### Effects of Reactive Power on Photovoltaic Inverter Reliability and Lifetime

Ramanathan Thiagarajan, Adarsh Nagarajan, Peter Hacke, and Ingrid Repins

National Renewable Energy Laboratory, Golden, CO, 80401, USA

---

**Introduction**

- An inverter subsystem is critical for the overall PV system reliability.
- An inverter system receives the largest amount of service calls for operation and maintenance [1].
- Physics of failure assessment using thermal cycling is used for determining overall system reliability and lifetime.
- Mission profile of ambient temperature and solar irradiance translates into junction temperatures of power switches.
- New grid codes [2] require PV inverters to provide reactive power support.
- A mission profile approach was used to study the impacts of reactive power on the inverter system reliability and lifetime.

**Workflow used to calculate lifetime of inverters**

1. Choose inverter topology
2. Datasheets, parameters, and values of switches, capacitors, and resistors
3. Develop loss model and thermal model in PLECS
4. Validate with hardware results
5. Develop electrothermal average model
6. Import mission profile for a year (Ambient temperature, solar irradiance)
7. Obtain yearlong values of junction temperature of switches
8. Use rain flow counting to identify number of cycles for each difference in junction temperature
9. Apply data from rain flow counting in the lifetime model of the inverter
10. Include the effect of reactive power by operating the inverter at same mission profile at non-unity power factors
11. Estimate lifetime of the inverter

---

**Development of in-house inverter**

- Two stage inverter rated at 1kW, with a synchronous DC-DC boost converter and H-bridge DC-AC inverter.
- Inverter designed to operate in grid connected mode and has capability of reactive power support.

**Results of electrothermal model**

- Temperature measurements from the simulation verified with thermocouple measurements on the power switches of in-house inverter.
- The temperature values from simulation matches the hardware measurements within 1°C accuracy at steady-state.
- Model was validated by placing in-house inverter inside thermal chamber.
- Inverter was operated at 500W in ambient temperatures of 25°C, 35°C, and 45°C and hardware results matched simulation values.

**Lifetime model**

- Rain flow counting used to record the number of device cycles, \( N_f \), under each difference in junction temperature, \( \Delta T_j \).
- A simplified Coffin-Manson model used to estimate the number of cycles to failure, \( N_f \):
  \[
  N_f = a \times (\Delta T_j)^n \tag{1}
  \]
- \( N_f \) is related with the \( N_i \) to estimate cumulative damage, \( Q \) for various \( \Delta T_j \):
  \[
  Q = \sum_{i=1}^{n} \frac{N_i}{N_i} \tag{2}
  \]
- The reciprocal, \( \frac{1}{Q} \), gives the number of mission profiles the device can survive, defined as Remaining Useful Lifetime.

**Impact of reactive power**

- Phoenix TMY reduced order model was repeated for non-unity power factors of 0.8 p.u. to 0.95 p.u.
- Results showed inverter lifetime decreasing as power factor moves away from unity.

**Conclusions**

- Reduced order electrothermal model was developed from detailed switching model to translate mission profile data into junction temperature of switches.
- Reduced order model was repeated for non-unity power factors.
- Inverter lifetime reduces as the power factor moves away from unity.

**References**

