Commonwealth

BESS WEBINAR

A DEEP DIVE INTO BESS ARC FLASH

Aug 2022

INTRODUCTION

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- 15 years in electric power
- 5 years in renewables, BESS, and microgrids
- 15+ BESS Arc Flash projects completed
- Planning and protection background
- Electrical Studies Director including NERC compliance

ARC FLASH OVERVIEW

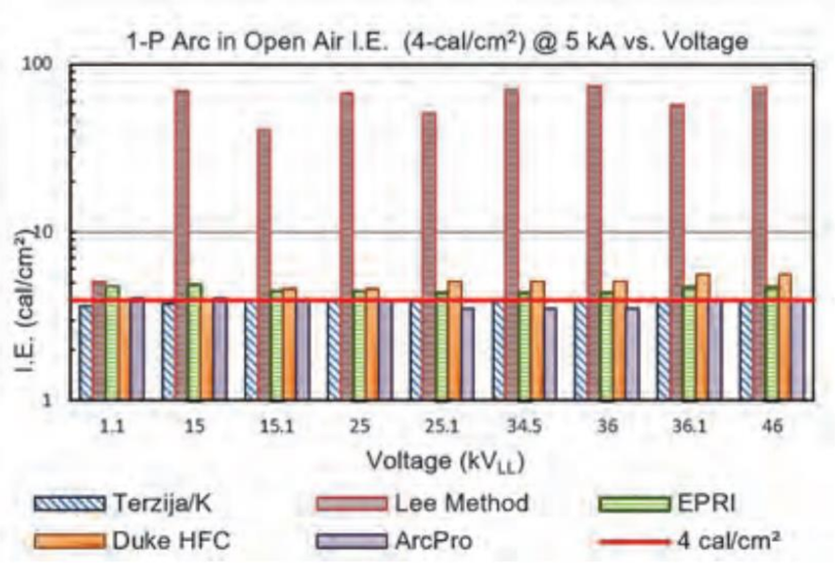
- Arc resulting from an electrical fault
- Capable of producing extreme heat and violent explosions
- Danger zone can be very large for high current faults
- Empirical data derived calculation is given by IEEE 1584
- Although IEEE 1584 has mitigating factors, in general, incident energy levels are a function of I^2T

HOW IS BESS ARC FLASH DIFFERENT?

- VERY HIGH DC FAULT CURRENTS
  - Due to high energy density in the Li-Ion batteries, and many parallel strings to get the desired voltage fault currents can be very high.
  - This can be a challenge to get equipment with appropriate ratings, i.e. over 100 kA.
  - Central inverter designs are worst on this issue.
- HIGH AC ARC FLASH AT INVERTER TERMINALS
  - Most BESS GSU transformers are spec'd by the inverter manufacturers.
  - Most transformers are large to save cost, sometimes with many inverters connecting into one transformer.
  - Fuses are selected by transformer manufacturer with protection in mind but not arc flash.
  - Arc Flash can reach 50-80 Cal/cm^2 at inverter AC terminals and GSU secondary terminals.
- Dangers
  - Not possible to de-energize BESS
  - Enclosed space and limited mobility to escape faults

METHODS OF ANALYSIS (TRANSIENT, VARIOUS AF FORMULAS)

- AC calculation methods
  - LV Below 15kV
    - IEEE 1584
  - MV above 15kV
    - Lee method/ArcPro/ETAP ArcFault, 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 and capacitance determines the DC fault current rise.



High-Voltage Arc Flash Assessment and Applications, Part 1
ALBERT MARROQUIN, ABDUR REHMAN, AND ALI MADANI

TYPICAL HAZARD LEVELS AT BESS SITES

- West Texas 40MW BESS
  - Commonwealth designed and studied a 40 MW Li-Ion BESS in west Texas.
  - The arrangement consisted of (20) 2.475 MW (operated De-rated) inverters with a total hourly capacity of 2 Hrs.
  - 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 OUR CUSTOMERS WITH THIS PROBLEM?

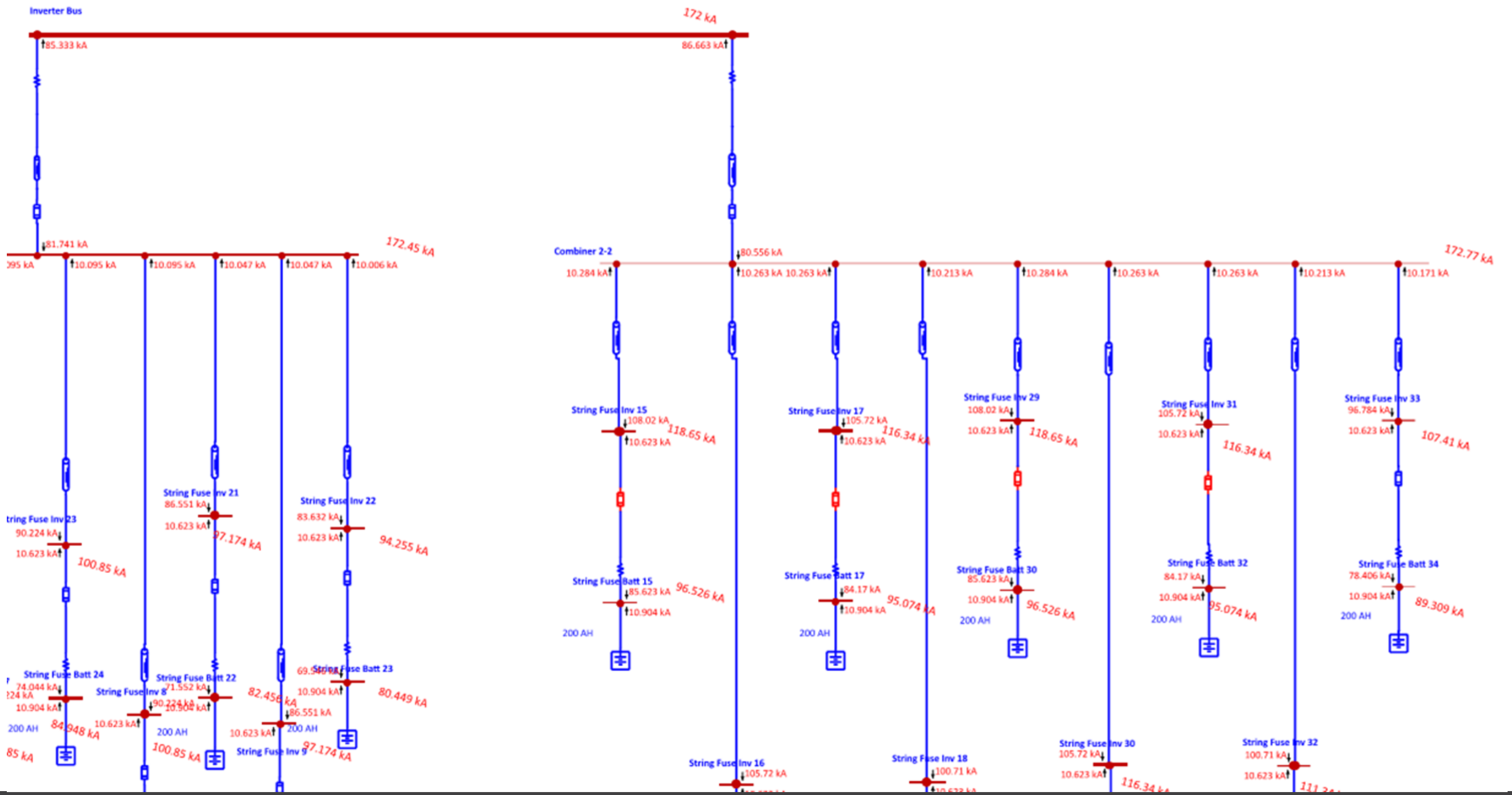
Recommend rated devices

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

Perform Transient Short Circuit Studies

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

WEST TEXAS 40MW BESS



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

TYPICAL PROTECTIVE DEVICES AVAILABLE AT BESS SITES

- AC
  - Relaying, breakers, and fuses
  - 10-15ms typical time constant
- DC
  - Fast burn fuses
  - Time-domain ratings
  - 500us available time constant

Manufacturer : SOCOMEC S.A. 67235 BENFELD France

Please find here after our SCCR analysis of your DC ESS application:

At the switch level:

- Max 455kA prospective SCCR
- 6x700A fuse, per fuse i^2t pre= 290.10^3 A^2s, i^2t tot= 1900.10^3 A^2s
- Fuse PN: 90 447 25.700
- L/R=0.5ms
- No capacitive

DC PROTECTIVE DEVICE OPTIONS

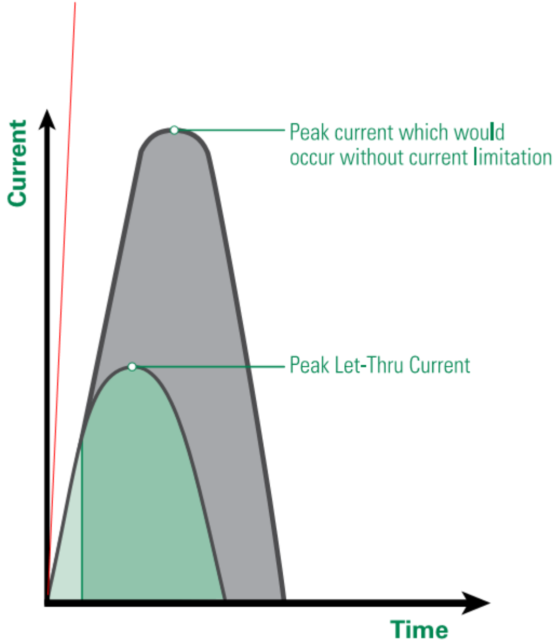
Certain manufacturers are developing high current devices

- Sinofuse has developed a string fuse with a DC rating of 250 kA
  - RSZ307-3, 1500VDC
- SIBA has developed DC fuses with up to 170 kA combiner fuses.
  - SIBA SQB-DC94 aR DC 1200V
- Mersen has developed a line of fuses with DC ratings of 100 kA
  - Mersen Protistor 72 aR 1200VDC(IEC)
- Bussmann has developed a line of fuses with DC ratings of 90 kA
  - Eaton BUSSMANN SERIES HIGH SPEED SQUARE BODY FUSES 170M4144
- Sinofuse has developed a string fuse with a DC rating of 85 kA
  - RS306-1-T5Z-250A 1250V-D

CURRENT LIMITING DEVICES

What can be done about high currents?

- The DC fuses are super fast acting.
  - Since we typically think in AC terms, we can use cycles at 60 Hz as a reference.
  - Most DC string fuses are very fast, with total clearing times around 500 us (this is 1/32 of a cycle)
- DC rise can also be fast, depending on where in the circuit as fast as 500 us



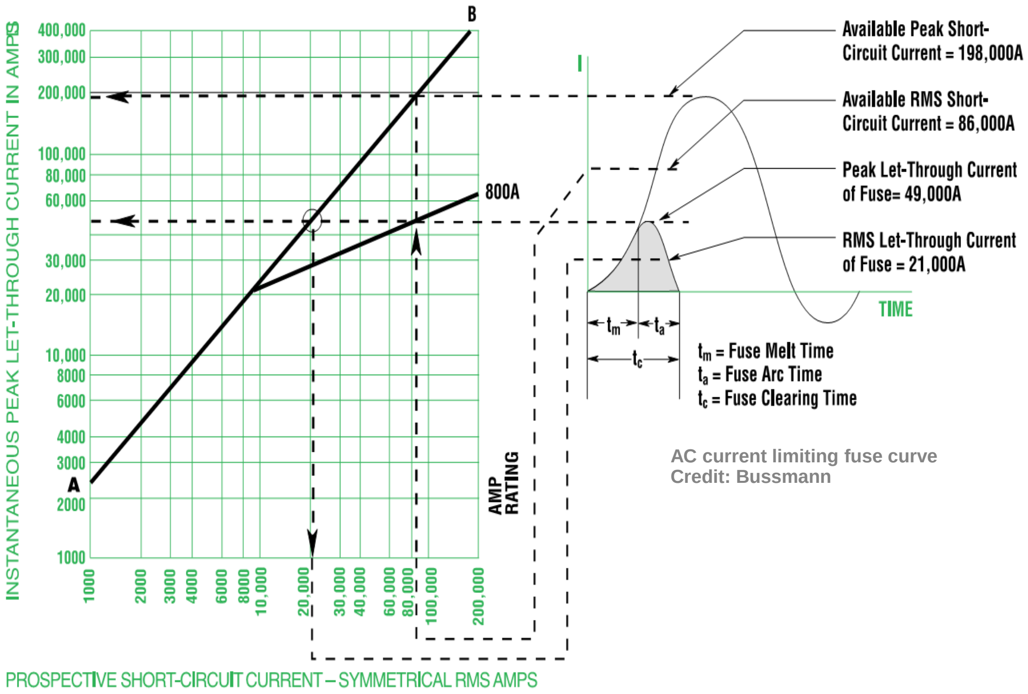
Credit: LIttlefuse

- This race against fuse clearing time and DC rise is where we can discuss the possibility of a current limiting fuse

PROTECTIVE DEVICE CONSIDERATIONS

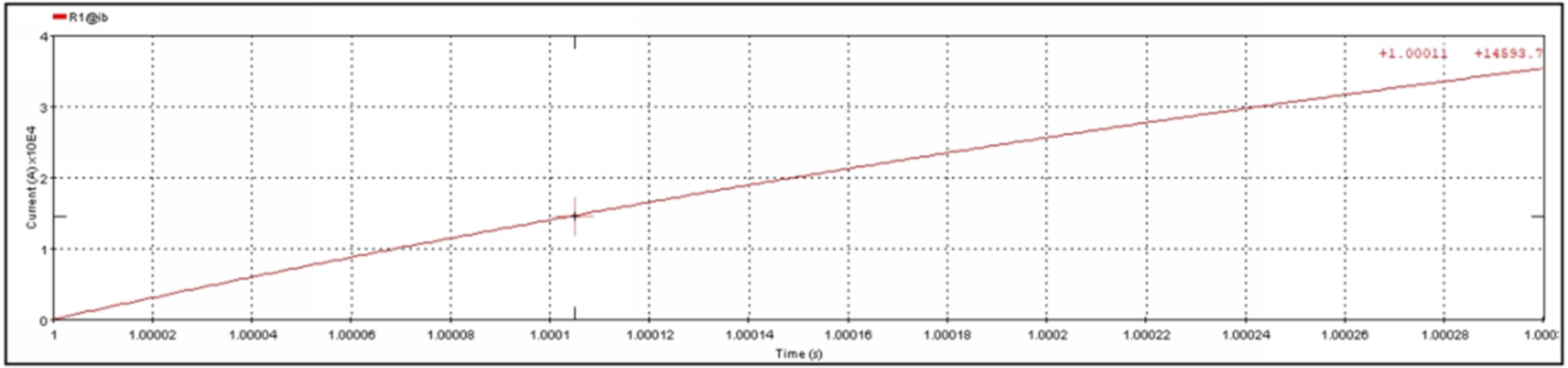
Is equipment rated to handle these high currents?

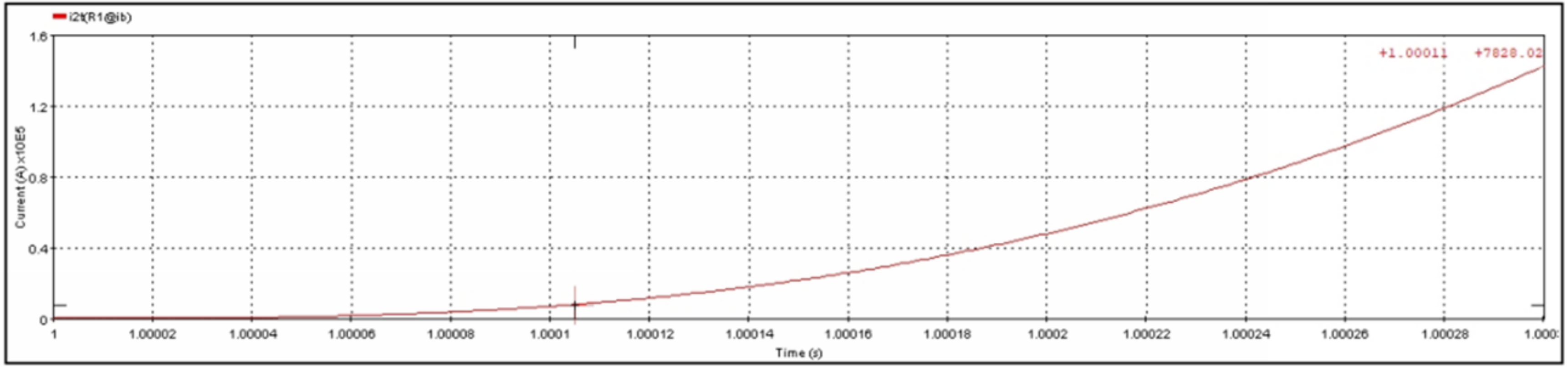
- The maximum for most DC fuses is 50 kA
- The time constant of BESS DC systems is typically 0.1 – 1 ms
  - The time constant of AC systems is usually greater than 10 ms



AC current limiting fuse curve
Credit: Bussmann

Graphs 8 & 9: RS306 High Speed Fuse – Through Current & I^2t – Fuse pre-arc let through current





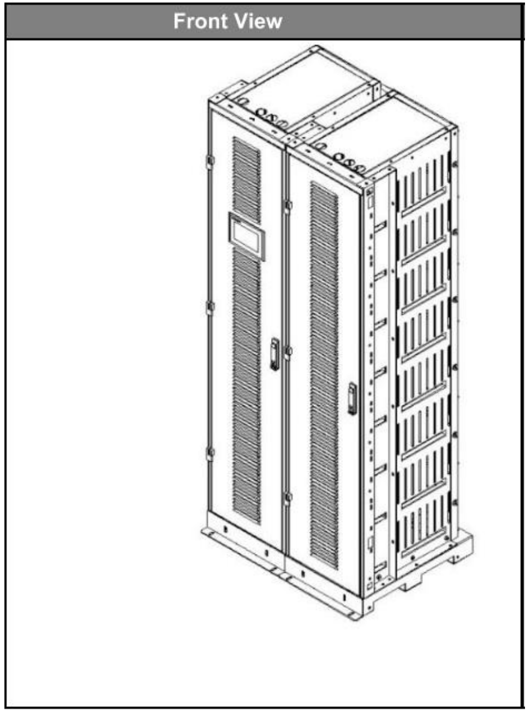
COMPARISON OF PROSPECTIVE VS TRANSIENT DC ARC FLASH ANALYSIS

- At the inverter
  - Prospective DC fault current of 125kA
  - Transient DC fault current of 15kA, limited by the string fuses
- At the combiner
  - Prospective DC fault current of 125kA
  - Transient DC fault current of 15kA, limited by the string fuses
- At the string fuse
  - Prospective DC fault current of 92kA
  - Transient DC fault current of 15kA, limited by the string fuses
- At the battery
  - Prospective DC fault current of 10.9kA
  - Transient DC fault current of 10.9kA, limited by the string fuses

- At the inverter
  - Arc Flash Incident Energy with prospective DC fault current of 2.61 Cal/cm^{2}Arc Flash Incident Energy with transient DC fault current of 0.02 Cal/cm^2
- At the combiner
  - Arc Flash Incident Energy with prospective DC fault current of 2.61 Cal/cm^{2}Arc Flash Incident Energy with transient DC fault current of 0.02 Cal/cm^2
- At the string fuse
  - Arc Flash Incident Energy with prospective DC fault current of 1.92 Cal/cm^2
  - Arc Flash Incident Energy with transient DC fault current of 0.02 Cal/cm^2
- At the battery
  - Arc Flash Incident Energy with prospective DC fault current of 45.5 Cal/cm^2
  - Arc Flash Incident Energy with transient DC fault current of 45.5 Cal/cm^2

FUSIBLE LINKS BETWEEN BATTERY MODULES

- Arc flash levels without fusible links on the battery modules can exceed 40 Cal/cm^2. This is because the full energy of the entire battery stack will discharge all of it's current with no protective device to interrupt.
- Many battery manufacturers are currently stacking battery modules in series using solid bus bar connections.
- Adding fusible links on at least one polarity of the series battery connections will reduce arc flash levels from 40 Cal/cm^2 to approximately 4 Cal/cm^2 for a fault on the worst case string fuse control box.
- This reduction is caused by one battery module feeding the fault current at a much lower voltage than the total series battery stack.



Credit: Narada Batteries

MAKE A POWERFUL DIFFERENCE.

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