

RE+ 2024, TECH SESSION



PV System Reliability and Asset Management

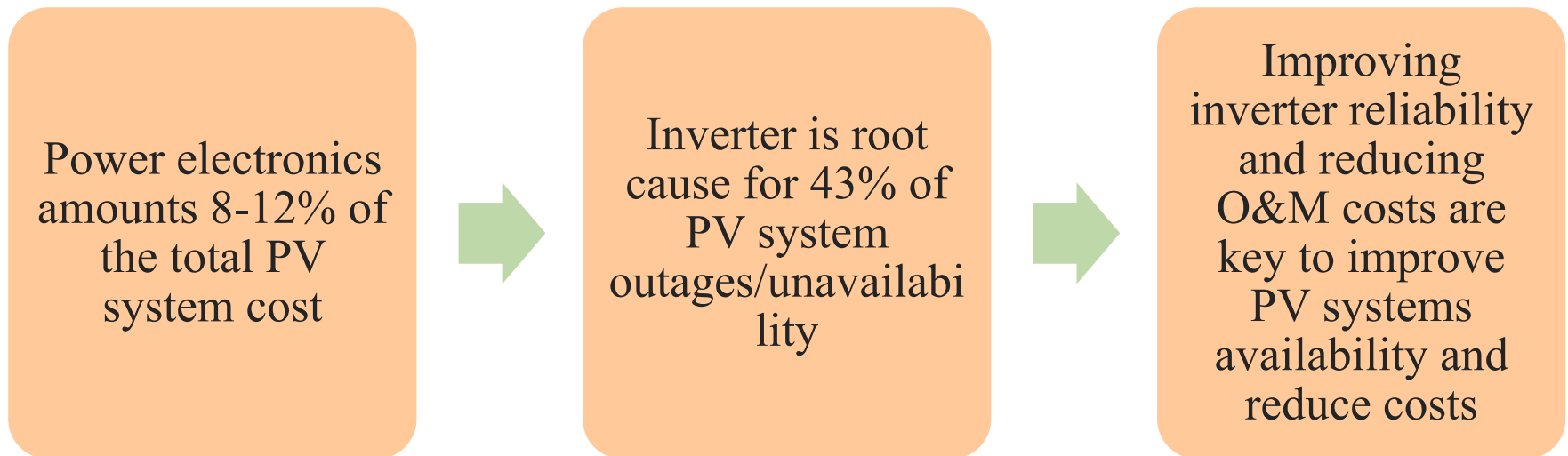
Session Moderator:

Bishnu Bhattarai, Ph.D.

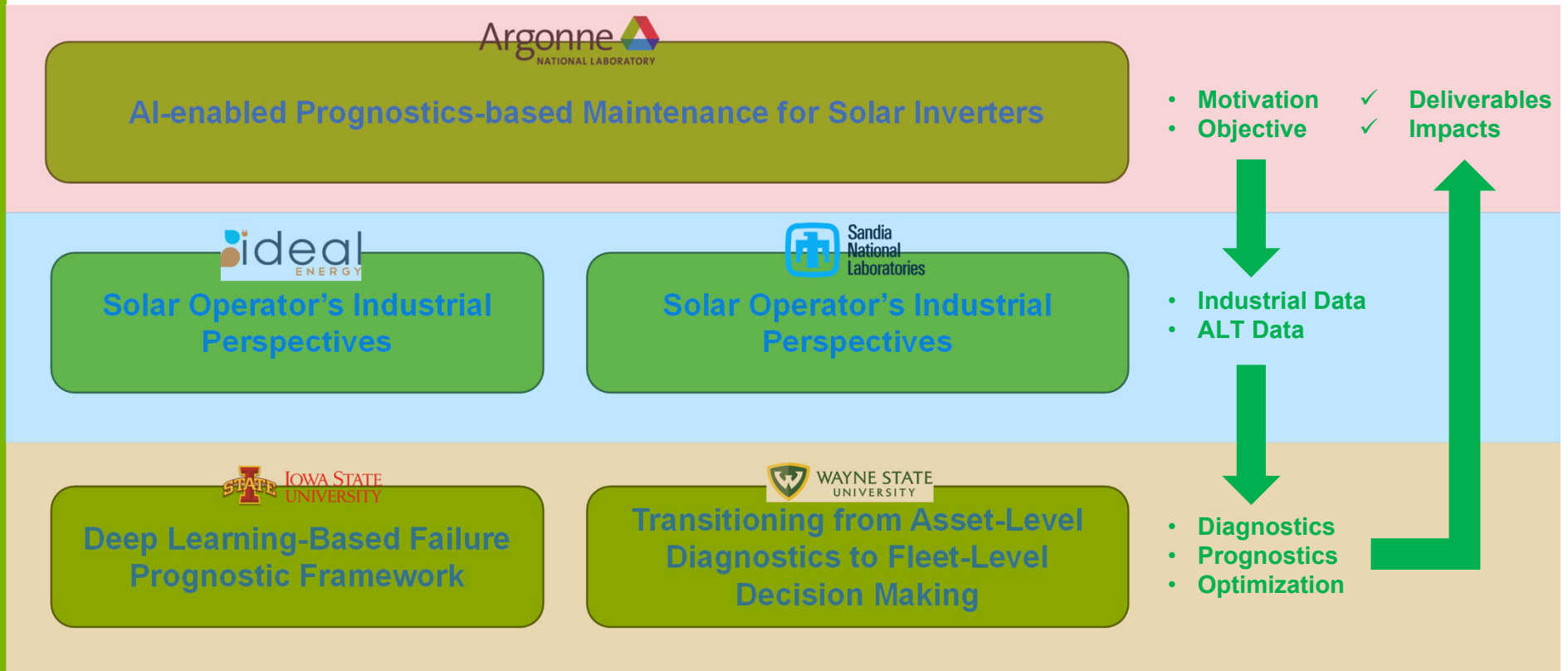
The U.S. Department of Energy – Solar Energy Technologies Office

Motivation

Why Inverter reliability and asset management?

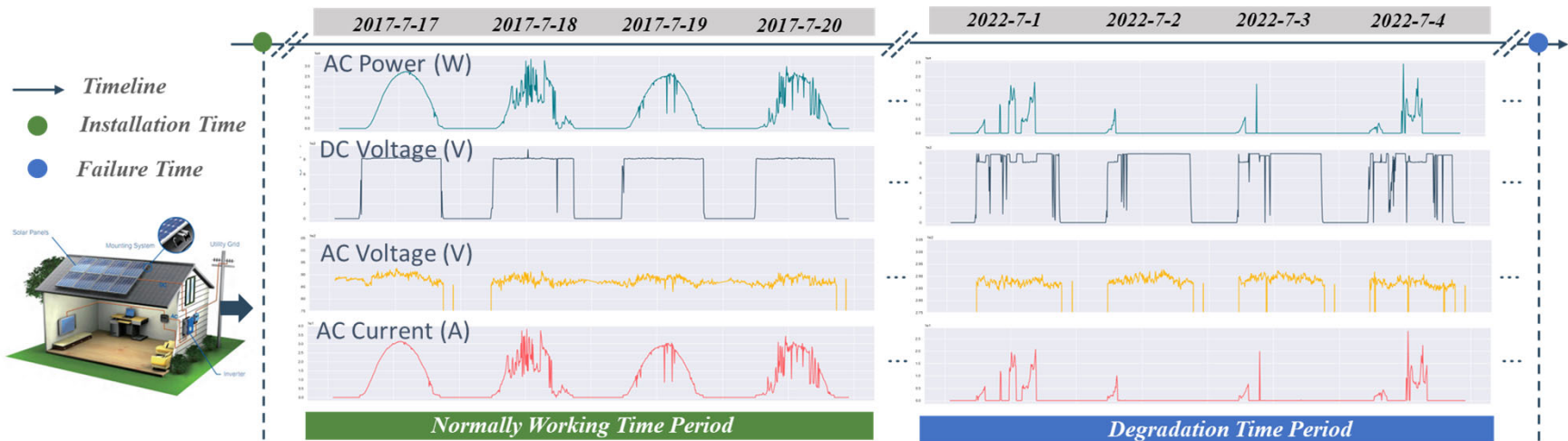


Agenda



Deep Learning-Based Failure Prognostic Framework

- Starting from a sample case



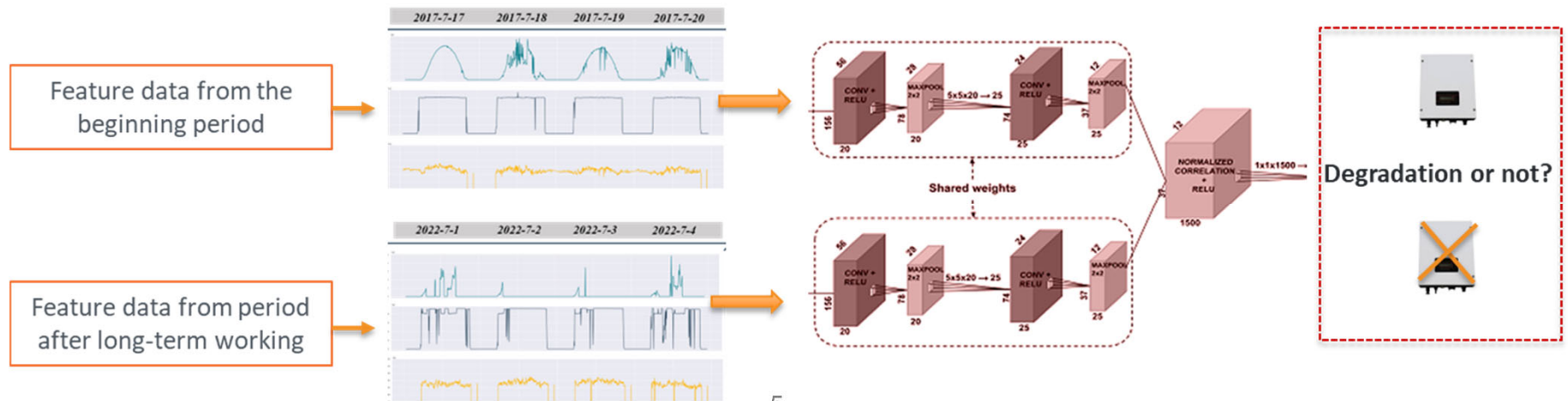
- Question1:** Besides the basic features, can we have more indicators to help us capture the degradation symptoms?
- Question2:** Is it possible to consider all the feature data to realize the comprehensive PV inverter failure prognostic?

We proposed a deep learning framework with multiple domain knowledge features to solve the questions.

Deep Learning-Based Failure Prognostic Framework

Essential idea of the deep learning framework

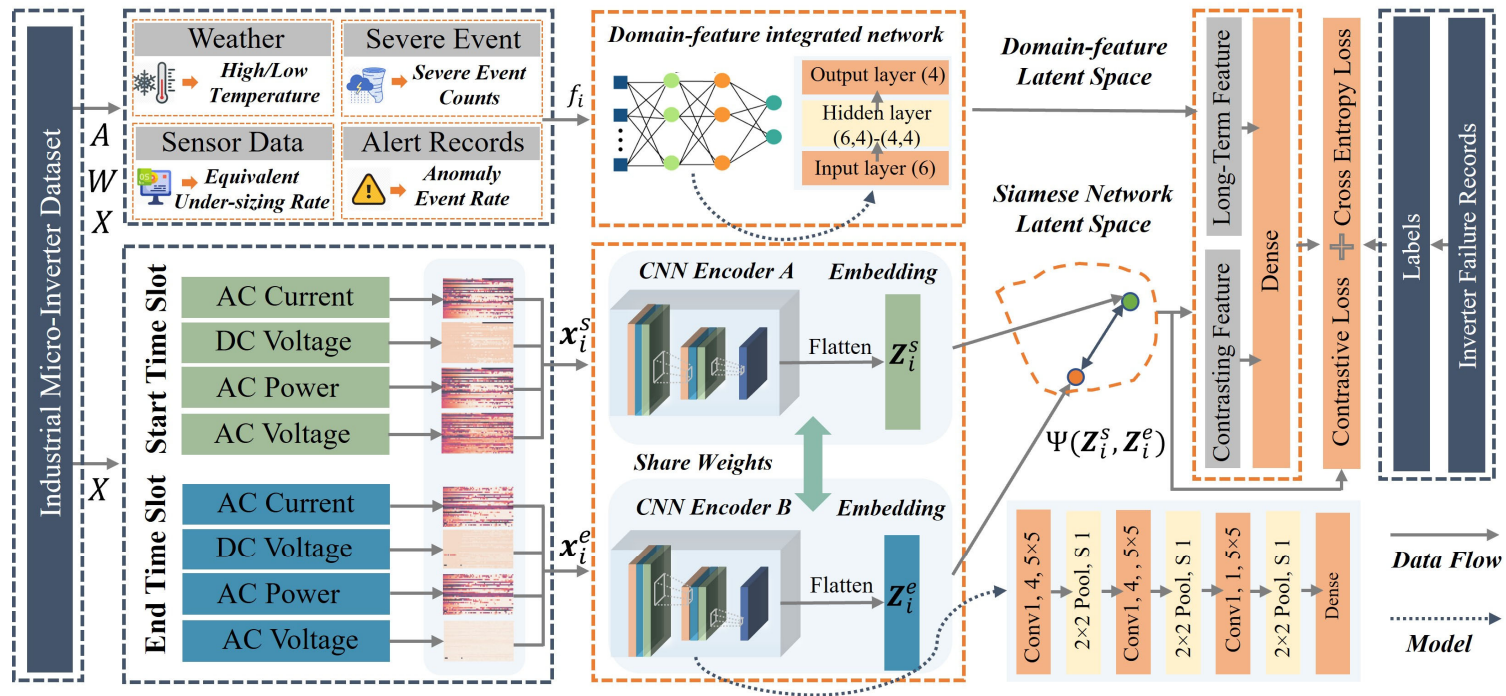
- The **Siamese Convolutional Neural Network (Siamese CNN)** is a type of neural network architecture designed for learning and extracting contrasting features from pairs of input data. It is commonly used in tasks such as similarity learning, e.g., face verification, signature verification, and more.
- Here, we used SCNN to **extract comparative features between the operation status at the beginning time and the period after long-term working.**



Deep Learning-Based Failure Prognostic Framework

Overview of the deep learning framework structure

- The framework adopts deep learning models to detect changes in operational features over time and combines them with domain knowledge features to assess the inverter's current status and predict potential failure.



Deep Learning-Based Failure Prognostic Framework

Inverter equivalent under-sizing rate (EUR)

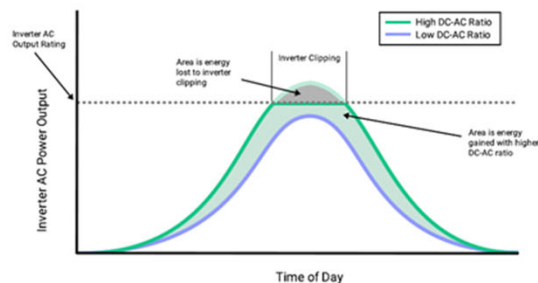
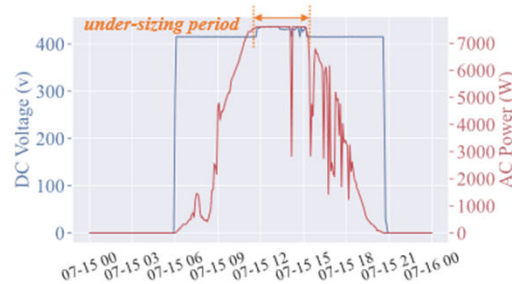
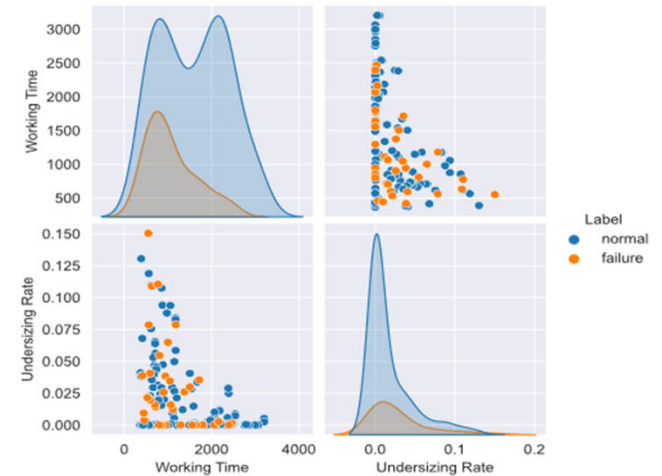


Illustration of inverter under-sizing[1]
(PV panel over-sizing)



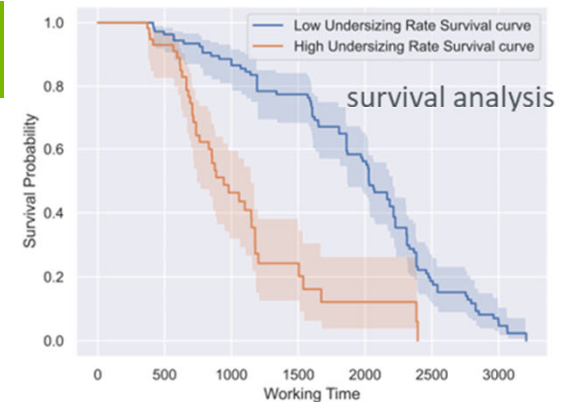
Inverter under-sizing illustration using
the real measurements



We define the equivalent under-sizing rate as the ratio of the inverter's actual under-sizing period to its total operating time.

- Based on the scatter plot, higher EUR values tend to occur in inverters with shorter working times. This pattern is observed in both failed and functioning inverters.
- The survival analysis clearly indicates that a higher under-sizing rate significantly increases the risk of inverter failure under consistent conditions.

* "Working Time" for failure cases refers to period from installation date to failure time, and it signifies the duration from the installation to the end of 2022 for functioning inverters

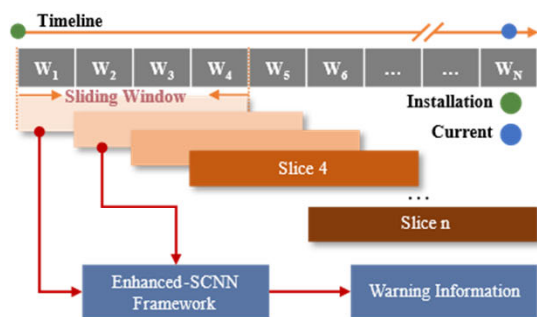


[1]<https://www.solarpowerworldonline.com/2017/05/solar-inverter-clipping/>

Deep Learning-Based Failure Prognostic Framework

Application of the deep learning framework

- The failure prognostic monitoring details for a single inverter throughout its lifetime are presented. Noticeable differences are evident between the periods before and after the warning signals.



Inverter measurements organization based on sliding window method

