Solar Energy Fundamentals with KPIs (Key Performance Indicators):

1) **Grid Down Hr. = GF + FM**
   Where GF = Gride Fault Down Hr., FM = Force Major Down Hr.

   Example: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

   Gride Down Hr. = GF + FM = 32.50 + 0.78 = 33.28 Hr.

2) **GA (Gride Availability) Hr. = (Operational Hr. – Gride Down Hr.)**
   Operational Hr. = (No. of Day x 24)

   Example: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

   GA Hr. = (Operational Hr. – Gride Down Hr.) = [(365 x 24) – 33.28] = 8726.72 Hr.

3) **GA % = [(Operational Hr. – Gride Down Hr.) / Operational Hr.] x 100**

   Example: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

   GA % = [(Operational Hr. – Gride Down Hr.) / Operational Hr.] x 100
   = [({365 x 24} – 33.28) / {365 x 24}] x 100
   GA % = 99.62 %

4) **Plant Down Hr. = S + U + NOR**
   Where S = Scheduled Plant Down Hr., U = Unscheduled Plant Down Hr. and NOR = Non Operational Reason Hr.

   Example: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2100 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

   Plant Down Hr. = S + U + NOR = 26.80 + 68.86 + 0.7 = 96.36 Hr.

5) **PA (Plant Availability) Hr. = (Grid Availability Hr. – Plant Down Hr.)**

   Example: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

   PA Hr. = (Grid Availability Hr. – Plant Down Hr.) = (8726.72 – 96.36) = 8630.36 Hr.

6) **PA % = [(Operational Hr. – {Gride Down Hr. + Plant Down Hr.}) / Operational Hr.] x 100**

<u>Example</u>: Total Yearly Generation of Plant 32,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC), PlantA/Inv2/SMB2A-2D/M4464/ 1182.96kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr.

PA % = [(Operational Hr. – {Gride Down Hr. + Plant Down Hr.}) / Operational Hr.] x 100
= [({365 x 24} – {32.50 + 0.78}) / (365 x 24)] x 100
PA % = 99.62 %

7) **Revenue = Meter Export Generation {kWh} x PPA (Power Purchase Agreement) Rs.**

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit for 25 Years from D.O.C. (Date Of Commissioning: 15th March, 2015). [PPA valid from 15th March, 2015 to 14th March, 2040]

Revenue = 31,95,550 x 2.90 = 92,67,095 Rs.

8) **PR (Performance Ratio)**

Performance Ratio (PR) is a key performance indicator used to assess the efficiency of a solar energy system. In other words, the Performance Ratio quantifies how efficiently a solar energy system is performing relative to its potential capacity.

A higher PR percentage indicates better performance and efficiency, while a lower percentage suggests that the system is not operating optimally, potentially due to factors like shading, soiling, system degradation, or other losses.

Evaluating the PR regularly helps identify any performance issues and allows for optimization measures to be taken to improve the overall efficiency of the solar energy system.

<u>Ideal Method</u>:

PR % = [Actual Energy Output / Calculated Energy Output] x 100
Where Calculated Energy Output = Irradiation {kWh/m^2} x Module Efficiency {%} x Plant Area {m^2} x No. of Day

<u>Or</u>

<u>Optional Method</u>:

PR % = [(Actual Energy Output) / (Irradiation {kWh/m^2} x Plant DC Capacity {kWh} x No. of Day)] x 100
Where Plant DC Capacity {kWh} = [Module Watt x No. of Module] / 1000

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit, Yearly Average Irradiation 5.5 kWh/m^2, Module 265 Watt, Module Efficiency 16%, Module Dimension Length 1.638 m^2 & Width 0.991 m^2.

PR % = [Actual Energy Output / Calculated Energy Output] x 100
Where Calculated Energy Output = Irradiation {kWh/m^2} x Module Efficiency {%} x Plant Area {m^2} x No. of Day

Module 265 Watt, Module Efficiency 16%, Module Dimension Length 1.638 m^2 & Width 0.991 m^2
Total Plant Module = 3888 + 4464 = 8352
Module Area = 1.638 x 0.991 = 1.6233 m^2, Total Module (Plant) Area = 1.6233 x 8352 = 13,557.80 m^2
Calculated Energy Output = 5.5 x 0.16 x 13,557.80 x 365 = 43,54,765.36 kWh

SCADA Generation PR % = [32,04,400 / 43,54,765.36] x 100 = 73.58 %
Meter Export Generation PR % = [31,95,550 / 43,54,765.36] x 100 = 73.38 %

_Or_

PR % = [(Actual Energy Output) / (Irradiation {kWh/m^2} x Plant DC Capacity {kWh} x No. of Day)] x 100

SCADA Generation PR % = [(32,04,400) / (5.5 x {1030.32 + 1182.96} x 365)] x 100 = 72.12 %
Meter Export Generation PR % = [(31,95,550) / (5.5 x {1030.32 + 1182.96} x 365)] x 100 = 71.92 %

9) IPR (Inverter Performance Ratio)

IPR is a key performance indicator used to evaluating the efficiency of inverter in converting DC Power to AC Power. Ideally Inverter Performance Ratio (IPR) is more than 95%.

IPR % = [(AC Energy output of Inverter / DC Energy Input of Inverter)] x 100

<u>Example</u>: Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/ 1000kWh (AC), Date: 01-07-2023; Time 14:30, ABB A-Inverter DC Input 1015 V and ABB A-Inverter AC Output 985 V and Date: 01-07-2023; Time 14:30, ABB B-Inverter DC Input 1170 V and ABB B-Inverter AC Output 1130 V.

IPR % = [(AC Energy output of Inverter / DC Energy Input of Inverter)] x 100
IPR of A-Inverter % = [(985 / 1015)] x 100 = 97.04 %
IPR of B-Inverter % = [(1130 / 1170)] x 100 = 96.58 %

10) PDR (Performance Degradation Ratio)

The Performance Degradation Ratio (PDR) is a key performance indicator used for solar energy refers to the rate at which the efficiency or performance of a solar energy system decreases over time.

It represents the annual percentage loss in the energy output of the solar panels as they age and is an essential metric for assessing the long-term performance of a solar system.

Generally solar plant performance is decreases by 1% annually from the date of commissioning (DOC).

PDR % = [(Initial Energy Output – Final Energy Output) / (Initial Energy Output x No. of Years)] x 100

<u>Example</u>: Total Yearly FY 2015-16 SCADA Generation of plant 31,98,466 kWh, Total Yearly FY 2018-19 SCADA Generation of plant 31,04,400 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC).

Total Yearly FY 2015-16 SCADA Generation of plant 32,50,466 kWh (1^{st} Year Generation)
Total Yearly FY 2016-17 SCADA Generation of plant 32,15,686 kWh (2^{nd} Year Generation)
Total Yearly FY 2017-18 SCADA Generation of plant 31,80,635 kWh (3^{rd} Year Generation)
Total Yearly FY 2018-19 SCADA Generation of plant 31,04,400 kWh (4^{th} Year Generation)

PDR % = [(32,50,466 – 31,04,400) / (31,04,400 x 4)] x 100 = 1.17 %

11) CFU (Capacity Utilization Factor)

Capacity Utilization Factor (CFU) is a key performance indicator for performance metric used to percentage of energy output by the power plant corresponding to installed capacity in that actual period.

CFU % = [(Actual Energy Output) / (Installed Capacity x Actual Operational Hr.)] x 100
Actual Operational Hr. = Total Operational Hr. – (Plant Down Hr. + Gride Down Hr.)

Solar Power Plant CUF: 15-35 %
Wind Power Plant CUF: 25-45 %
Hybrid (Solar + Wind) Power Plant CUF: 35-50 %

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit.

CFU % = [(Actual Energy Output) / (Installed Capacity x Actual Operational Hr.)] x 100
Actual Yearly Operational Hr. = 8760 – (96.36 + 33.28) = 8630.36
SCADA Generation CFU % = [(32,04,400) / (2000 x 8630.36)] x 100 = 18.56 %
Meter Export Generation CFU % = [(31,95,550) / (2000 x 8630.36)] x 100 = 18.51 %

12) PLF (Plant Load Factor)

Plant Load Factor is a key performance indicator for performance metric used to percentage of energy output by the power plant corresponding to installed capacity in that total period.

PLF % = [(Actual Energy Output) / (Installed Capacity x Total Operational Hr.)] x 100

Solar Power Plant PLF: 15-30 %
Wind Power Plant PLF: 25-40 %
Hybrid (Solar + Wind) Power Plant PLF: 35-45 %

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit.

Total Yearly Operational Hr. = 365 x 24 = 8760
SCADA Generation PLF % = [(32,04,400) / (2000 x 8760)] x 100 = 18.29 %
Meter Export Generation PLF % = [(31,95,550) / (2100 x 8760)] x 100 = 18.24 %

13) PAF (Plant Availability Factor)

PAF is the ratio of the actual operating hours of a power plant to the total scheduled operating hours during a given period.

PAF % = [No. of Actual Operational Hr. / No. of Total Operational Hr.] x 100

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview:

PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit.

Total Yearly Operational Hr. = No. of Day x 24 = 365 x 24 = 8760
Actual Yearly Operational Hr. = Total Yearly Operational Hr. – (Gride Down Hr. + Plant Down Hr.)
= 8760 – (33.28 + 96.36) = 8630.36

PAF % = (No. of Actual Operational Hr. / No. of Total Operational Hr.) x 100
= (8630.36 / 8760) x 100 = 98.52 %

14) MTBF (Mean Time Between Failure)

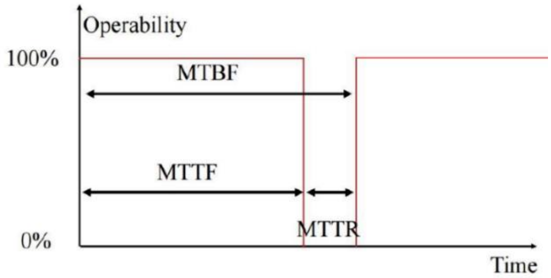
MTBF is the average time between system breakdowns.
MTBF = Total Plant Operational Hr. / No. of Breck Down
MTBF is good as high as possible. (Plant Total Hr.)

15) MTTR (Mean Time To Restore)

MTTR is the average time required to fix a failed component or device and return it to production status.
MTTR = Total Plant Down Hr. / No. of Breck Down
MTBF is good as low as possible. (Plant Down Hr.)

16) MTTF (Mean Time To Failure)

MTTF is a maintenance metric that measures the average amount of time a non-repairable asset operates before it fails.
MTTF = MTBF – MTTR
MTTF is good as high as possible. (Plant Running Hr.)



<u>Example</u>: Total Plant Operational 24 Hr., Total Plant Down 2.50 Hr. and 1 No. of Breck Down (Fault)

MTBF = Total Plant Operational Hr. / No. of Breck Down = 24 / 1 = 24 Hr.
MTTR = Total Plant Down Hr. / No. of Breck Down = 2.50 / 1 = 2.50 Hr.
MTTF = MTBF – MTTR = 24 – 2.5 = 21.5 Hr.

17) TLL (Transmission Line Loss)

TLL Unit {kWh} = (SCADA Generation {kWh} – Meter Export Generation {kWh})
TLL % = [(SCADA Generation {kWh} – Meter Export Generation {kWh}) / (SCADA Generation {kWh})] x 100

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit.

TLL Unit {kWh} = 32,04,400 – 31,95,550 = 8,850 kWh
TLL % = [(32,04,400 – 31,95,550) / (57,50,000)] x 100 = 0.15 %

18) RPL (Reactive Power {RKVAH} Loss)

RPL Unit {kWh} = Meter Import RKVAH Unit {kWh}
RPL % = [Meter Import RKVAH Unit {kWh} / Meter Export Generation {kWh}] x 100

<u>Example</u>: Total Yearly SCADA Generation of plant 32,04,400 kWh, Meter Export Generation 31,95,550 kWh, Meter Import RKVAH Unit 8,740 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Yearly Grid Fault (GF) 32.50 Hr., Force Major (FM) 0.78 Hr., Plant Schedule (S) Down 26.80 Hr., Plant Unschedule (U) Down 68.86 Hr. and Plant Not Operational Reason (NOR) 0.7 Hr., PPA 2.90Rs./Unit.

RPL % = [8,740 / 31,95,550] x 100 = 0.27 %

19) Opportunity Loss

Opportunity loss is defined as the difference between the optimal generation and the actual generation received from plant. Opportunity Losses are always calculated approximately.

In short opportunity loss is the loss incurred due to failure of not adopting the best possible course of action or strategy. Opportunity losses are calculated, separately for each plant of nature that might occur.

<u>Plant Opportunity Loss</u>: Breakdown, Shading, Soiling, Wiring Loss, Sunlight Reflection Loss, Derating of module or string, Preventive Maintenance etc.

<u>Grid Opportunity Loss</u>: Internal Grid – Breakdown, Preventive Maintenance, Testing, PSS Shutdown etc.
External Grid – Breakdown, Preventive Maintenance, Testing, Load Curtailment etc.

<u>Other Opportunity Loss</u>: ROW, Material Delay/Shortage, Force Major etc.

<u>Example</u>: Date 01-07-2023, SCADA Generation of Plant 11,800 kWh, Meter Export Generation 11,785 kWh, Meter Import RKVAH Unit 15 kWh, Installed Capacity of Plant 2 MW = 2000 kWh; Plant Overview: PlantA/Inv1/SMB1A-1D/M3888/1030.32kWh(DC)/1000kWh(AC) and PlantA/Inv2/SMB2A-2D/M4464/1182.96 kWh(DC)/1000kWh(AC), Grid Fault (GF) 0 Hr., Force Major (FM) 0 Hr., Plant Schedule (S) Down 0 Hr., Plant Unschedule (U) Down 2.50 Hr. and Plant Not Operational Reason (NOR) 0 Hr., Plant Operational 21.50 hr., Average Irradiation 5.9 W/m^2, PPA 2.90 Rs./Unit.

Plant Break Down 2.50 Hr., Grid Fault 0 Hr. and Plant Operational 21.50 Hr. (24 Hr. Day: 2.50 + 0 + 21.50 = 24)

Plant Operational Hourly Generation {kWh} = Plant Generation {kWh} / Plant Operational Hr.
= 11,800/21.50 = 548.83 kWh

Opportunity Loss Generation {kWh} = Plant Down Hr. x Plant Operational Hourly Generation {kWh}
= 2.50 x 548.83 = 1,372.07 kWh

Opportunity Loss Revenue {Rs.} = Opportunity Loss Generation {kWh} x PPA
= 1,372.07 x 2.90 = 3,979 Rs.

Therefore, approximation opportunity loss due to plant break down will be 1,372.07 kWh units or 3,979 Rs. revenue.

20) Solar Losses Summary:

Solar losses refer to the various factors that reduce the efficiency and output of a solar energy system, leading to a decrease in the amount of electricity it can generate. Several types of solar losses can occur.

Understanding and mitigating these solar losses are crucial for maximizing the efficiency and output of solar energy systems. Regular maintenance, proper system design, cleaning, and monitoring can help minimize these losses and improve the overall performance of solar installations.

1) Shading Losses: When shadows from surrounding objects, structures, or even nearby vegetation fall on solar panels, it reduces the amount of sunlight reaching the panels and thus reduces their output.

2) Soiling Losses: Dust, dirt, pollen, bird droppings, and other debris can accumulate on the surface of solar panels, blocking sunlight and reducing their efficiency.

3) Temperature Losses: Solar panels' performance typically decreases as their temperature increases. High ambient temperatures can reduce the efficiency of solar panels, leading to lower energy production.

4) Wiring and Electrical Losses: Resistance in the electrical wiring and connections within the solar system can lead to energy losses and decreased overall system efficiency.

5) Mismatch Losses: In some cases, not all solar panels in an array may perform at the same level due to manufacturing variations or partial shading. When panels are mismatched, the overall system efficiency decreases.

6) Dirt and Reflection Losses: The accumulation of dirt and dust on the front glass of the solar panels can create a reflecting surface, causing some of the sunlight to bounce off rather than being absorbed by the solar cells.

7) Angle of Incidence Losses: The angle at which sunlight strikes the solar panels affects their efficiency. Sunlight that hits the panels at oblique angles provides less energy compared to direct sunlight.

8) Inverter Losses: The Inverter, which converts the DC electricity generated by the solar panels into AC electricity used in homes or the grid, incurs some energy losses during this conversion process.

9) System Downtime: Any time the solar system is not operational, whether due to maintenance, repairs, or other issues, results in lost opportunities to generate electricity.

10) Degradation Losses: Over time, solar panels can experience performance degradation, where their efficiency slowly decreases due to exposure to environmental factors, including UV radiation and temperature fluctuations.

11) Operational Losses: Inadequate maintenance practices, equipment failures, and operational inefficiencies can lead to losses. Regular maintenance, cleaning, and prompt repairs are crucial to minimize these losses

Understanding and mitigating these solar losses are crucial for maximizing the efficiency and output of solar energy systems. Regular maintenance, proper system design, cleaning, and monitoring can help minimize these losses and improve the overall performance of solar installations.

21) Solar Plant Inspection Summary:

Sr. No.	Components	Solar Plant Inspection Summary
1	General	Ensure completeness of boundary fencing, surrounding land area road approaches etc.
		Check plant peripheral light pole with earthing, illumination.
		Check weather monitoring system (pyranometer, temperature sensor, wind van and wind anemometer or ultrasonic wind sensor etc.), network system etc.
		Check control office SCADA system, CCTV system, site reports, spare material inventory etc.
		Check plant cleanness, vegetation, painting, corrosion, fire fitting equipments etc.
2	PV Module and Mounting Structure	Check the module specification in accordance with the design simulation and that all installed modules are of the same characteristics.
		Check the module cleanness of dust, scratches, hotspot, cell discolour, module damage, glass broken, module burn, frame damage, over heated module (Due to temperature) etc.
		Check modules are well oriented in south or north direction by using compass (according to the hemisphere), by positioning the compass against the east or west edge of a module, inclination of the modules (tilt angle) using the inclinometer.
		Check and measure the voltage output from each string and ensure it's consistent with the design and that it's uniform across all the strings.
		Check arrays open circuit voltage and short circuit current.
		Check and ensure that every module is fastened to the structure at every bolt hole in a manner that is robust.
		Check module back side junction box, cable and MC4 connectors.
		Check mounting structure foundation, corrosion, array orientation, earthings, nomenclature sticker or paint, solar tracking system etc.
		Conduits and cables are adequately supported and ends are adequately sealed.
3	String Monitoring Box (SMB)	Check cable laying from string and array to SMB.
		Check SMB cable sealed conduit, copper lug, cable insulation, ferruling, gland, termination, SMB panel with structure, nomenclature sticker or paint etc.
		Check fuse protection, surge protection, contactor, switch etc.
4	Inverter Control Room (ICR)	Check Inverter control panel, Inspection board, Precaution board, ICR illumination etc.
		Check Inverter converter (IGBT) and capacitor panel.
		Check Inverter cooling system.
		Check Inverter power panel and ACB.
		Check auxiliary transformer panel.
		Check CRP (Control Relay Panel) panel for transformer protection.
		Check UPS (Uninterruptible Power Supply) and RTU (Remote Terminal Unit) panel.
		Check ICR fire extinguisher and first aid box.
		Check ICR surrounding earthing pits structure, GI earth road with connection, and earthing register value.
		Check SCADA Systems, Inverter area illumination, CCTV, air circulation, civil work etc.
		Check ICR all panels filter, cooling fan, light, blow out device, zest capsule, cable lopping, emergency switch, component status with connection.

If solar plant performance efficiency is down after 5 year (More than 1 % of each year) then must require Thermography Testing for PV Modules and Major electrical equipments.

Thermography Testing knows the real status of Degradation/Broken Module, Hot spot due to temperature or vegetation, Bypass diode issue, Underperforming string, Healthiness of equipments, Faults etc.

22) USS (Unit Substation) Inspection Summary:

Sr. No.	Components	USS Inspection Summary
1	General	Ensure completeness of civil work for yard assembly.
		Check USS danger board and CCTV board, door with lock.
		Check gravel and vegetation in yard area.
		Check light pole, Illumination of light, earthing and CCTV camera.
		Check earthing pits structure, GI earth road with connection, and earthing register value.
2	Fire & Safety	Check fire bucket and it's structure.
3	Conductor and OFC Cable	Ensure use of correct size of insulator, clamps, connection and stay wire.
		Check clamping of conductor tightness and orientation.
		Check clearance of conductor (P-P and P-E), Drop Out (DO) fuse etc.
		Check OFC cable stress absorber with tightness, OFC DB and OFC cable laying.
4	Isolator	Check level and alignment of busbar, housing assembly, greasing and flanges.
		Check clearance between phase to phase and phase to earth.
		Check operation of isolator for proper engagement of contacts during open and close.
		Check equipment earthing tightness.
5	LA	Check overall alignment, connection and earthing tightness.
6	CT	CT oil level/ leakage/ damage/ clearance/ live parts/ connection of cable/ earthing tightness.
7	PT	PT oil level/ leakage/ damage/ clearance/ live parts/ connection of cable/ earthing tightness.
8	CB	CB visual & mechanical inspection with alignment, tightness of connection with structure, top disk gap, tripping ckt., spring charge operation, operations (local and remote), earthing etc.
9	Control and Relay Panel	Check tightness of all connection, earthing etc.
		Check circuit wirings, relay, fuse, Ammeter, Voltmeter, Indicators.
10	Transformer	Check for oil level and leakage in main tank, conservator tank, HV and LV bushing.
		Check buchholz relay.
		Check oil leakage from gasket or cooling vents or pipes.
		Check for marshalling box and availability of oil in OTI/WTI pocket.
		Check earthing connection of main tank, LV neutral, radiator etc.
11	Meter	Check meter box with government seal, meter display, meter actual readings, indication etc.
12	UG Cable	Check insulation of cables, clamp, gland, lug and terminations tightness.
		Check power cable are laid in PVC conduits with tripoidal arrangements.
		Check all earthings connection tightness.

23) Line Inspection Summary:

Sr. No.	Components	Line Inspection Summary
1	General	Ensure completeness of civil work for pole and guy.
		Check surrounding land area and vegetation (Tree) and road approach etc.
		Check overall line crossing and guarding status.
2	Earthing	Check earthing strip or cable, earthing condition, earthing strip or cable green colour, welding condition etc.
3	Pole	Check pole marking status, danger board, anticlimbing armour etc.
		Check pole and channel conditions likes corrosion, tension, etc.
		Check bird protector condition.
4	Conductor and OFC Cable	Check conductor visually status likes stress, sagging, tightness, corrosion etc.
		Check conductor and jumper clearance condition (P-P and P-E), tightness.
		Check conductor damper and bird diverter(reflector) condition.
		Check OFC cable stress absorber with tightness, OFC DB and OFC cable laying.
5	Hardware Assembly	Ensure use of correct size of insulator, clamps, conductor and stay wire.
		Check jumper/lug/connection condition, clamping of conductor tightness and orientation.
		Check overall hardware tightness, corrosion condition etc.
6	Insulator	Check Insulator condition.
		Check Insulator with connection tightness.