PV Inverter Failures Cause AC Breaker damage – Power Quality

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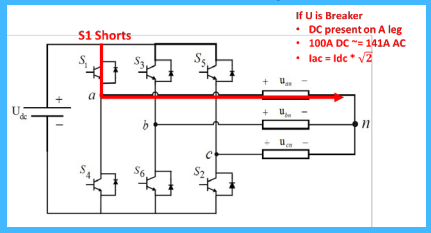
Failure Progression

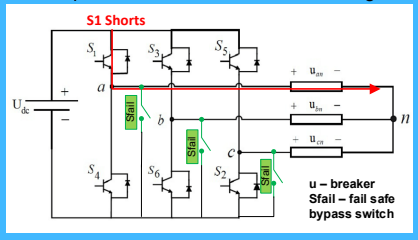
1. PV String Inverter Fails Catastrophically.
   a. Switch network shorts through at least 1 pole.



3. Replacement Inverter Installed.
4. Power Quality Issues Cause Intermittent Inverter Drop Out.

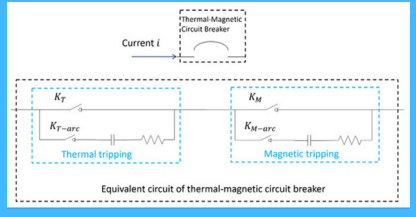
Inverter Types – String <150kW

- May not have failure if safeguard switching installed (S fail below).
- Would prevent DC current from contacting AC bus.



Breakers – AC Molded Circuit Breaker

- 100KA fault current, 175A nominal trip point.
- Internal components damged from DC current.



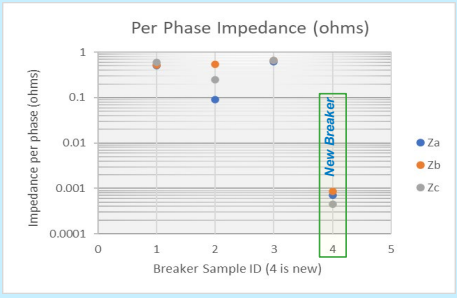
[1] Lei C, Tian W. Probability-Based Customizable Modeling and Simulation of Protective Devices in Power Distribution Systems. *Energies*. 2022; 15(1):199. https://doi.org/10.3390/en15010199

Long-Term Goals

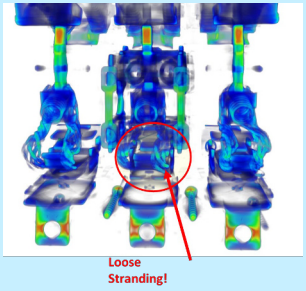
- Help system owners identify power quality issues and origins.
- Help Inverter and/or Circuit Breaker Manufacturers develop safer failure modes.
- Develop addendums to standards for failure testing of breakers and inverters.

Breaker Data

Breaker Pole Impedance Testing – compared to new (**sample #4**)
- Damaged Pole Resistances 10-100 times higher.
- Measured Impedance also 10-100 times higher.



X-ray imaging shows unusual loose stranding of main conductors internal to breaker pole connections.



Harmonic Model Analysis & Tests (Power Quality and Impedance)

- Power drop across breakers increases heat, changes impedance parameters and could cause fire or other damage.

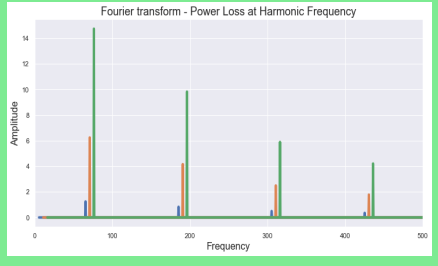
$$P(t) = V * I * \cos(N * \omega * t + \Theta)$$

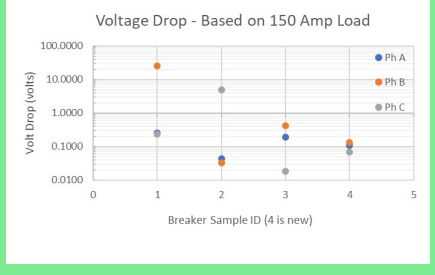
N = order of harmonics
ω = center frequency (radians)
t = time

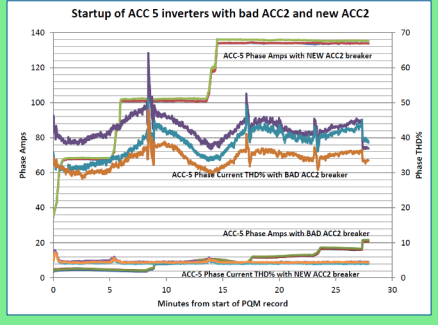
$$P(t) = \sum_{1}^{N} I^2 * z * \sin(N * \omega * t)$$

N = order of harmonics
ω = center frequency (radians)
t = time

- **Voltage and Current Harmonics** Small changes in impedance cause significant harmonic power increase.







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