A Deep Dive Into BESS Arc Flash

Ian A. Hutt, P.E., PMP - Electrical Studies Director

Commonwealth

Arc Flash Overview

Arc resulting from an electrical fault.

Extreme heat and violent explosions can occur.

Danger zone can be very large for high-current faults.

IEEE 1584 provides empirical data-derived calculation.

Incident energy levels are generally a function of I^2T, although IEEE 1584 has mitigating factors.

How is BESS Arc Flash Different?

Very high DC fault currents

- Due to high-energy density in the Li-Ion batteries.
- Many parallel strings for desired voltage.
- Challenge to get equipment wth appropriate ratings such as over 100 kA.
- Central inverter designs are the worst on this issue.

High AC arc flash at inverter terminals

- Inverter manufacturers spec most BESS GSU transformers.
- Transformers are large with many inverters connecting to one to save cost.
- Manufacturer selects fuses with protection (not arc flash) in mind.
- Arc flash can reach 50-80 Cal/cm^2 at inverter AC terminals and GSU secondary terminals.

Dangers:

- Impossible to de-energize BESS.
- Enclosed space and limited mobility to escape faults.

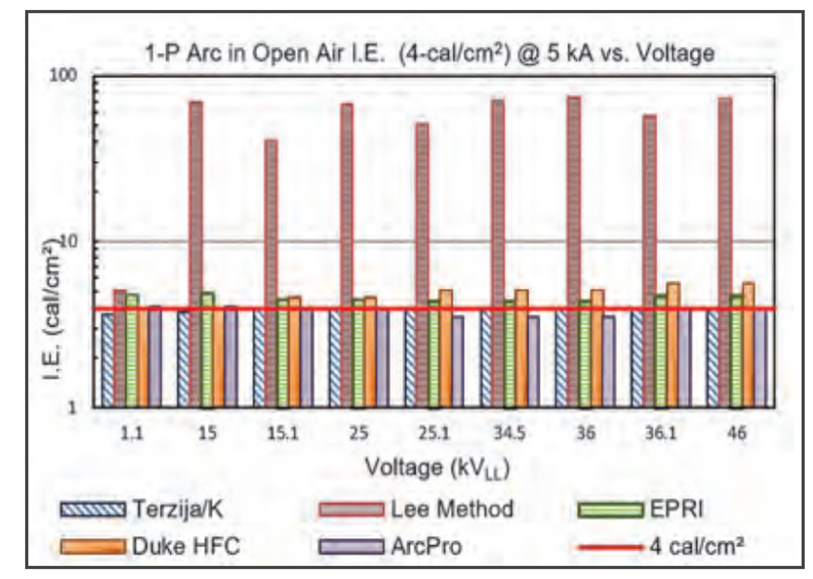
Methods of Analysis: Transient, Various AF Formulas

AC calculation methods

- LV Below 15 kV (IEEE 1584)
- MV above 15 kV (Lee method, ArcPro, ETAP ArcVault, EPRI, Terzija/Konglin, Duke Heat Flux Calculator)

DC calculation methods

- Steady State (NFPA 70E)
- Transient (EMTP-RV transient model of the DC circuit including inductance & capacitance determines the DC fault current rise).



Typical BESS Site Hazard Levels

West Texas 40 MW Li-Ion BESS Study

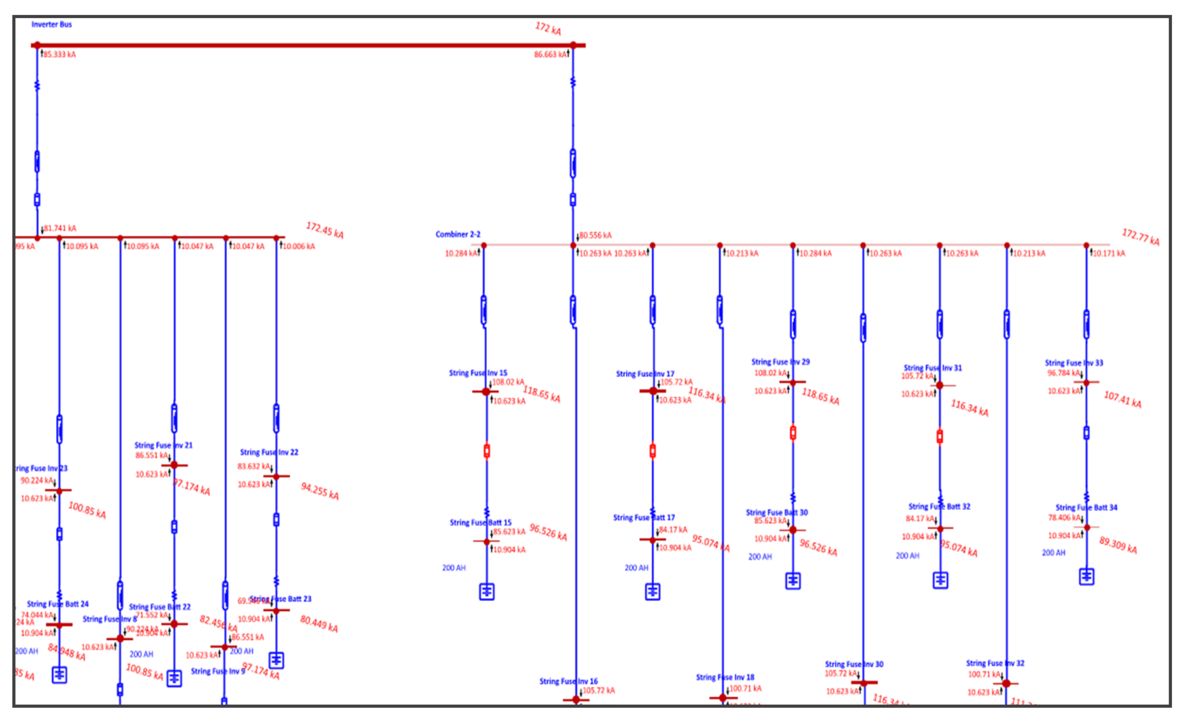
(20) 2.475 MW (operated De-rated) inverters with 2-hour total capacity.

Transmission-connected facility with a 34.5 kV connection to a 500 MW solar facility connected ultimately at 345 kV.

Prospective DC fault currents exceeded 173 kA at the inverter.

Prospective combiner fuse fault currents exceeded 87 kA.

Prospective string fuse fault currents exceeded 86 kA.



How Can We Help With This Problem?

Recommend rated devices

- Perform early calculations showing worst case equipment ratings.
- Get involved early in procurement to select the correct devices.
- Have device manufacturers certify equipment performance for our application.
- Form strategies to reduce fault current.

Perform Transient Short-circuit Studies

- Review current limiting function of devices against DC rise.
- If current is limiting, state maximum fault currents seen by protective devices and equipment.
- Being site-specific, the DC circuit changes slightly for each project.

Mitigation

Faster fuses (requires DC transient analysis)

Longer cables

- Can lower arc flash, but adds losses.
- Making them uniform so the short runs match the long runs.

Early design

- Higher DC voltage.
- Lower energy density per inverter.

Protective Devices at BESS Sites

AC

- Relaying, breakers, and fuses
- 10-15ms typical time constant

DC

- Fast burn fuses
- Time-domain ratings
- 500us available time constant

Current Limiting Devices: *High Currents*

DC fuses are super fast-acting.

- In AC terms, we can use cycles at 60 Hz as a reference.
- Most DC string fuses are very fast with total clearing times at 500 us (1/32 of a cycle).

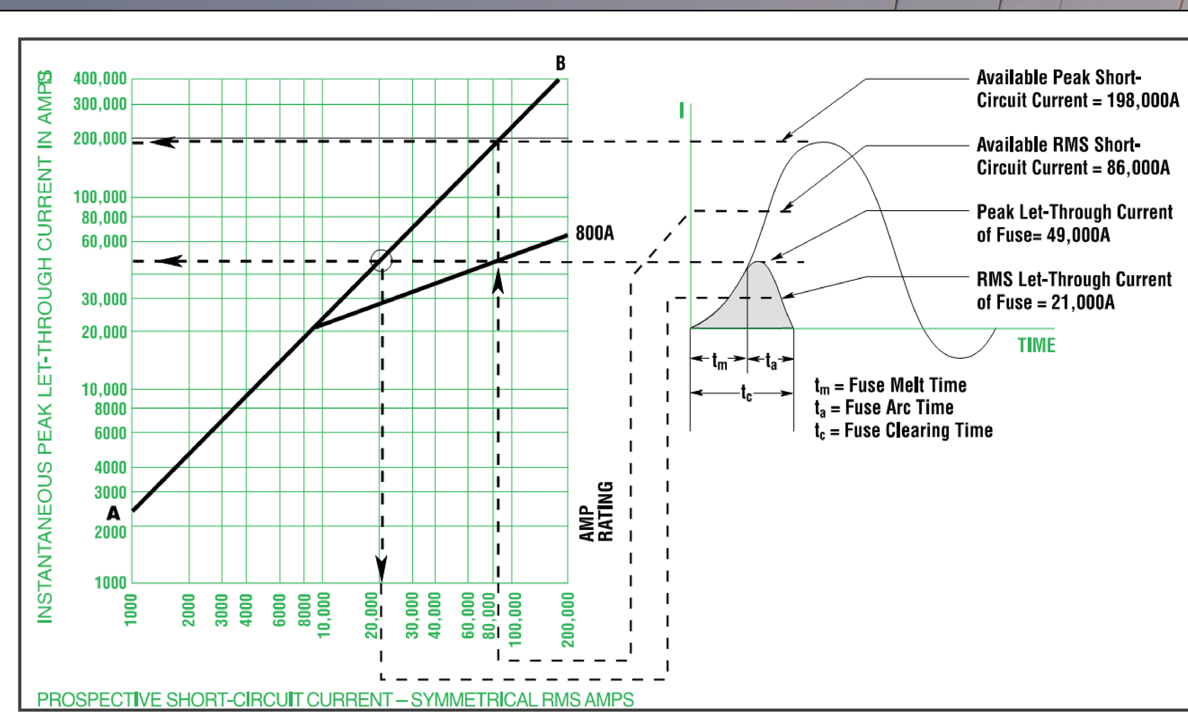
DC rise can be as fast as 500 us depending on where in the circuit.

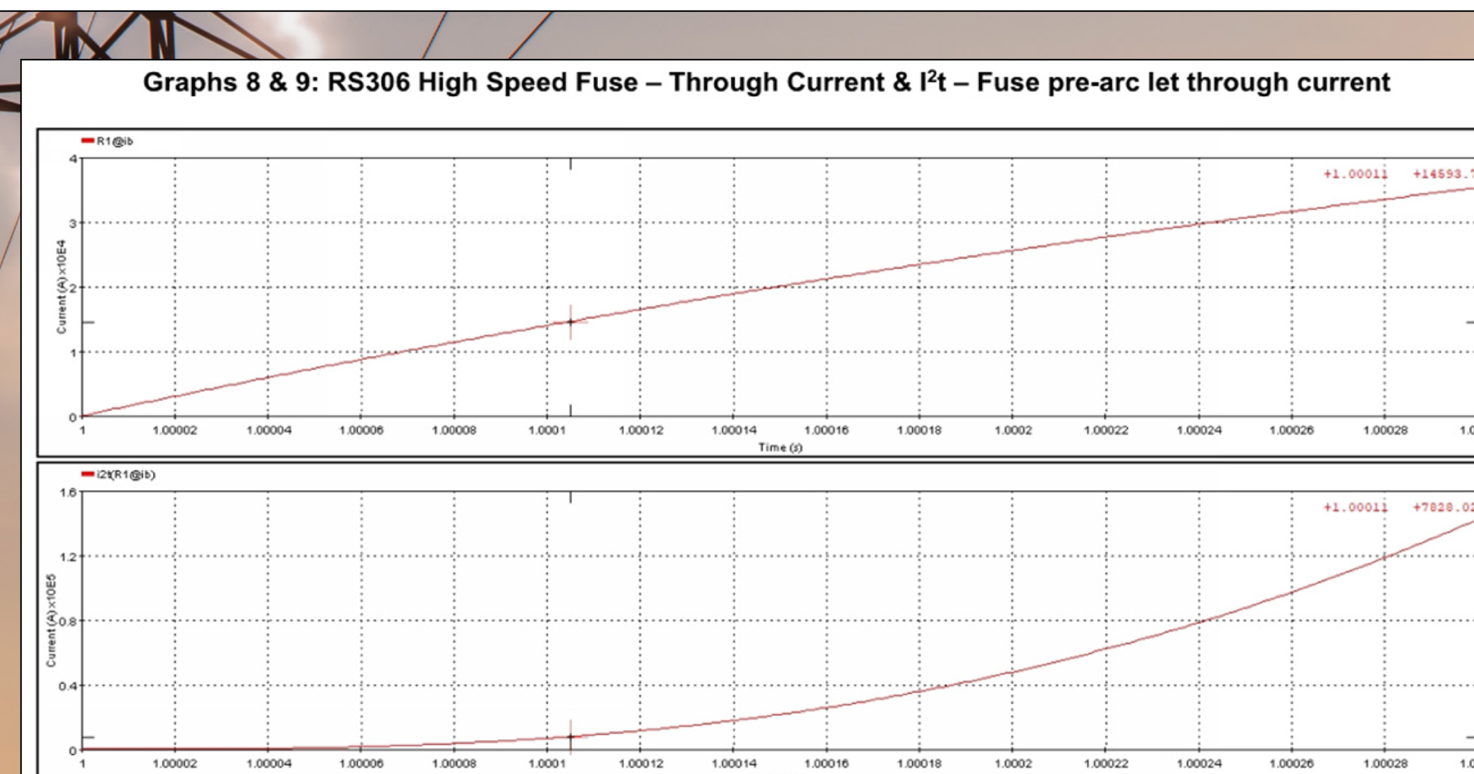
This race against fuse clearing time and DC rise starts the discussion of a current limiting fuse.

Protective Device Considerations

Is equipment rated to handle these high currents?

- Maximum for most DC fuses is 50 kA
- Time Constant of BESS DC systems 0.1-1 ms. (Time constant of AC system is >10 ms)





Prospective DC Fault Current vs. Transient DC Arc Flash Analysis

At Inverter

- Prospective 125kA
- Transient 15kA limited by string fuses

At Combiner

- Prospective 125kA
- Transient 15kA limited by string fuses

At String Fuse

- Prospective 92kA
- Transient 15kA limited by string fuses

At Battery

- Prospective 10.9kA
- Transient 10.9kA limited by string fuses

At Inverter - Arc flash incident energy

- Prospective 2.61 Cal/cm2
- Transient 0.02 Cal/cm2

At Combiner - Arc flash incident energy

- Prospective 2.61 Cal/cm2
- Transient 0.02 Cal/cm2

At String Fuse - Arc flash incident energy

- Prospective 1.92 Cal/cm²
- Transient 0.02 Cal/cm²

At Battery - Arc flash incident energy

- Prospective 45.5 Cal/cm²
- Transient 45.5 Cal/cm²

MAKE A POWERFUL DIFFERENCE.