Solar PV Power Plant Performance Specification

Meridian Flats Solar Park

Meridian Basin, New South Highlands

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Engineer of Record: Dr. James Okafor, PE
Project Owner: Synapse Infrastructure Holdings

Prepared by **Nexa Solar Energy Solutions Pty Ltd** on behalf of **Synapse Infrastructure Holdings**. This document is confidential and shall not be distributed to third parties without the written consent of the Project Owner. The information contained herein constitutes the binding technical specification governing the construction, commissioning, and 25-year operational performance of the Meridian Flats Solar Park.

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1 Introduction & Project Scope

This Performance Specification establishes the technical requirements, acceptance criteria, and monitoring obligations for the **Meridian Flats Solar Park** — a ground-mounted photovoltaic (PV) power plant rated at 48.6 $\mathrm{MW_p}$ (DC) / 40 MW (AC), located in the Meridian Basin, New South Highlands. The document governs the relationship between **Nexa Solar Energy Solutions** (Engineer of Record) and the Project Owner, **Synapse Infrastructure Holdings**, throughout the plant's operational lifetime.

1.1 Document Purpose

The specification defines:

- Module-level and string-level degradation limits and measurement protocols.
- Inverter efficiency requirements and maximum allowable downtime thresholds.
- Shading analysis methodology and permissible energy losses attributable to inter-row and near-horizon obstructions.
- Annual and lifetime energy generation targets with associated performance ratio (PR) floors.
- Data acquisition (SCADA) requirements and reporting cadences.
- Warranty and liquidated damages (LD) triggers.

1.2 Applicable Standards & References

This specification is prepared in conformance with the following normative documents:

- IEC 61724-1:2021 — *Photovoltaic system performance — Part 1: Monitoring.*
- IEC 61215-2:2021 — *Terrestrial PV modules: Design qualification and type approval.*
- IEC 62548:2016 — *PV arrays: Design requirements.*
- ASTM E1036-15 — *Standard Test Methods for Electrical Performance of Nonconcentrator Terrestrial PV Modules.*
- Nexa Engineering Standard NES-PV-03 Rev. 2 — *Site Assessment and Energy Yield Methodology.*

1.3 Project Parties

Role	Organisation	Responsible Contact
Project Owner	Synapse Infrastructure Holdings	Elena Markov, VP Projects
Engineer of Record	Nexa Solar Energy Solutions	Dr. James Okafor, PE
EPC Contractor	Vertex Constructors Pty Ltd	Lena Schultz, PM
O&M Provider	Nimbus Field Services	Carlos Reyes, Ops Director
Independent Engineer	Apex Technical Advisory	Priya Nair, Senior Analyst

1.4 Plant Configuration Summary

The Meridian Flats Solar Park is configured as follows: 132 strings of 30 **Vertex VS-370M** monofacial PERC modules (bifacial gain excluded from base-case P50 yield) per string, wired to 12 **Nimbus NX-3400** central inverters each rated 3333 $\mathrm{kW_{ac}}$. The plant operates at a DC/AC

clipping ratio of **1.215**, consistent with prevailing industry practice for sites with the site's irradiance profile (5.42 kW h/(m^2 d) average GHI).

2 PV Module Degradation Requirements

2.1 Degradation Rate Limits

Module power output shall not degrade below the thresholds specified in Table 1. Degradation is measured relative to nameplate STC power (370 W_p per module) as confirmed by the flash-test certificate issued at factory acceptance.

Table 1: Maximum Allowable Module Power Degradation — Vertex VS-370M

Year	Min. Power (%)	Max. Degradation (%)	Trigger Action
1	97.5	2.5	Warranty claim
2–5	96.0	0.5† /yr	Monitoring alert
6–15	91.0	0.5/yr	Performance review
16–25	83.5	0.5/yr	O&M inspection

† Linear degradation model; annual fleet-level average.

2.2 Measurement Protocol

Degradation shall be quantified using the **In-Situ I-V Curve** method (IEC 61829) conducted during clear-sky conditions (POA irradiance $\geq 800\,W/m^2$, module temperature within $25\,°C \pm 5\,°C$ of standard). Measurements are to be performed:

1. At commissioning baseline (Year 0), within 30 days of COD.
2. Annually during the O&M scheduled shutdown in April.
3. Within 14 days of any hail or wind event exceeding the module's IEC environmental classification.
4. On a statistical sample of not less than 5% of total modules per year, with stratified sampling across all DC combiner zones.

2.3 Soiling Correction

All degradation measurements shall apply a soiling loss correction factor S_f derived from the monthly soiling sensor readings. The corrected power P_{corr} is:

$$P_{\text{corr}} = \frac{P_{\text{meas}}}{1 - S_f}$$

where S_f is the fraction of irradiance blocked by soiling (dimensionless). The long-term site average soiling loss is modelled at 1.8 % based on the Nexa field campaign conducted in Year 0 (Nexa Report MER-SL-2025-04).

2.4 Electroluminescence Inspection

A full-plant electroluminescence (EL) imaging campaign shall be conducted:

- At Year 1, Year 5, Year 10, Year 15, and Year 20.
- Following any event that triggers string-level power reduction $\geq 3\%$ below fleet median.

Modules exhibiting **crack propagation** affecting $> 20\%$ of cell area, **inactive cell regions** $> 10\%$, or evidence of **potential-induced degradation (pid)** at $> 5\%$ module level shall be

flagged for replacement within the next scheduled maintenance window, not to exceed 90 days.

3 Inverter Performance Requirements

3.1 Efficiency Specifications

Each **Nimbus NX-3400** central inverter shall demonstrate the weighted efficiency values specified in Table 2. Weighted European Efficiency (η_{EU}) and CEC Efficiency are the primary acceptance metrics.

Table 2: Inverter Efficiency Requirements — Nimbus NX-3400

Metric	Required (%)	Tested Value (%)	Status
Peak Efficiency ($\eta_{\max}$)	98.50	98.71	**Pass**
European Weighted (η_{EU})	97.80	98.02	**Pass**
CEC Efficiency	97.50	97.88	**Pass**
Night-time Standby Power	≤ 50 W		**Pass**

The European Weighted Efficiency is calculated per IEC 61683:

$$\eta_{\text{EU}} = 0.03\,\eta_{5\%} + 0.06\,\eta_{10\%} + 0.13\,\eta_{20\%} + 0.10\,\eta_{30\%} + 0.48\,\eta_{50\%} + 0.20\,\eta_{100\%}$$

where $\eta_{x\%}$ denotes inverter efficiency at $x\%$ of rated AC output power.

3.2 Availability Requirements

Inverter availability A_{inv} is defined as:

$$A_{\text{inv}} = \frac{T_{\text{total}} - T_{\text{unplanned}}}{T_{\text{total}}} \times 100\%$$

where $T_{\text{unplanned}}$ excludes grid curtailment events and scheduled maintenance windows. The minimum contractual availability floor is 98.5 % per inverter per rolling 12-month period.

Availability Triggers

If $A_{\text{inv}} < 98.5\%$ for any single inverter in a 90-day window, Nimbus Field Services shall dispatch a Level 2 technician within **24 hours**. Sustained underperformance ($< 97\%$ over 6 months) triggers a hardware audit and potential unit replacement at EPC cost.

Response Time SLA

- Critical fault: **4 hr** remote, 24 hr on-site.
- Minor fault: 48 hr remote, 5 day on-site.
- Scheduled PM: 30-day advance notice.

3.3 Inverter Efficiency vs. Loading — PGFPlots Figure

Figure 1 illustrates the measured efficiency curve of the Nimbus NX-3400 across the full loading range, compared to the contractual minimum threshold.

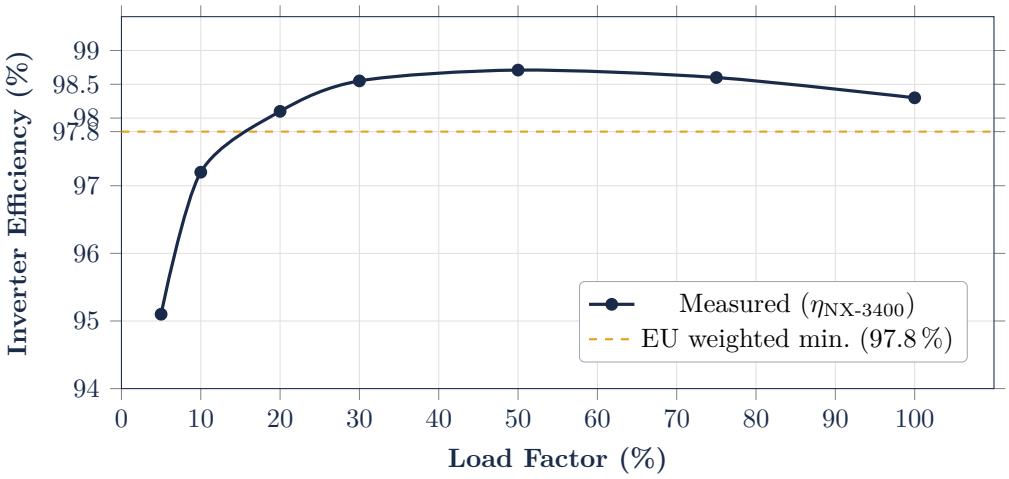

Figure 1: Nimbus NX-3400 measured efficiency curve across loading range. Dashed amber line: contractual EU weighted minimum.

3.4 Harmonic Distortion & Grid Compliance

Total Harmonic Distortion (THD) at the point of common coupling (PCC) shall not exceed **3%** under full load, in conformance with IEEE 519-2022. Each inverter shall incorporate active anti-islanding protection compliant with AS 4777.2:2020.

4 Shading Analysis & Loss Budget

4.1 Methodology

Shading analysis was performed using **Nexa SolarSim v4.3** with 3D terrain and obstacle modelling derived from LIDAR survey data (point density 8/m^2). The analysis distinguishes three loss categories per IEC 61724-1:2021 Annex A:

[1] **Near shading** — inter-row, fence, and inverter shelter obstructions within the plant boundary.

[2] **Far shading** — topographic horizon profile derived from 30 m DEM.

[3] **Electrical mismatch** — string-level power reduction from partial shading on non-bypass-diode-isolated cells.

4.2 Inter-Row Shading Design

Rows are oriented **N–S** with modules tilted at **22°** (optimised for latitude −34.1ř). The ground coverage ratio (GCR) is 0.40, yielding the following inter-row shading loss profile:

Table 3: Monthly Inter-Row Shading Loss — Meridian Flats Solar Park

Month	Beam Shading (%)	Diff. Shading (%)	Irradiance Loss (kWh/m²)
January	0.32	1.65	6
February	0.35	1.67	5
March	0.61	1.70	7
April	1.20	1.72	9
May	2.41	1.75	12
June	3.15	1.78	14
July	2.98	1.77	13
August	1.88	1.73	10
September	0.90	1.71	8
October	0.48	1.66	6
November	0.33	1.65	5
December	0.29	1.64	5
Annual	**1.24**	**1.70**	**100**

4.3 Shading Loss Budget Summary

The total shading-related loss budget is summarised below. All values are expressed as a percentage of annual GHI in-plane irradiation (1977 kW h/(m^2 yr)).

Loss Component	Energy Loss (%)	Limit (%)
Inter-row beam shading	1.24	1.50
Inter-row diffuse shading	1.70	2.00
Far horizon shading	0.18	0.25
Electrical mismatch (shading)	0.35	0.50
Total Shading Loss	**3.47**	**4.25**

The modelled total shading loss of **3.47%** is within the contractual limit of **4.25%**. If measured annual shading loss (derived from SCADA irradiance comparison) exceeds 4.25%, Vertex Con-

structors shall conduct a structural alignment audit of all tracker or fixed-tilt mounting systems within 60 days.

4.4 Horizon Obstruction Profile — TikZ Diagram

Figure 2 shows the simplified horizon obstruction profile at the plant centroid (GPS: −34.07° S, 147.32° E), derived from LIDAR survey. Shaded area indicates sun path regions intercepted by horizon obstructions.

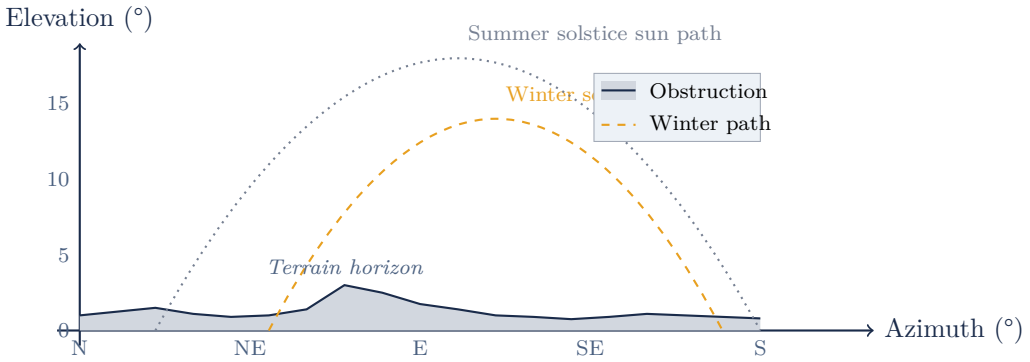

Figure 2: Simplified horizon obstruction profile at plant centroid. Shaded band indicates terrain profile. Maximum terrain obstruction of 3.0° elevation occurs at the NE quadrant (azimuth ≈ 40°).

5 Energy Generation Targets & Performance Ratio

5.1 Annual Energy Yield Targets

Table 4 specifies the contractual energy generation targets for the Meridian Flats Solar Park across the 25-year project life. Targets are stated at both P50 and P90 probability levels, net of all losses (shading, soiling, degradation, inverter, transformer, and MV cable losses).

Table 4: Contractual Annual Net Energy Yield Targets (P50 / P90)

Year	P50 (MWh)	P90 (MWh)	$\mathbf{PR_{P50}}$ (%)	$\mathbf{PR_{P90}}$ (%)
1	79,120	72,890	81.5	75.1
2	78,724	72,516	81.1	74.7
5	77,548	71,400	79.9	73.6
10	75,804	69,847	78.1	71.9
15	74,110	68,245	76.4	70.3
20	72,420	66,690	74.6	68.7
25	70,785	65,188	72.9	67.2
Lifetime	**1 875 300**	**1 727 000**	—	—

5.2 Performance Ratio Definition

The Performance Ratio (PR) quantifies overall plant efficiency relative to ideal yield for the installed capacity:

$$\mathrm{PR} = \frac{E_{\mathrm{ac,net}}}{H_{\mathrm{poa}} \cdot P_{\mathrm{ref,stc}} / G_{\mathrm{stc}}}$$

where:

- $E_{\mathrm{ac,net}}$ — measured net AC energy delivered to the grid (kW h).
- H_{poa} — POA irradiation (kW h/m^2).
- $P_{\mathrm{ref,stc}}$ — total nameplate DC capacity at STC (kW$_\mathrm{p}$).
- G_{stc} — reference irradiance at STC, 1.0 kW/m^2.

The contractual PR floor in Year 1 is 79.5 % on a rolling 12-month basis, declining by 0.3 % per year thereafter.

5.3 Loss Waterfall

The modelled Year 1 loss budget from GHI to net AC energy is:

Loss Category	Loss (%)	Residual (%)
Gross GHI irradiation		100.0
POA transposition gain	−1.2	101.2
Shading (total)	3.47	97.73
Soiling	1.80	95.93
Reflection (IAM)	2.10	93.83
Module temperature losses	4.80	89.03
Module quality / mismatch	1.50	87.53
DC wiring & diodes	0.60	86.93
Inverter losses	1.98	84.95
Transformer & MV cable	0.85	84.10
Auxiliary consumption	0.40	83.70
Clipping (DC/AC ratio)	1.90	81.80
Curtailment / availability	0.30	81.50
Net PR (Year 1)	—	**81.50**

5.4 Liquidated Damages

If the measured 12-month rolling net AC energy falls below the P90 threshold in any Year 1–5, Nexa Solar Energy Solutions (as EPC warranty administrator) shall trigger liquidated damages as follows:

$$\text{LD} = \left(E_{\text{target,P90}} - E_{\text{measured}}\right) \times \$\,95\,/\,\text{MW\,h}$$

Maximum LD exposure is capped at **15%** of the total EPC contract value ($AUD 47.3 M). LD payments are calculated annually and invoiced by Synapse Infrastructure Holdings to Vertex Constructors Pty Ltd within 30 days of the anniversary of COD.

6 Monitoring, Data Acquisition & Reporting

6.1 SCADA System Requirements

The plant's Supervisory Control and Data Acquisition (SCADA) system shall be supplied by **Apex Digital Systems** and shall meet the requirements of IEC 61724-1:2021 Classification A (highest accuracy tier). Key specifications:

- **Data resolution**: 1 min intervals for all primary sensors; 15 min intervals for energy meters.
- **Data availability**: $\geq$ 99.0% uptime of the data acquisition backbone over any rolling 30-day period.
- **Time synchronisation**: NTP-referenced, $\leq$ 1 s drift.
- **Cybersecurity**: Conformant to IEC 62443-3-3 Security Level 2.
- **Remote access**: Encrypted VPN tunnel to Nexa Engineering portal; read access granted to Synapse asset management team.

6.2 Required Instrumentation

Table 5: Mandatory Instrumentation — Meridian Flats Solar Park

Instrument	Parameter	Accuracy	Qty
Pyranometer (class A)	POA irradiance	±2 %	6
Pyranometer (class A)	GHI irradiance	±2 %	2
Pyrheliometer	DNI	±1 %	1
Module temperature	Back-of-module temp.	±1 °C	12
Ambient temperature	Ambient air temp.	±0.5 °C	4
Wind speed/direction	Anemometer (at hub ht)	±3 %	3
Revenue-grade meter	Net AC energy (MWh)	Class 0.2	1
Soiling sensor	Soiling ratio	±0.5 %	4
String monitor	DC string current/V	±0.5 %	132

6.3 Reporting Requirements

Nimbus Field Services shall deliver the following mandatory reports to Synapse Infrastructure Holdings and Nexa Solar Energy Solutions:

1. **Daily Report** — automated: energy generation, availability, active alarms, soiling index. Delivered by 07:00 local time each calendar day.
2. **Monthly Technical Report** — within 10 business days of month end: detailed energy summary, PR calculation, inverter performance, fault log, maintenance completed, and financial reconciliation for LD tracking.
3. **Annual Performance Report** — within 30 business days of year-end anniversary: full degradation assessment, shading analysis update, 5-year energy forecast revision, and warranty claim status.
4. **Event-Triggered Report** — within 48 hours of: single-inverter downtime > 4 hours, SCADA data loss > 2 hours, grid fault or curtailment event > 1% of daily energy budget, or any physical security incident.

Data Retention Obligation

All raw 1 min SCADA data shall be retained for a minimum of **25 years** in a geographically redundant cloud archive (Apex Cloud Vaulting Service or equivalent). Synapse Infrastructure Holdings retains unrestricted rights to all operational data generated at the Meridian Flats site.

7 Acceptance Testing & Sign-Off Criteria

7.1 Commissioning Test Programme

Prior to Commercial Operation Date (COD), the following acceptance tests shall be completed under the supervision of Apex Technical Advisory as Independent Engineer:

Table 6: Commissioning Acceptance Test Programme

Test	Standard	Pass Criterion	Mandatory
Module flash test (sample 5%)	IEC 61829	Within ±2% of nameplate	Yes
Thermal imaging (IR scan)	IEC 62446-3	No class-C hotspots	Yes
IV curve tracing (all strings)	IEC 61829	I_{sc} within ±3%	Yes
Inverter load test (100% load)	IEC 62116	$\eta_{\max} \geq 98.5\%$	Yes
Anti-islanding verification	AS 4777.2:2020	Trip within 2 s	Yes
Earth continuity (DC)	IEC 62548	$R \leq 1\,\Omega$	Yes
SCADA data validation	IEC 61724-1	$\geq 99\%$ data capture	Yes
Soiling sensor calibration	Mfr. spec.	Within ±0.5%	Yes

7.2 Performance Acceptance Test (PAT)

A formal Performance Acceptance Test shall be conducted within 60 days of COD during a continuous **7-day** test period. Acceptance criteria:

- Measured net AC energy $\geq$ P90 target for the test period (irradiance-normalised).
- SCADA data availability $\geq 99.0\%$ throughout the test period.
- No single inverter downtime exceeding 4 continuous hours during the test.
- Measured PR (7-day rolling) $\geq$ **79.5%**.

If the PAT is failed on first attempt, Vertex Constructors has 30 days to rectify and retest. A second failure triggers the LD mechanism defined in Section 5.

7.3 Sign-Off Authority

Test Category	Sign-Off Authority	Witness
Module-level tests	Nexa Site Engineer	Apex TE
Inverter tests	Nimbus Commissioning	Apex TE
SCADA validation	Apex Digital Systems	Synapse PM
PAT final sign-off	Dr. James Okafor (PE)	Elena Markov
Grid connection	Network Operator	Apex TE

COD Trigger Conditions

COD is declared when: (1) all mandatory acceptance tests in Table 6 are passed; (2) the PAT is passed; (3) the network operator has issued a *Connection Agreement Commencement Certificate*; and (4) Apex Technical Advisory has issued its *Independent Engineer's Commissioning Sign-Off Letter*.

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