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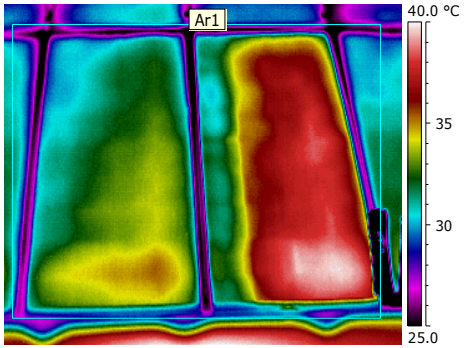

PV System Availability: Definitions, Applications and Challenges

Solar Asset Management North America

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Why *Availability*, how is it defined?

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- **IEEE St. 762-2006** – …the fraction of time in which a unit is capable of providing service and accounts for outage frequency and duration
- **Inverter mfg. 2010** – Probability that a system will be operable when called upon
- **Other** – The proportion of time that a system is in an operable and usable state over a specified time period that the system is intended to be used
- **Operational Availability** – The proportion of time that a system is in an operable and usable state over a specified time period that includes any necessary corrective maintenance, preventative maintenance, or any other logistics downtime required for the system to remain either operable or recover from inoperability (failure)
- **Inherent Availability** – The proportion of time that a system is in an operable and usable state over a specified time period that only includes failures and repairs inherent to the design of the system and excludes preventative maintenance or any other logistics downtime

SNL Focus – *Availability* for O&M contracts and reliability analysis

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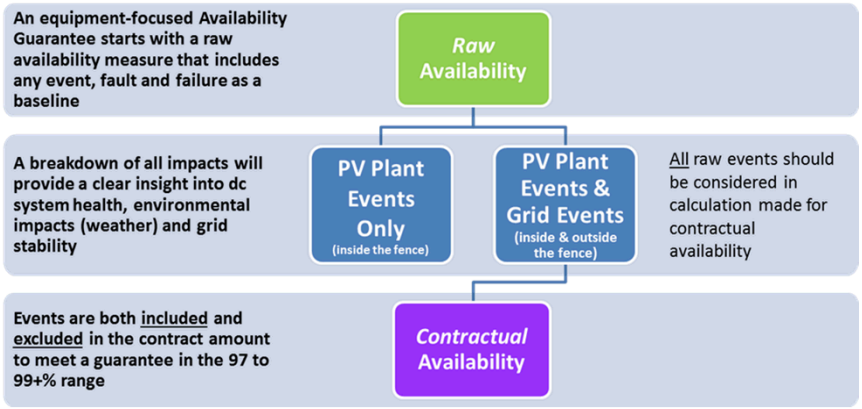
- **Methods, equations and classifications for collecting data to determine Availability**

Raw Component Availability

$$A_{raw\_i} = 1 - \frac{DownTime_i}{TotalTime_i}$$

Raw System Availability

$$A_{raw\_sys} = \frac{\sum_{i=1}^{n} A_{raw\_i} \times NP_i}{\sum_{i=1}^{n} NP_i}$$

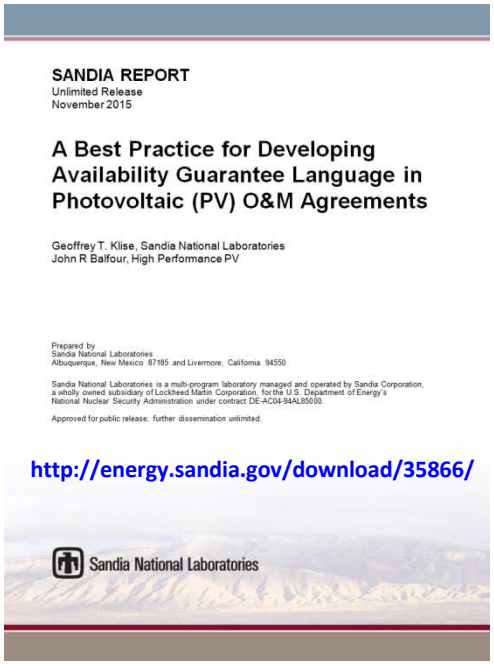


Irradiance-Weighted Raw Availability

$$A_{raw\_irr} = 1 - \sum \left(\frac{DownTime_{i\_irradiance}}{\sum irradiance} \right)$$

Contractual Availability

$$A_{exclude\_i} = 1 - \frac{DownTime_i - ExcludedTime_i}{TotalTime_i - ExcludedTime_i}$$



New availability data collection & analysis classification

Data Area/System Class	A	B	C
Data Granularity	High	Medium	Low
Components measured and potentially subject to availability calculation	Inverter, combiners (ac, dc), disconnects, modules, transformer, DAS, SCADA	Inverter, Combiners (dc), disconnects, DAS	Inverter
Necessary Instrumentation	DAS, SCADA, POA irradiance, Utility grade meter, inverter	DAS, SCADA, inverter, irradiance	DAS, inverter
Timestep	1 to 15 minutes	15 minutes	15 minutes
External Grid Events	Grid outage, curtailment, grid support	Grid outage, curtailment	Grid outage

DC Overbuild & Availability

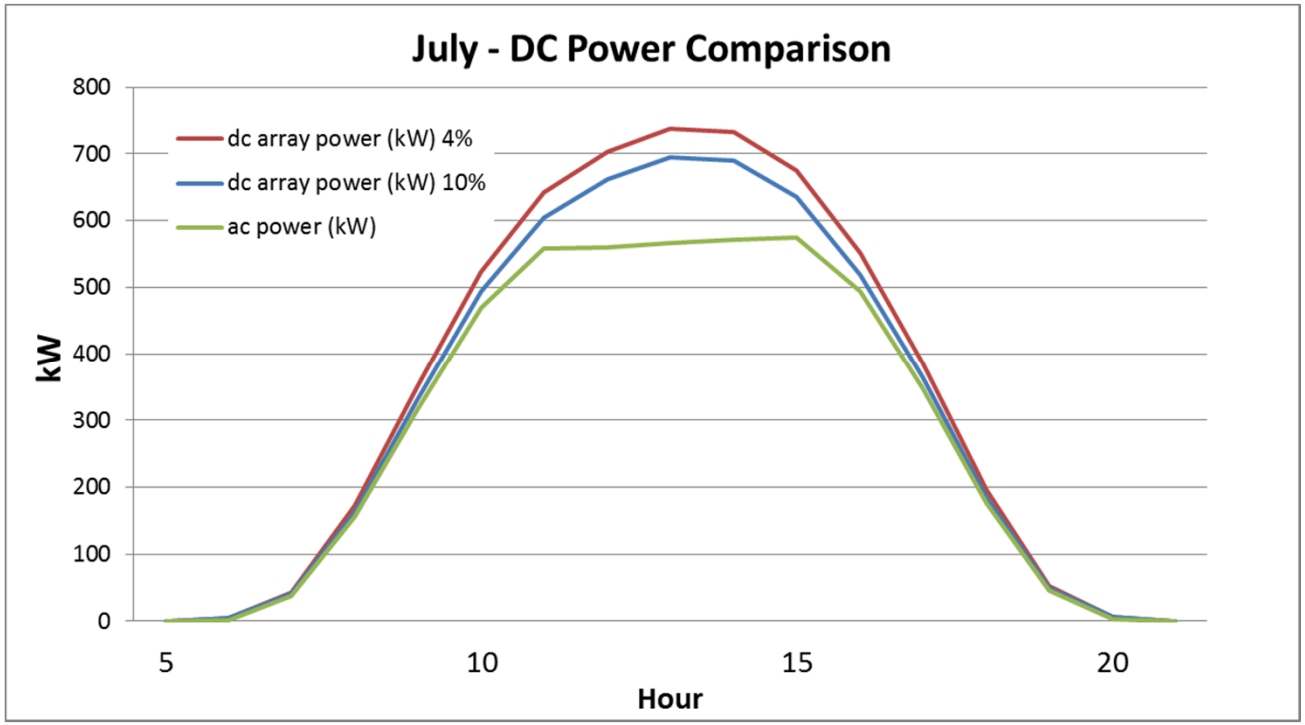
- Why Overbuild?
  - Interconnection limit
  - Good PPA price for peak demand periods
  - Mitigate cloud variability
  - Lower DC equipment cost
- O&M Working Group Concerns:
  - Impact to equipment reliability
    - Warranty concerns – operating out of spec.
  - O&M services can be less frequent
  - Lack of visibility into DC health

Impact to contractual obligations if high availability is specified

  - Highly reliable DAS necessary for monitoring
  - Wasted energy – economical to store?
    - Losses estimated at 2% to 16%, with Overbuild of 20% to 80% DC to AC

DC Overbuild & Availability

Modeled 1MW PV system in Phoenix, AZ. 1.7 DC to AC ratio. 4% DC loss (wiring, soiling, mismatch, etc).

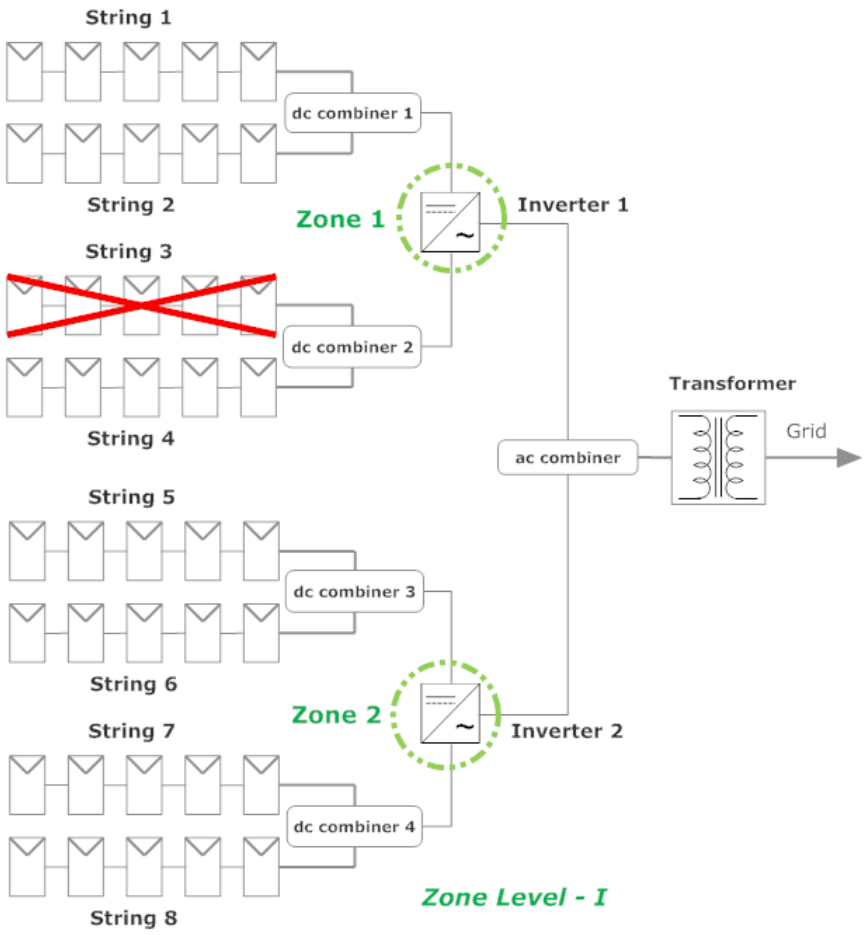


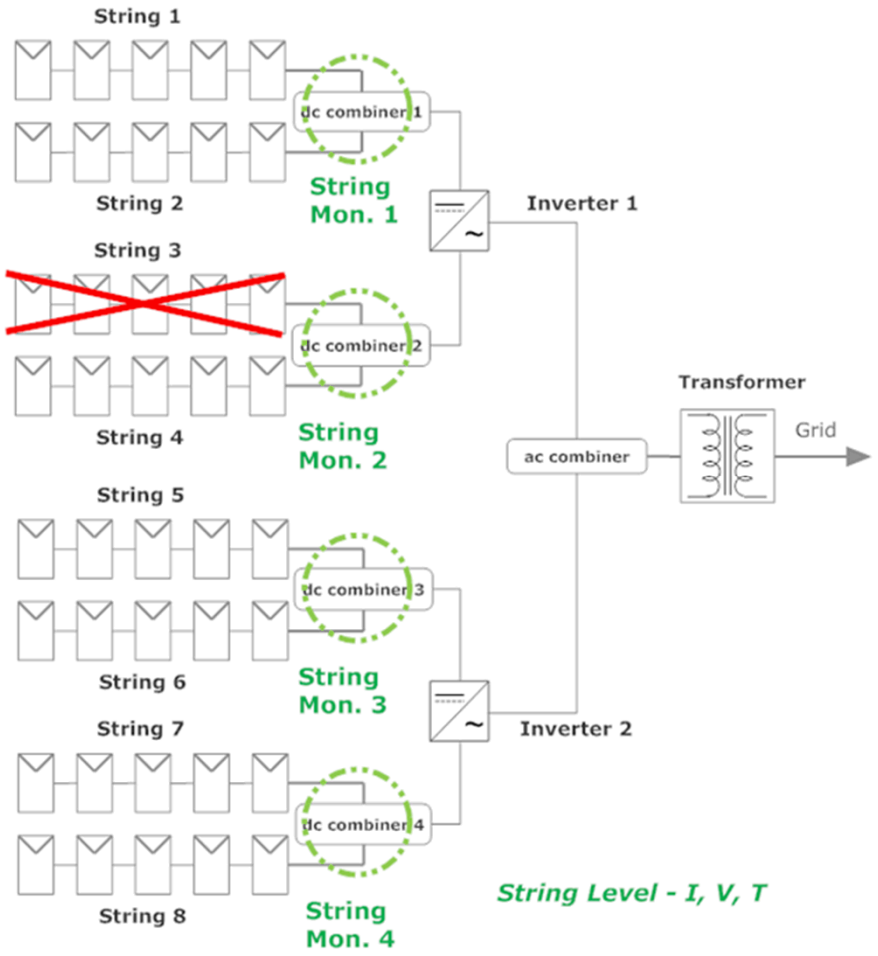
- **Additional 6% power loss due to DC outages does not impact AC power output**
- **AC power will suffer after 10% total DC power loss, in this example**

Inverter availability (as a proxy for system availability) is 100%, but DC availability may be much lower

DC Availability - Monitoring Differences

1.7 DC to AC ratio Wiring issue at combiner – Lose string visibility





Inverter Availability: 100%

DC Combiner Availability: ?

Inverter Availability: 100%

DC Combiner Availability: 95%

DC Overbuild & Availability - Thoughts

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- High *inverter-only* availability reduces visibility of most DC side issues
  - Are O&M providers on the hook for DC side issues if they have no visibility other than quarterly or semi-annual inspections?
  - Assigning availability to other DC components needs to be backed up with monitoring *on* or *most proximate to* that piece of equipment
- Reconcile **performance guarantee** with **availability guarantee**
  - DC energy loss conceals equipment issues even when AC targets are met
- Does the lack of accurate *non-operational* DC equipment data make it harder to make module or BOS warranty claim?