Photovoltaic Performance and Reliability in Qatar

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Outline & Objectives

- **Motivation**
  - The deployment of Photovoltaic in Qatar

- **Objectives**
  - Evaluating the performance of various Photovoltaic PV technologies & mitigate the impact of Qatar climatic conditions

- **Challenges**
  - PV performance & reliability in desert climates

- **Outdoor Performance**
  - Effect of temperature, dust and degradation on performance
Solar Resource in Qatar

- **Location**
  - Doha: Latitude 25.33° North, Longitude 51.43° East

- **Insolation Data**
  - 13 Solar ground-based monitoring stations
  - Global Horizontal Irradiation GHI = 2013 kWh/m²/year

- **Other factors**
  - Dust Storm, rain Falls, ...


Annual average sums of Global Horizontal Irradiation GHI 2003-2013
Photovoltaic Technologies

- Installed capacity 142 kW
- Silicon and thin films technologies
- Fixed: tilted = 22° due South
- Sun tracking: 1-axis and 2-axis

Photovoltaic Technologies installed at the Solar Test Facility in Doha, Qatar.
Solar Test Facility 2-2

- **Meteorological Data**
  - Global Plane of Array irradiance
    \[ G-\text{POA} = 6.2 \text{ kWh/m}^2/\text{day} \ & \text{GHI} = 5.9 \text{ kWh/m}^2/\text{day} \]
  - High Diffuse Horizontal Irradiation DHI
  - Power demand following the daily irradiance
  - Temperature = 31 °C
  - Relative Humidity RH = 43%

Measured average G-POA, GHI, DNI and DHI

Daily irradiance

Daily Temperature & Humidity
Crystalline Silicon and/or Thin Film Technologies? 1-2

- **Energy Yield [kWh/kWp]**
  - Two years data 2014-2015
  - Arrays of approx. 8 modules
  - Similar conditions: cleaning
  - Performance at low irradiance
  - Degradation
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Dust Effect

- The short-circuit current $I_{sc}$ is the most electrical parameter affected by dust accumulation.
- Modeling energy yield uses soiling losses 2%.
- Energy yield drops by 15-20% per month due to dust accumulation (Doha).
- Dust storm frequency: dust characteristics.

PV arrays before and after dust storm
Adaptation: Module Cleaning

- Effect of module cleaning: High (every week), Medium (every 2 months) and Low (every 6 months)
- Power output increases after module cleaning or rain fall
- Total cost ~ 0.02 USD/m²
Mitigation: Dust Characteristics

- Dust samples from exposed modules
- Average particle size of 10 µm
- XRD: Calcite (CaCO$_3$), quartz (SiO$_2$) 7%, etc.
- Magnetic hysteresis loop of dust particles
- Effect of temperature, humidity, wind, sun tracking, the surroundings
**Dust Effect 4-4**

- **Mitigation: Anti-dust Coatings**
  - Commercial anti-dust coatings A & B
  - No significant effect on PR
  - Anti-dust coatings vs. module cleaning

- **Challenges**
  - Minimize light reflection
  - Durability: adhesion & abrasion
  - Applications
  - Cost

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**Comparing anti-dust coatings A & B & module cleaning (every 2 months)**
Degradation of Thin Film Technologies

- **Buckling and Delamination of Thin Films**
  - High operating temperatures
  - High residual compressive strains
  - Poor adhesion at the interface
  - Moisture ingress to the interface
  - UV exposure: annual 120 kWh/m^2

- **IV curve**
  - Fill factor (FF) drops: resistive losses at the interconnection

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**IV curve of a reference module and a module with thin film delamination (Tandem)**
Summary

- **Temperature Effect**
  - Silicon Heterojunction (SHJ) technology showed a higher open circuit voltage ($V_{oc}$) compared with conventional silicon technology

- **Dust effect**
  - A drop of by 15-20% per month on power output due to dust accumulation
  - Optimum schedule module cleaning

- **Degradation of thin films**
  - Bucking and delamination of thin films due to high biaxial residual compressive strain and/or a poor adhesion at the interface
Thank You

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