DC Arc Flash Calculations for Solar Farms

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DC Arc Flash Calculations for Solar Farms

- Method described in NFPA 70E and CSA Z462-12
- Method for photovoltaic cells
- Differences between the two methods

DC Arc Flash Calculations for Solar Farms

Review of Basic Concepts – Common for Both Methods

Arc Energy

$E = P_{arc}\ t_{arc}$

Incident Energy

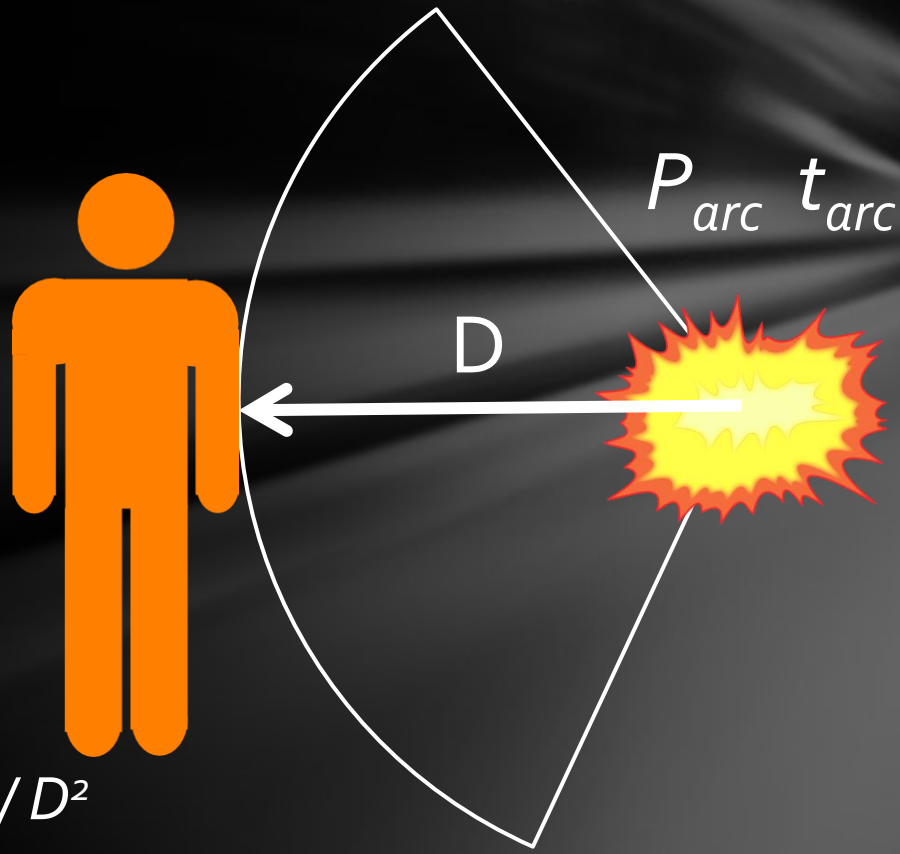
$IE = P_{arc}\ t_{arc} / Area$

Surface of the Sphere

$Area = 4\ \boldsymbol{p}\ D^2$

Maximum Incident Energy

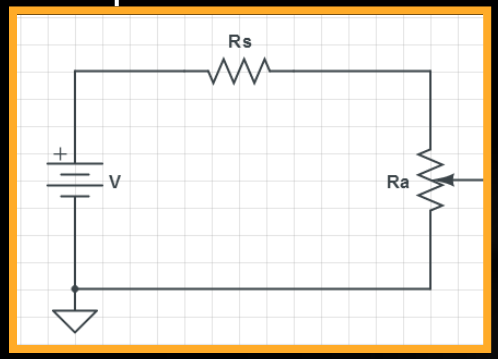
$IE_{max} \approx 0.02\ P_{max\text{-}arc}\ t_{arc} / D^2$



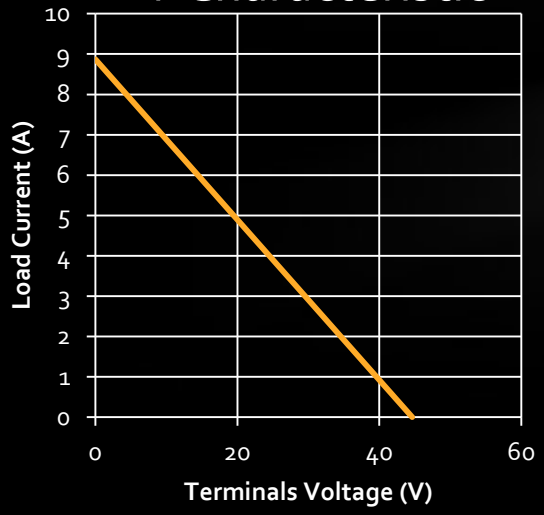
DC Arc Flash Calculations for Solar Farms

Linear power source

Equivalent Circuit

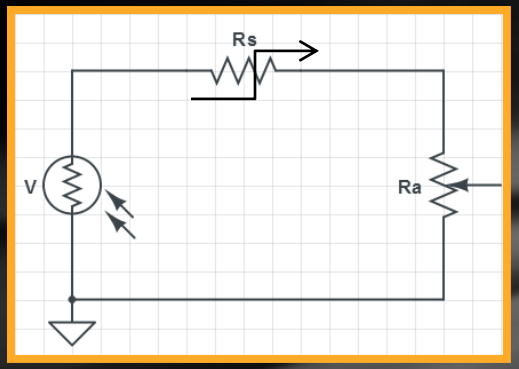


I-V Characteristic

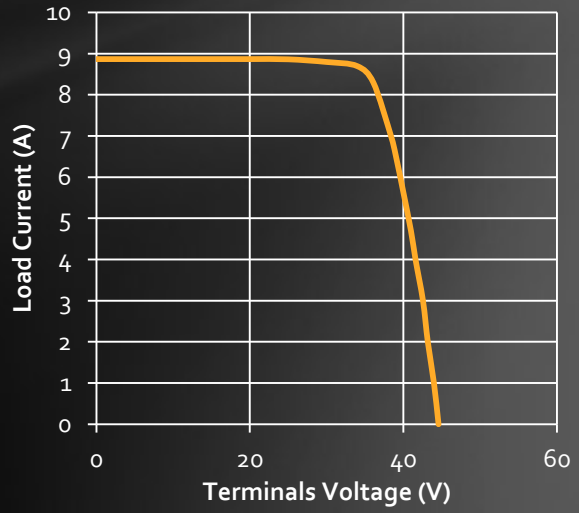


Photovoltaic Cell

Equivalent Circuit



I-V Characteristic



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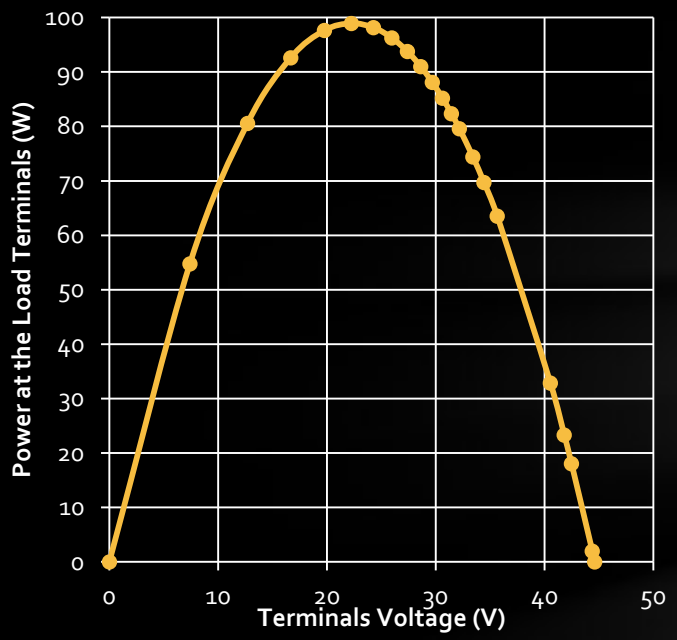
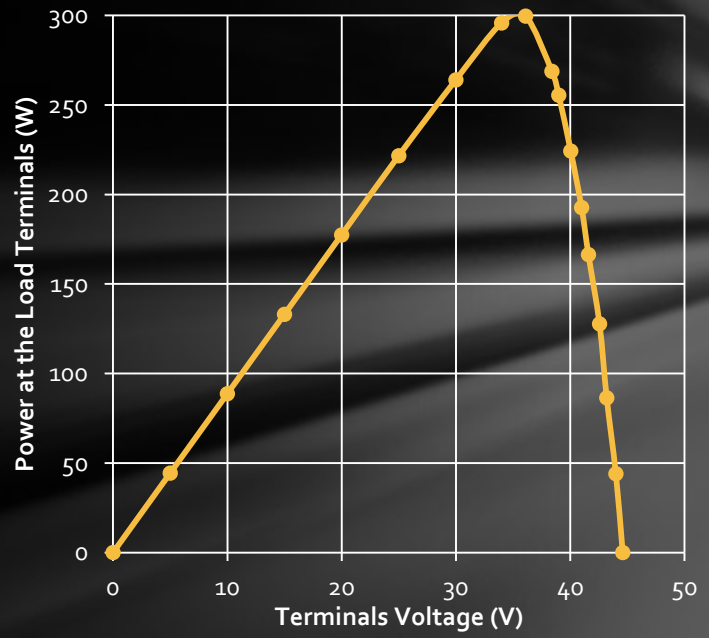
Linear Power Source



$$I_{arc} = 0.5\, I_{bf}$$

$$P_{max} = 0.5\, V_{sys}\, I_{arc}$$

Photovoltaic Cell



$$V_{arc\text{-}pv} = V_{mp\text{-}pv}$$

$$I_{arc\text{-}pv} = I_{mp\text{-}pvc}$$

$$P_{max\text{-}pv} = V_{arc\text{-}pv}\, I_{arc\text{-}pv}$$

DC Arc Flash Calculations for Solar Farms

NFPA 70E and CSA Z462-12

$IE_m = 0.01\ V_{sys}\ I_{arc}\ t_{arc} / D^2$

Photovoltaic Cell

$IE_{max\text{-}pv} = 0.02\ V_{arc\text{-}pv}\ I_{arc\text{-}pv}\ t_{arc} / D^2$

IE max NFPA 70E and CSA Z462-12 vs. IE max Photovoltaic Cell

Survey Results

Ratio of Electrical Characteristics for Utility-grade PV Cells	
$V_{mp} / V_{oc} = V_{arc\text{-}pv} / V_{oc\text{-}pv}$	0.797 to 0.815
$I_{mp} / I_{sc} = I_{arc\text{-}pv} / I_{sc\text{-}pv}$	0.931 to 0.947

$$IE_{max\text{-}pv} \approx 3\ IE_m$$

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Effects of Temperature

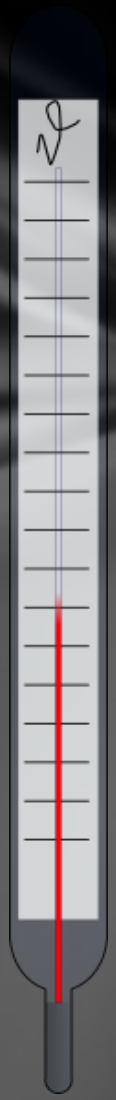
$$IE_{max\text{-}pv\text{-}comp} = IE_{max\text{-}pv}\ (1-(KT-P_{max}/100)*(25^{o}C-T_{min}))$$

For a Typical Solar Farm Example

$$KT @ P_{max} = -0.43\ \%/^{o}C$$

Maximum Compensated Incident Energy @ -13^{o}F / -25 ^{o}C

$$IE_{max\text{-}pv\text{-}comp} = 1.215\ \ IE_{max\text{-}pv}$$



DC Arc Flash Calculations for Solar Farms

Personal Protective Equipment (PPE) Selection

NFPA 70E and CSA Z462-12

Incident Energy Limits (cal/cm²)	Hazard/Risk Category
1.2	0
>1.2 to 4	1
>4 to 8	2
> 8 to 25	3
> 25 to 40	4
> 40	Dangerous

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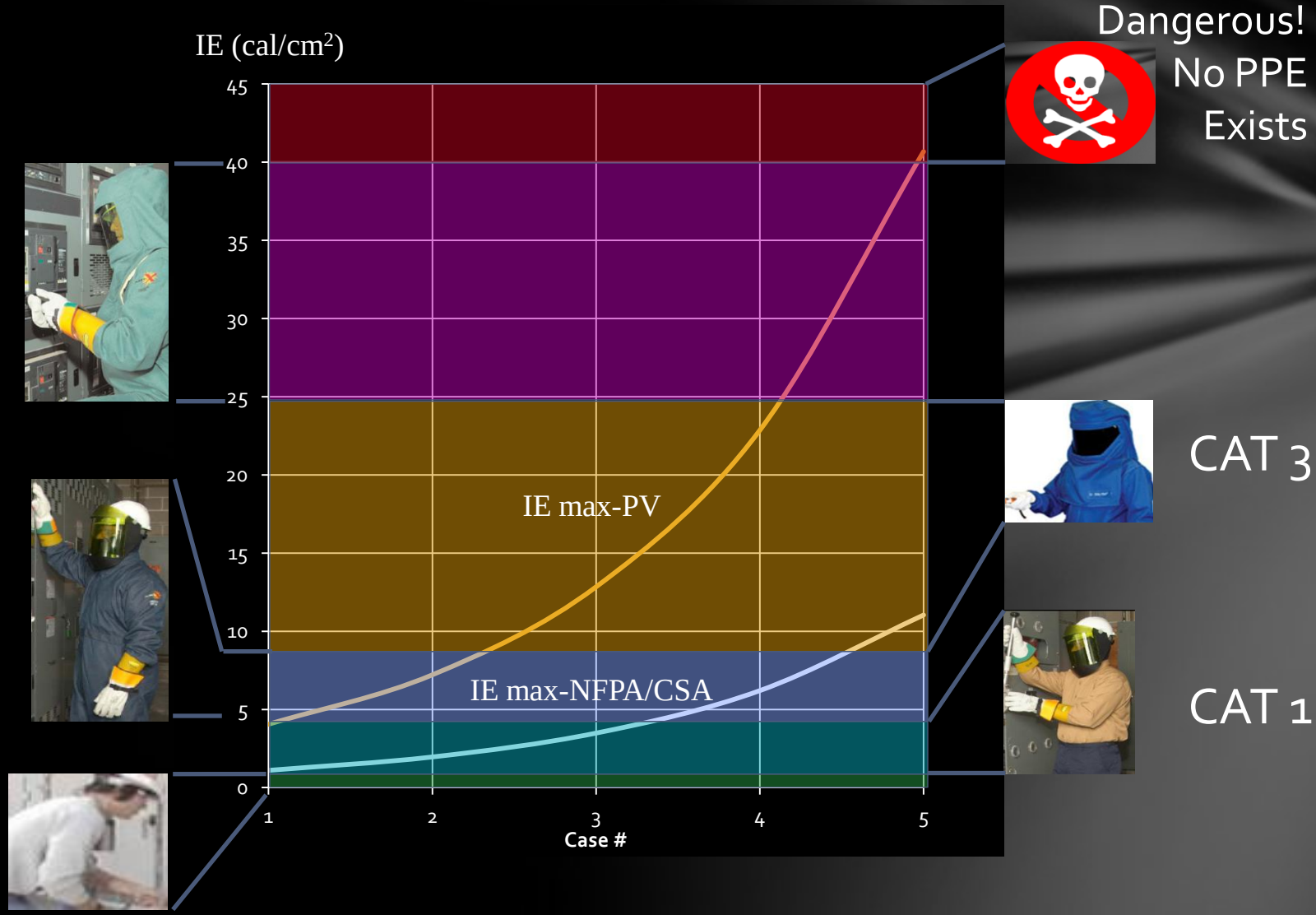

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Conclusions

- The incident energy calculations described in NFPA 70E and CSA Z462-12 do not apply for PV-fed systems
- In low temperature applications, the incident energy increases
- Software tools use the calculations shown in NFPA 70E and CSA Z462-12 for PV systems, underestimating the maximum incident energy levels.

QUESTIONS?

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