Multi-modal Quality Assessment and Physics-based Degradation Modeling of in-field Solar-Photovoltaic Systems in Bangladesh

Abstract

Bangladesh's grid-connected solar PV capacity has grown from under 50 MW in 2018 to approximately 1 GW by 2025/2026, driven by SREDA targets of 10 GW by 2030 and 40 GW by 2040. Despite this rapid expansion, financial models and Levelized Cost of Energy (LCOE) calculations continue to rely on assumed module lifetimes of 15–25 years, without empirical evidence specific to Bangladesh's tropical monsoon climate. No standardized, physics-informed framework exists for assessing the quality and degradation status of operating PV assets in the country. This gap introduces systemic uncertainty into investment bankability, national energy planning, and long-term yield forecasting.

The underlying problem is that passing standardized laboratory qualification tests (IEC 61215) does not guarantee 25-year operational reliability under Bangladesh's hot-humid, monsoon-cycle conditions. In-field failure modes — Potential-Induced Degradation (PID), encapsulant (EVA) browning, moisture ingress, contact corrosion, solder-bond fatigue, and bypass-diode failure — co-evolve under combined thermal, humidity, and soiling stress. Field diagnostic data from operating utility-scale and industrial PV assets in Bangladesh are extremely sparse, and no national quality assurance (QA) framework exists for periodic in-field system audits.

To address the abovementioned gap, East West University (EWU) has signed a Memorandum of Understanding (MoU) with the Infrastructure Development Company Limited (IDCOL) to collaborate on the technical assessment, performance monitoring, and reliability analysis of solar photovoltaic (PV) systems aiming to develop standardized Quality Assurance framework in Bangladesh. This proposal describes the first phase of the EWU–IDCOL research collaboration: a multimodal field diagnostic campaign targeting IDCOL-financed utility-scale solar parks and industrial rooftop PV systems, stratified across operating ages (Year 1 through Year 5+). The campaign integrates two complementary non-destructive modalities — (i) high-precision outdoor current-voltage (I–V) curve tracing at string and module level, and (ii) UAV-based radiometric infrared (IR) thermography — enabling comprehensive in-situ health assessment without plant shutdown or module extraction.

The core scientific innovation is the development of distributed SPICE-type electro-thermal models that simulate localized defects — hotspots, bypass-diode failures, micro-cracks, shunt anomalies, and partial shading — under real ambient conditions (measured irradiance, temperature, wind speed). Existing validated circuit models for PV fault diagnosis assume Standard Test Conditions (STC); this proposal extends them to in-field tropical operation, creating a physics-validated diagnostic bridge between macro-level electrical measurements and micro-level failure physics.

The EWU team will contribute the thermal drone system, physics-based modeling expertise and tools, and statistical analytics. IDCOL will contribute to site access, field personnel, commissioning equipment, and SCADA/generation logs under the signed MoU.

Expected outputs include:

1) a validated, ambient-aware distributed electro-thermal model linking IR thermal signatures to circuit-level degradation parameters;
2) diagnostic assessments of newly installed and aged sites
    a) Data from new sites will give vital statistical feedback on the quality of panels and balance-of-system equipment currently being imported and deployed in Bangladesh.
    b) Overall this will be Bangladesh's first database of Performance Loss Rates (PLR) stratified by site type and operating age;
3) a draft National Solar PV Field Audit and Commissioning Guideline for submission to IDCOL, SREDA, and BERC.

This work will lay the groundwork for a standardized national solar PV auditing and quality assurance (QA) framework. It directly advances SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action) by establishing the technical foundations for evidence-based, long-term management of Bangladesh's growing solar asset portfolio.