**Assessment**

### **Problem Statement**

Photovoltaic (PV) modules are prone to defects that impact their efficiency, reliability, and lifespan. Among these, **hotspot defects** and **diode failures** are particularly critical as they lead to power losses, overheating, and potential safety hazards. Identifying these anomalies early is crucial for ensuring optimal performance and preventing long-term damage.

Traditional inspection methods rely on **manual thermographic analysis**, which is time-consuming and prone to human error. To improve efficiency and accuracy, there is a need for an **automated computer vision-based system** that can detect and classify defects in thermal images of PV modules.

### **Objective**

The goal of this task is to develop an **AI-ML Model** that can:

1. **Classify the type of defect** into either **hotspot defect,** **diode failure** or **No Defect** (**Classification**).
2. **Detect defective regions** in thermal images of PV modules by identifying hotspots and diode failures (**Object Detection**).

### **Context**

Photovoltaic (PV) systems, both large and small, are prone to equipment failures, particularly in modules, due to operational stresses and installation errors. While these failures can result from various internal and external factors, a common manifestation is the presence of **hot spots** in defective module areas. This phenomenon leads to an immediate reduction in power generation and, over time, accelerates equipment degradation due to excessive heat accumulation.

Photovoltaic (PV) modules develop **hotspot defects** and **diode failures**, causing power losses and safety risks. Manual inspections are slow and error-prone, necessitating an **automated computer vision system** for defect detection and classification.

#### **Diode Defect**

A **diode defect** in a PV module refers to the malfunction of bypass diodes, which are designed to protect solar cells from excessive voltage stress under shading or partial failure. These defects disrupt the current flow and can lead to severe power losses or localized heating.

##### **Causes of Diode Defects:**

* **Open-Circuit Failure:** The diode fails to conduct, forcing excessive voltage across shaded cells, leading to overheating.
* **Short-Circuit Failure:** The diode remains continuously conducting, bypassing entire cell strings and reducing module efficiency.
* **Thermal Aging:** Prolonged exposure to high temperatures degrades diode performance, increasing the risk of failure.

#### **Hotspot Defect**

A **hotspot defect** is a localized area of excessive heat in a PV module, caused by electrical mismatches, shading, or material degradation. When certain cells operate in reverse bias, they dissipate energy as heat instead of generating power, leading to **thermal stress** and **irreversible damage**.

##### **Causes of Hotspot Defects:**

* **Cell Mismatch & Shading:** Forces certain cells to absorb excess current, overheating them.
* **Microcracks & Soldering Defects:** Increase resistance, causing localized heating.

### **Dataset**

The dataset consists of two folders:

1. **Train** – Contains thermal images of PV modules along with an \_annotations.csv file.
2. **Test** – Contains thermal images for evaluation.

The \_annotations.csv file in the **Train** dataset includes the following columns:

* **filename** – Name of the image file.
* **width, height** – Dimensions of the image.
* **class** – Defect type (**hotspot** or **diode**).
* **xmin, ymin, xmax, ymax** – Bounding box coordinates for the defect region.

The model must perform **both detection and classification** on the **Train dataset**.

### **Submission File**

Candidates must submit a CSV file named **<your\_name>.csv**, containing the following columns:

* **filename**
* **class** (hotspot or diode)
* **xmin, ymin, xmax, ymax** (bounding box coordinates)

A **sample\_submission file** is attached for reference.

### **Final Outcomes**

A zip file (<your\_name>.zip) that will have -

* Script.py and Jupyter Notebook (whole python script for the assessment)
* A detailed document (pdf) explaining your approach.
* Requirements file (requirements.txt)
* Submission file <your\_name>.csv

Please ensure that results are reproduceable.