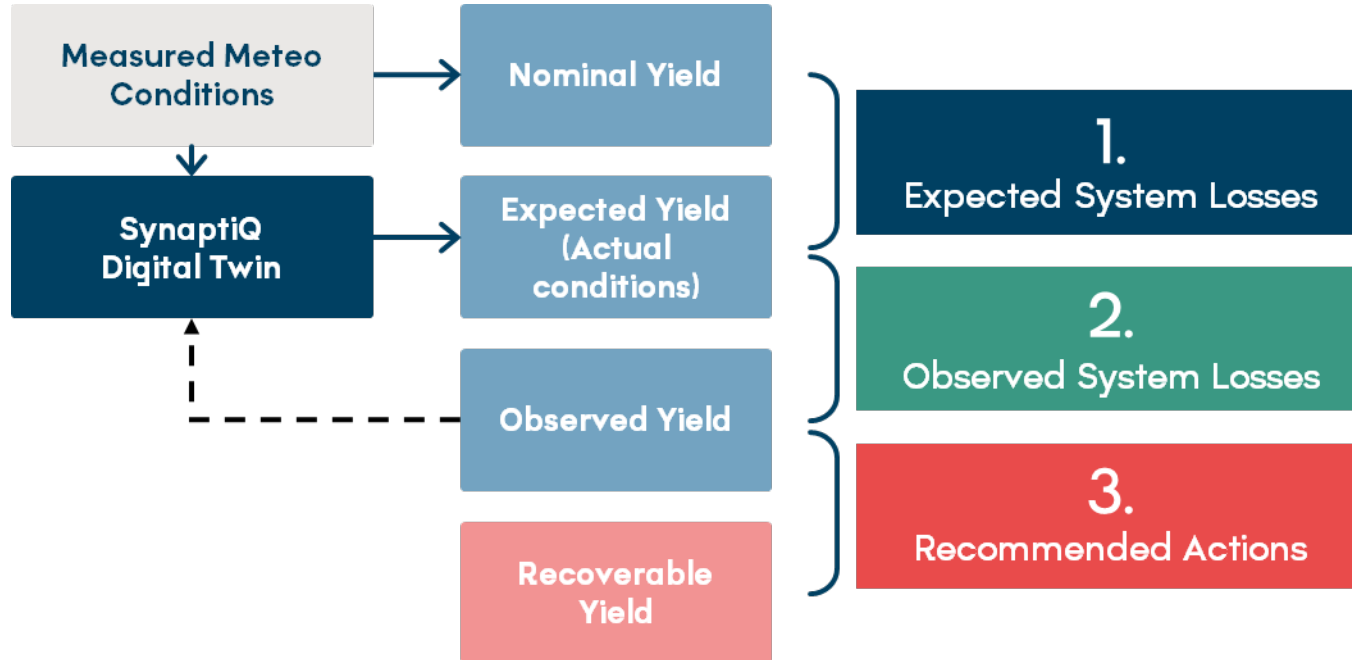
2021

Launch of
3E's digital
platform
SynaptiQ

3E digital solutions



From meteorological data to recommended actions



Expected System Losses



SynaptiQ Simulation Model 2.0.



$$P_{ac} = ILM * \sum_{inverter-inputs} I_{mpp} * V_{mpp} * number - of - strings * modules - per - string$$

where:

- ILM is the Inverter loss modifier
- I_{mpp} is the Module MPP current
- V_{mpp} is the Module MPP voltage

The module MPP current is simulated using following formula:

$$I_{mpp} = I_{mpp,ref} * G_{poa} / G_{STC} * SHM * SLM * IAM * SMM * MQM * DLM$$

where:

- $I_{mpp,ref}$ is the reference MPP current at Standard Test Conditions
- G_{poa} is the irradiance in the plane-of-array
- G_{STC} is the reference irradiance at Standard Test Conditions (= 1000 W/m²)
- SHM is the shading loss modifier
- SLM is the soiling loss modifier
- IAM is the incidence angle modifier
- SMM is the spectral mismatch modifier
- MQM is the module quality modifier
- DLM is the degradation loss modifier

The module MPP voltage is simulated using following formula:

$$V_{mpp} = V_{mpp,ref} * TMM * IMM * DCM$$

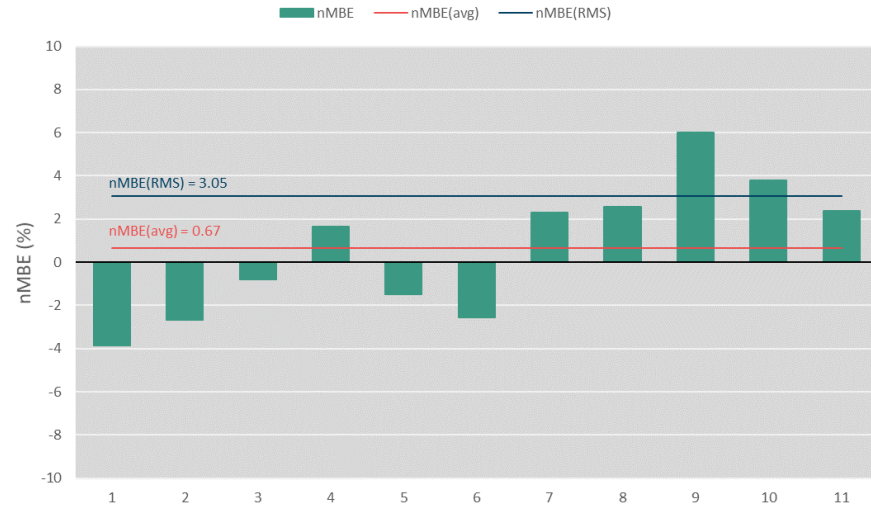
where:

- $V_{mpp,ref}$ is the reference MPP voltage at Standard Test Conditions
- TMM is the temperature model modifier
- ILM is the irradiance model modifier
- CLM is the dc cable loss modifier

Simulation Model Validation (1)



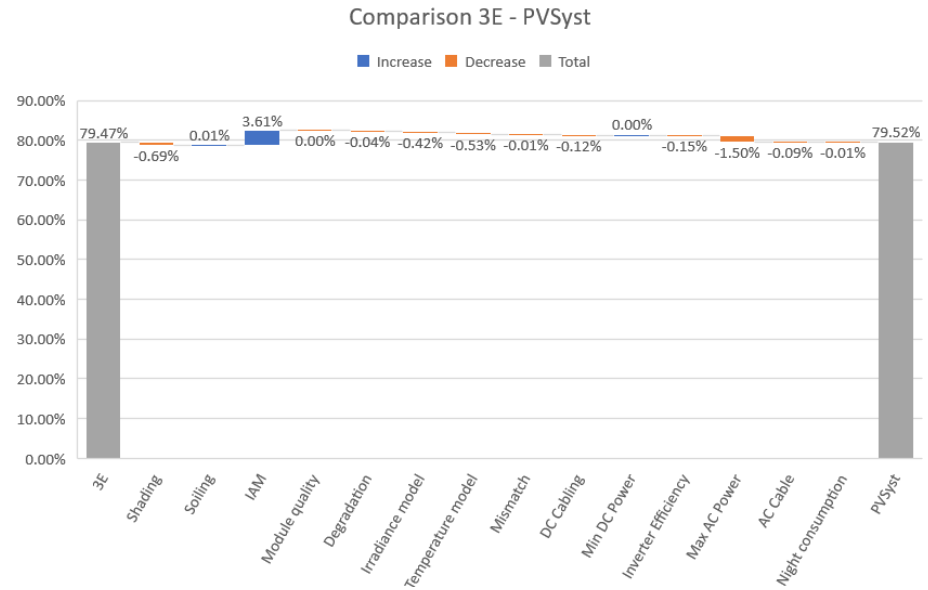
- Validation against operational plants
 - 11 selected well-operating plants
 - 15-min granularity
- Dependent on
 - Measurement accuracy
 - Operational issues
- White paper upcoming



Simulation Model Validation (2)



- Validation against PV Syst
- Various projects
 - rooftop
 - ground-based
 - Single-axis tracker
- Each loss component
- Dependent on assumptions



Observed System Losses

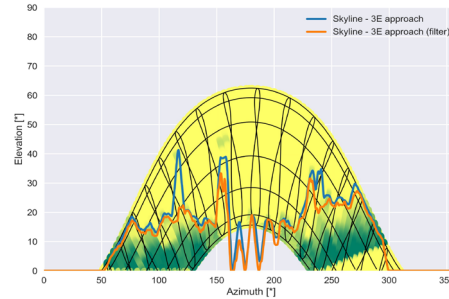


Detailed loss analysis



Shading

- From data
- Skyline
- Solar access



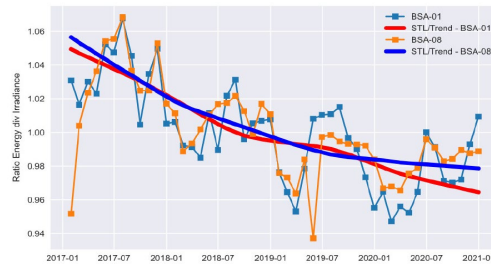
Soiling

- Soiling rate
- Cleaning event
- Residual



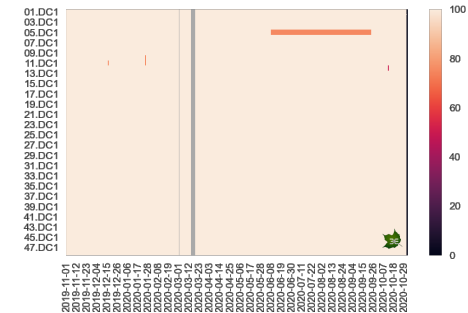
Degradation

- Statistical approaches
- Degr. rates
- Warranties

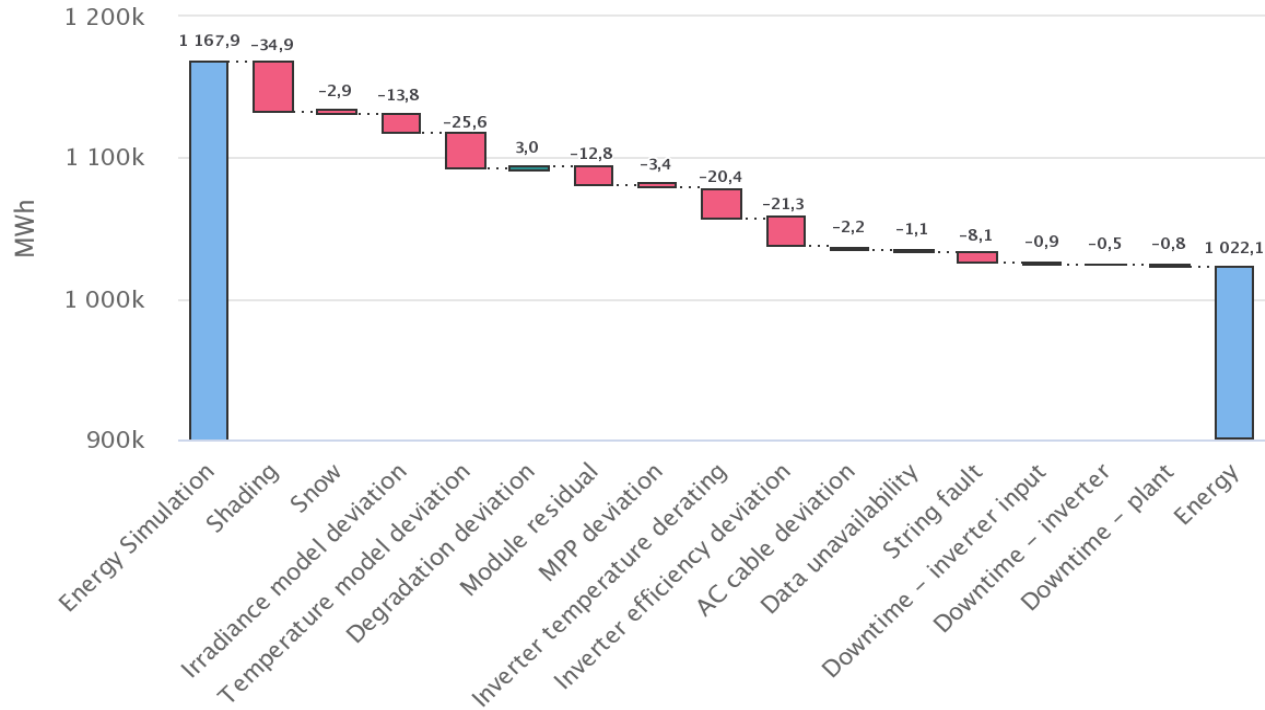


String Failure

- Daily calc.
- Failure duration
- Fast detection



Automated performance loss identification



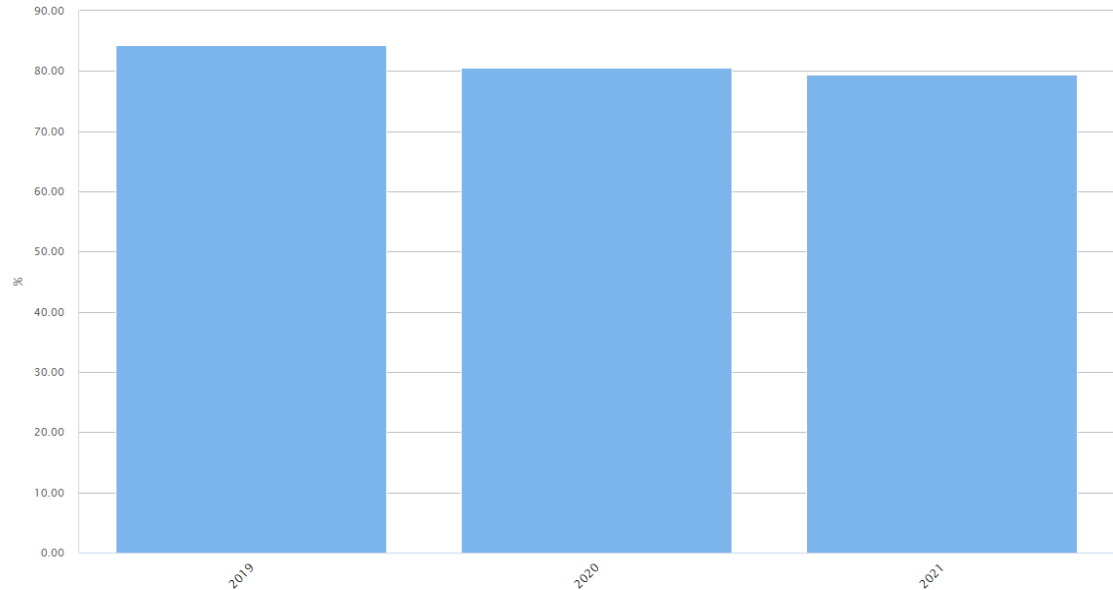
Example



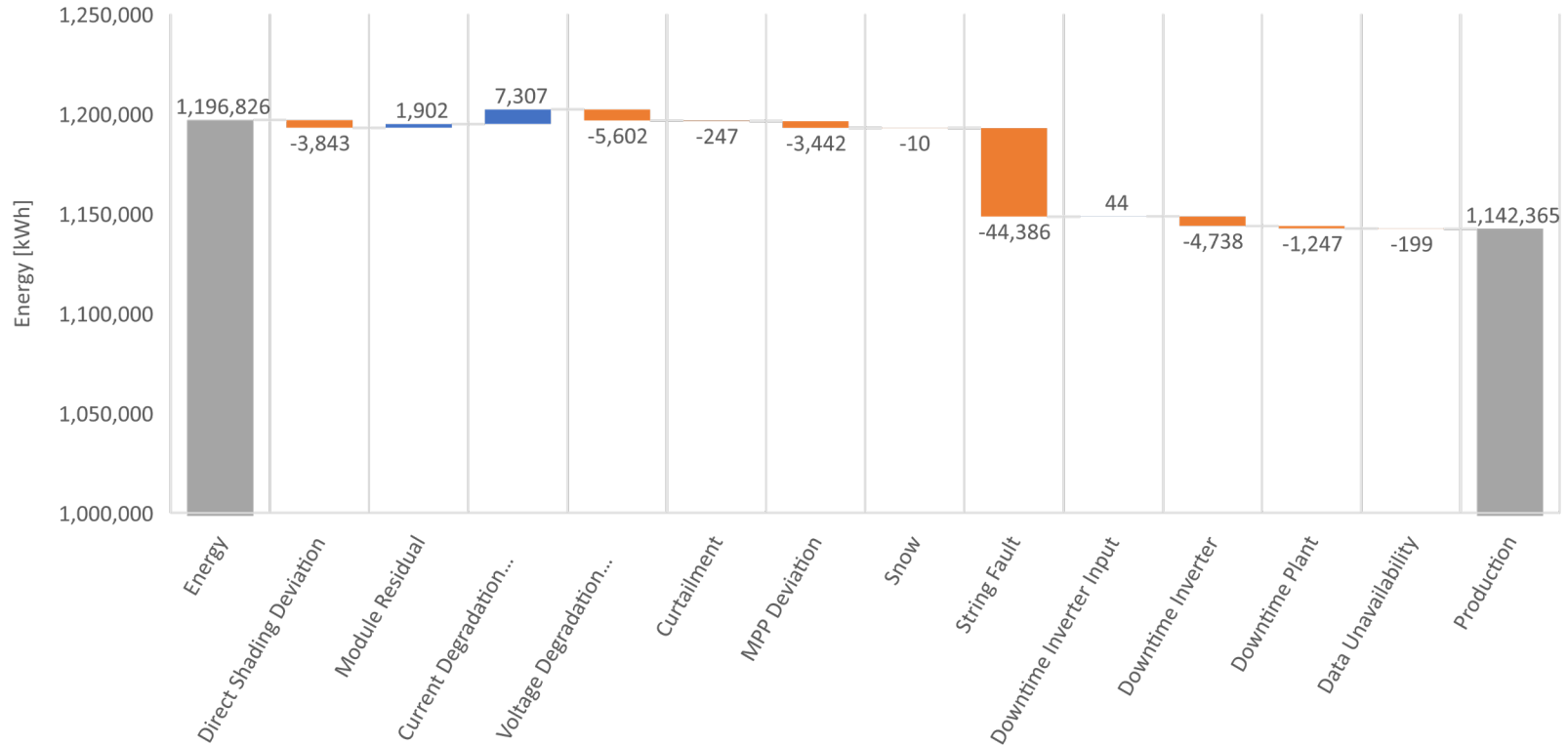
Example



- Large rooftop installation
- 1,39 MWp
- Rapidly declining PR



Yearly loss breakdown



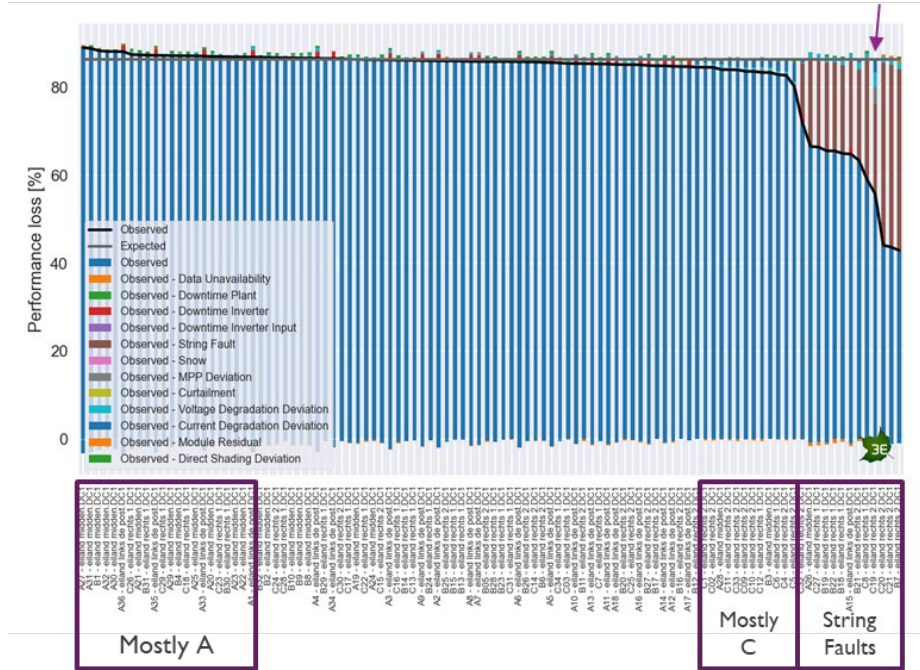
Loss breakdown – inverter level



C19

- Observations

- Area A performs best
- Higher current degradation in area C
- 16 string faults, mostly in area B and C



Validation: drone inspection (1)



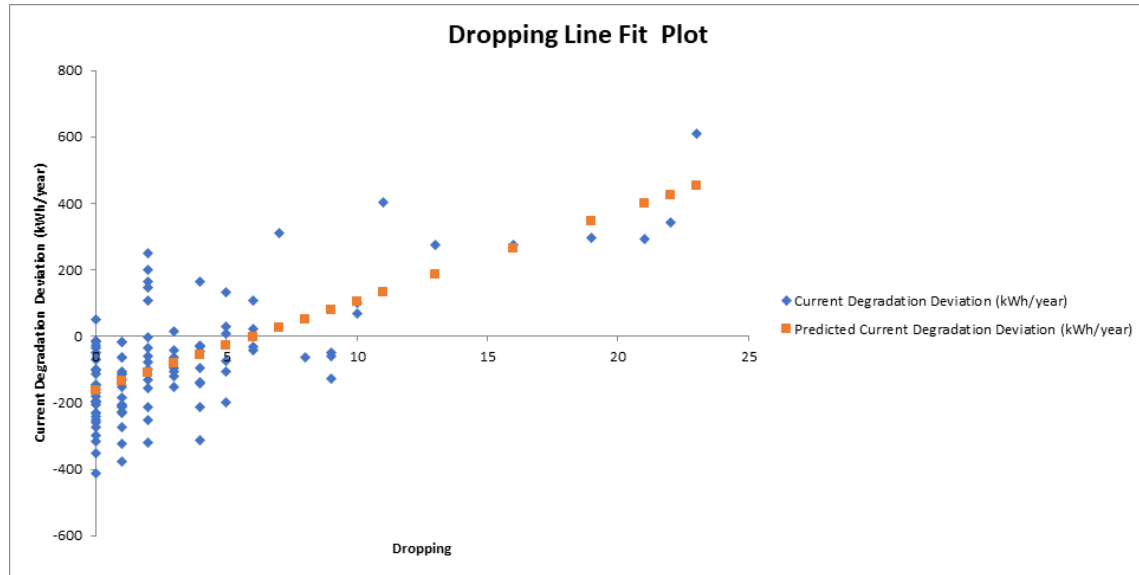
- String faults confirmed
- High degradation in area C due to bird droppings
- One string fault missed by drone
- One inverter (C19) with three additional open modules



Validation: drone inspection (2)



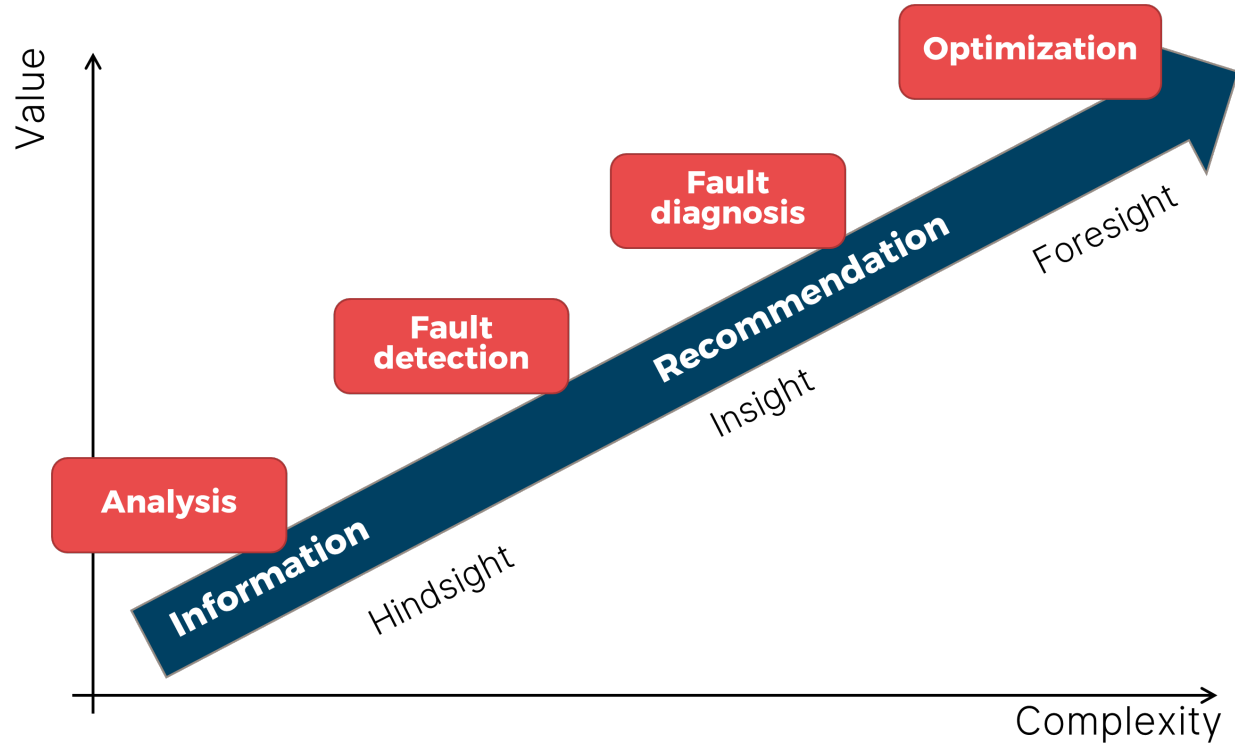
- High correlation between current degradation deviation and hotspots
- In average one bird dropping causes loss of 27 kWh/year



Future work



From hindsight to foresight



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Booth A5.673

