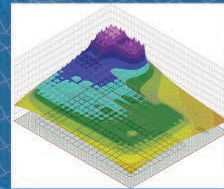
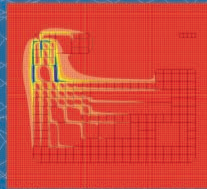
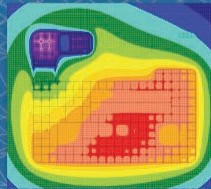
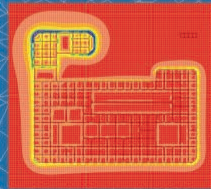


Grounding Analysis for Utility Scale Photovoltaic Power Plant

Presented by David Lewis

XGSLab
SOFTWARE



EasyPower®

Introduction

- The purpose of this presentation is to outline a methodology for grounding system analysis of large utility scale photovoltaics, with regards to IEEE Std 80. At the end of this presentation you will be able to:
 - Describe a typical solar power plant grounding layout
 - Identify challenges encountered when evaluating solar power plant grounding systems
 - Describe analysis techniques to accurately assess grounding system performance

Outline

- Utility Scale Photovoltaic Power Plant
- Grounding Basics
- Photovoltaic Power Plant Grounding
- Challenges for Grounding Analysis
- Case Study

Photovoltaic Power

- Photovoltaic (PV) panels interconnected
- DC power inverted into AC power

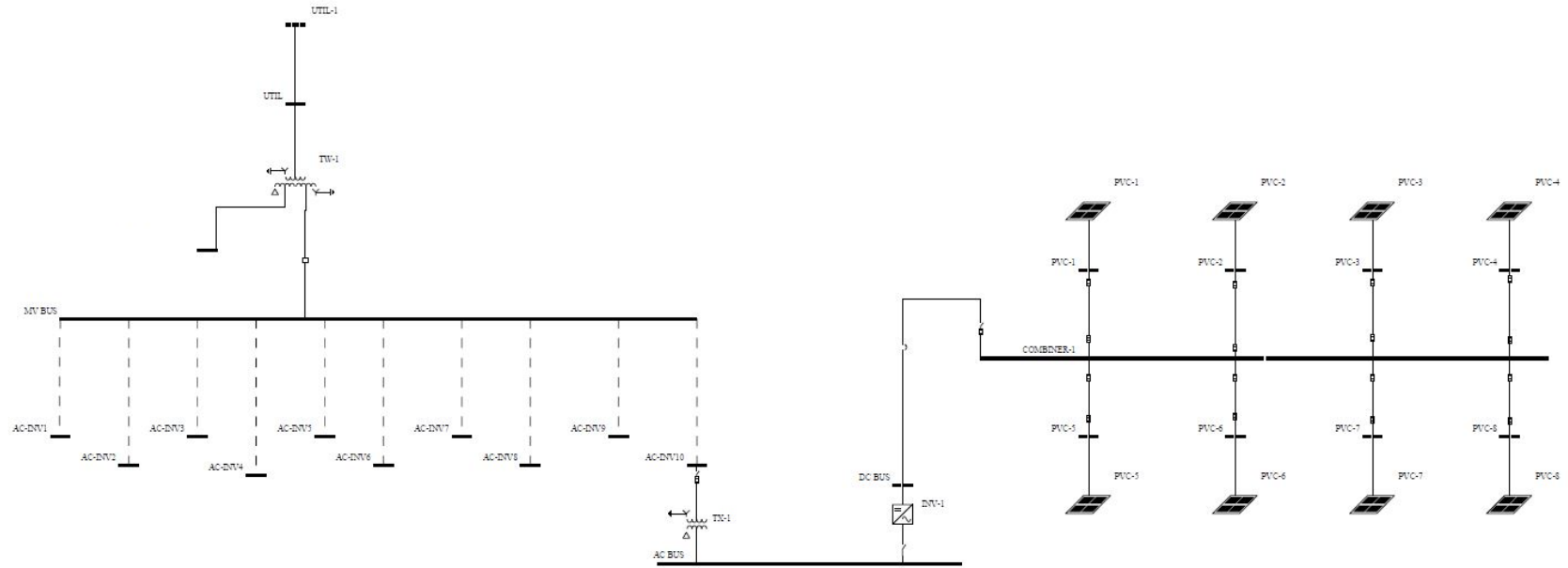


Photovoltaic Power Plant

- Utility scale photovoltaic power plant



Photovoltaic Power Plant



GROUNDING BASICS

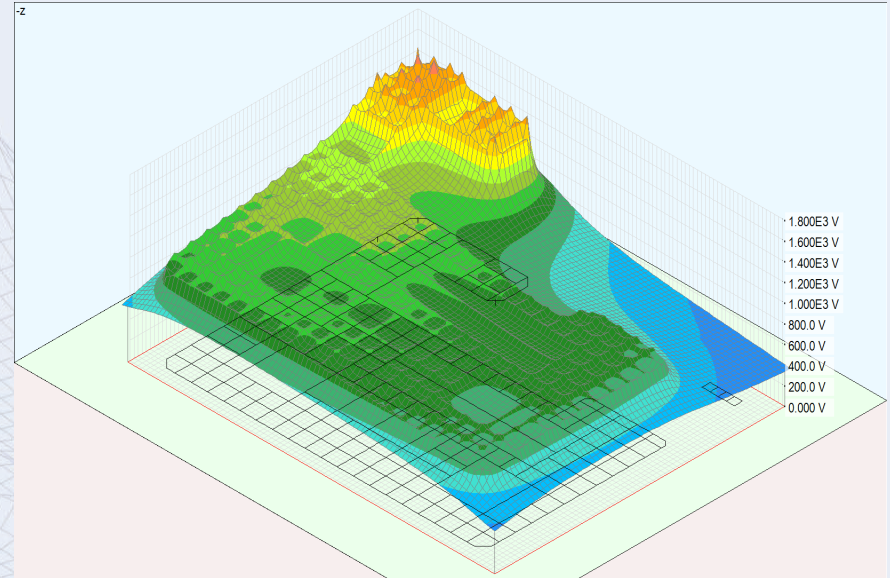


Why Grounding?

- Allows proper equipment operation in normal and fault conditions
- Provide surge/lightning protection
- Personnel protection under fault conditions

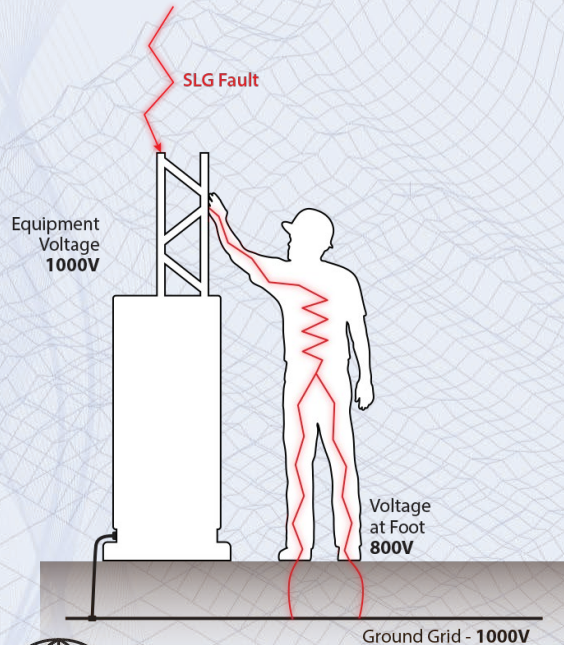
Grounding Definitions

- Earth/Ground Current
 - Current through ground grid returning to its source through earth
- Ground Potential Rise (GPR)
 - Maximum electrical potential that ground grid and surrounding soil may attain relative to “remote earth”

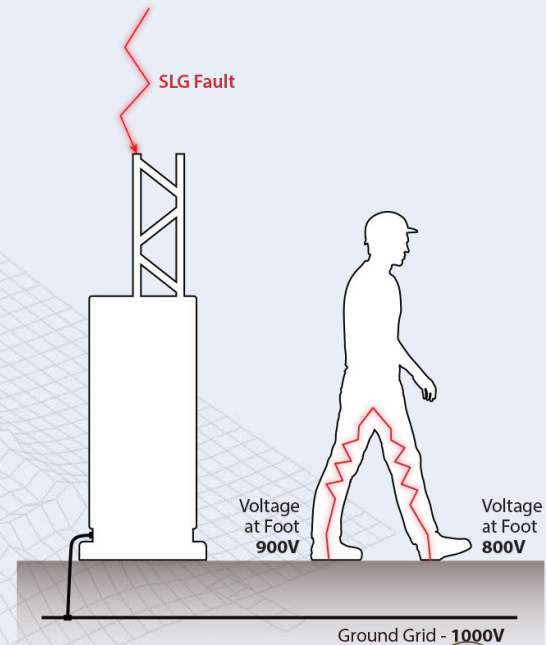


Grounding Definitions

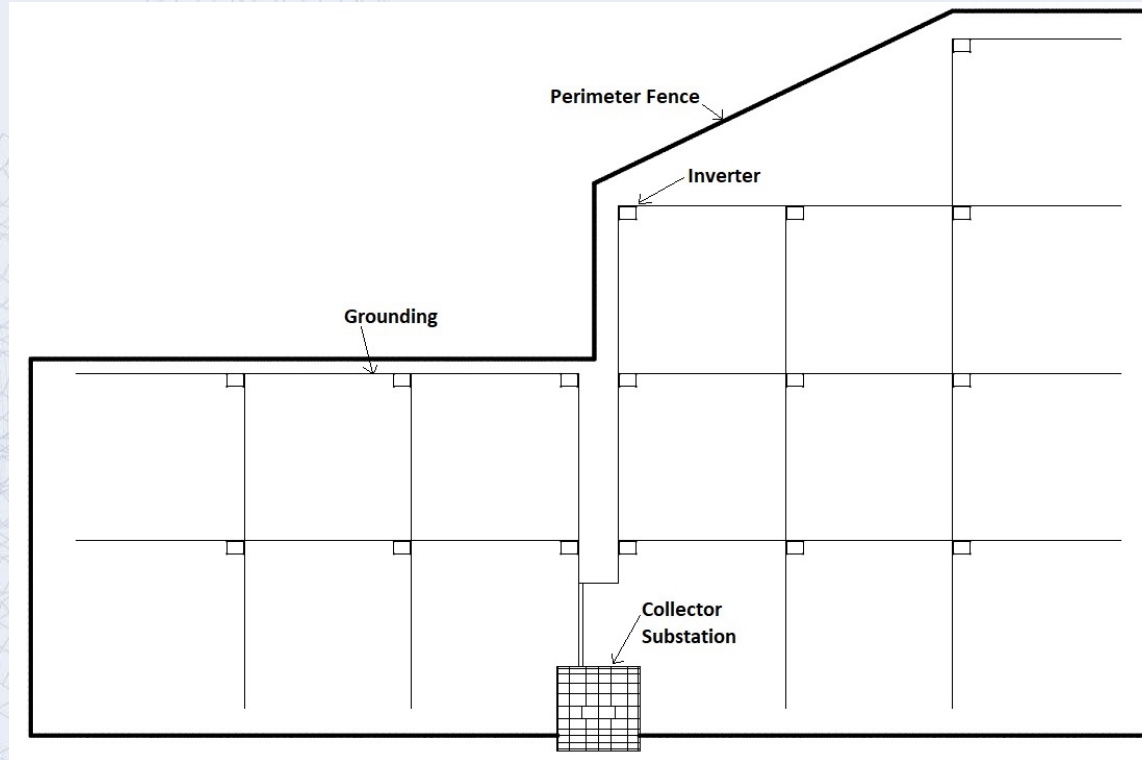
- Touch Voltage



- Step Voltage



Photovoltaic Power Plant Grounding

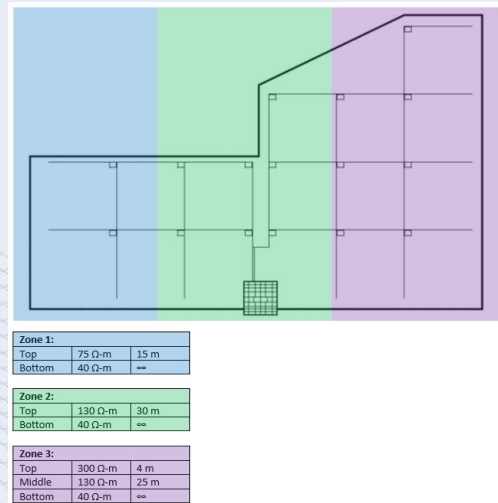


Photovoltaic Power Plant Challenges

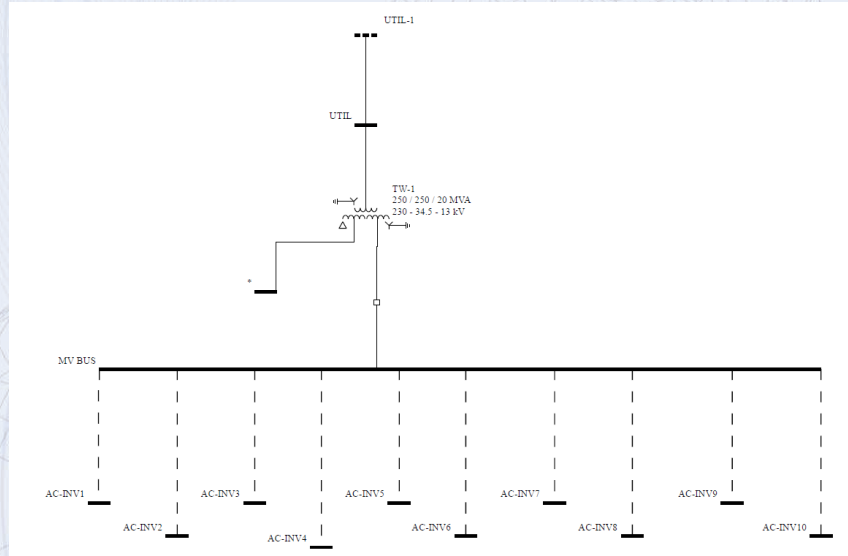
- Data acquisition
 - Soil characteristics
 - Fault and coordination data
- Requires detailed understanding of the physical and electrical system
- Software capabilities

Soil Characteristics

- Soil characteristics may vary across the site
 - Upper soil layer typically greater variation
- Multiple measurements
 - Several shorter traverses
 - Sufficient long traverses
- Surfacing layer is uncommon



Fault and Coordination Data



- Utility POI
- Collector substation
- Collector feeders
- Determine sources



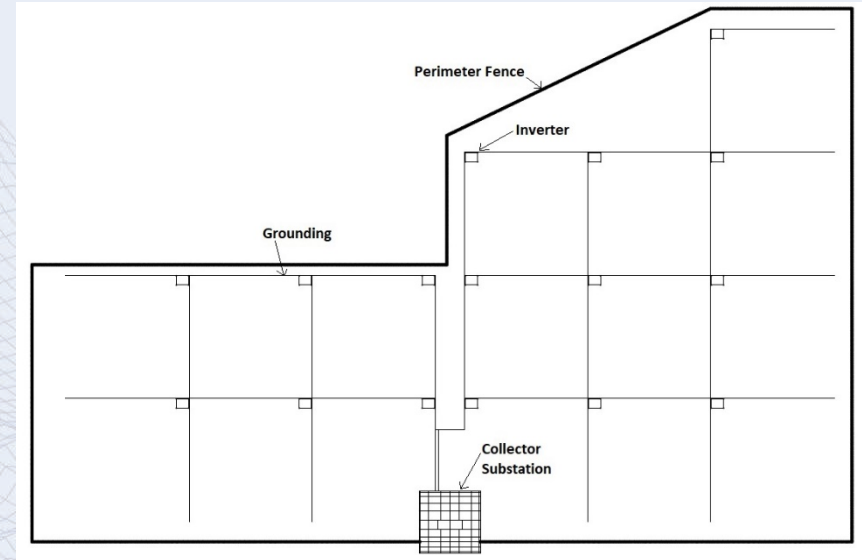
Electrical and Physical Design

- PV arrays grounded
 - Continuous conductor
 - Panel track
 - Ground connection at support post
- PV panel span



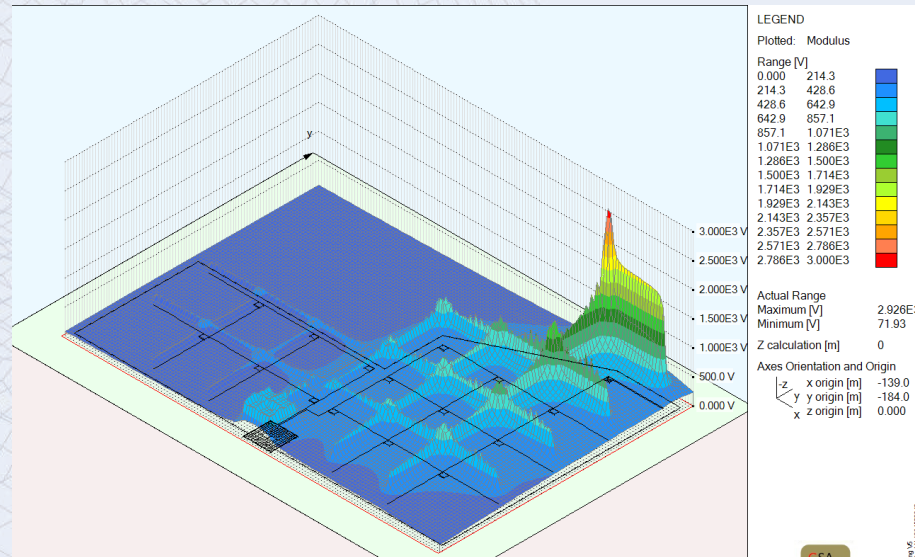
Electrical and Physical Design

- Collector substation
 - Connection to plant grounding
 - Neutral or shield wires



Software Limitation

- Conductor impedances
 - Equipotential grounding system not applicable



Software Limitation

- System electrification
 - Multiple sources/energized conductor
- Soil modeling
- Computational capability

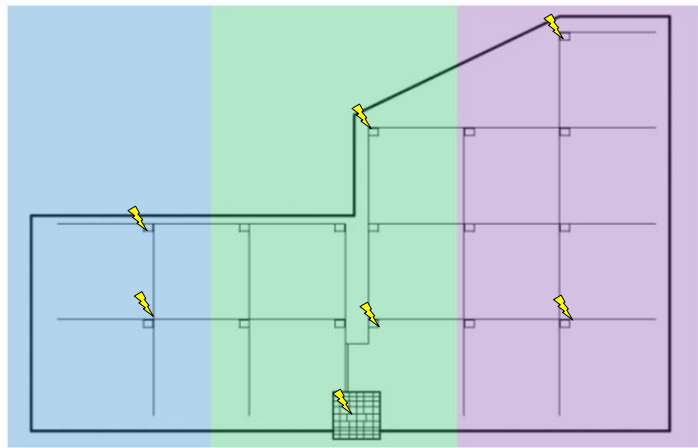
Determination of Touch/Step Voltage Hazards

- Determine hazardous scenarios
 - Fault magnitude
 - Grounding geometry
- Consider touch and step voltage criteria
 - Soil characteristics
 - Clearing time

Additional Considerations

- Perimeter fence
 - Assess hazardous scenarios
 - Grounding may be required
 - Consider transfer voltages from substation/array
- Fault current split
 - Modeling shield/neutral wires is recommended
- Field testing can be complex

Case Study



Zone 1:		
Top	75 Ω -m	15 m
Bottom	40 Ω -m	∞

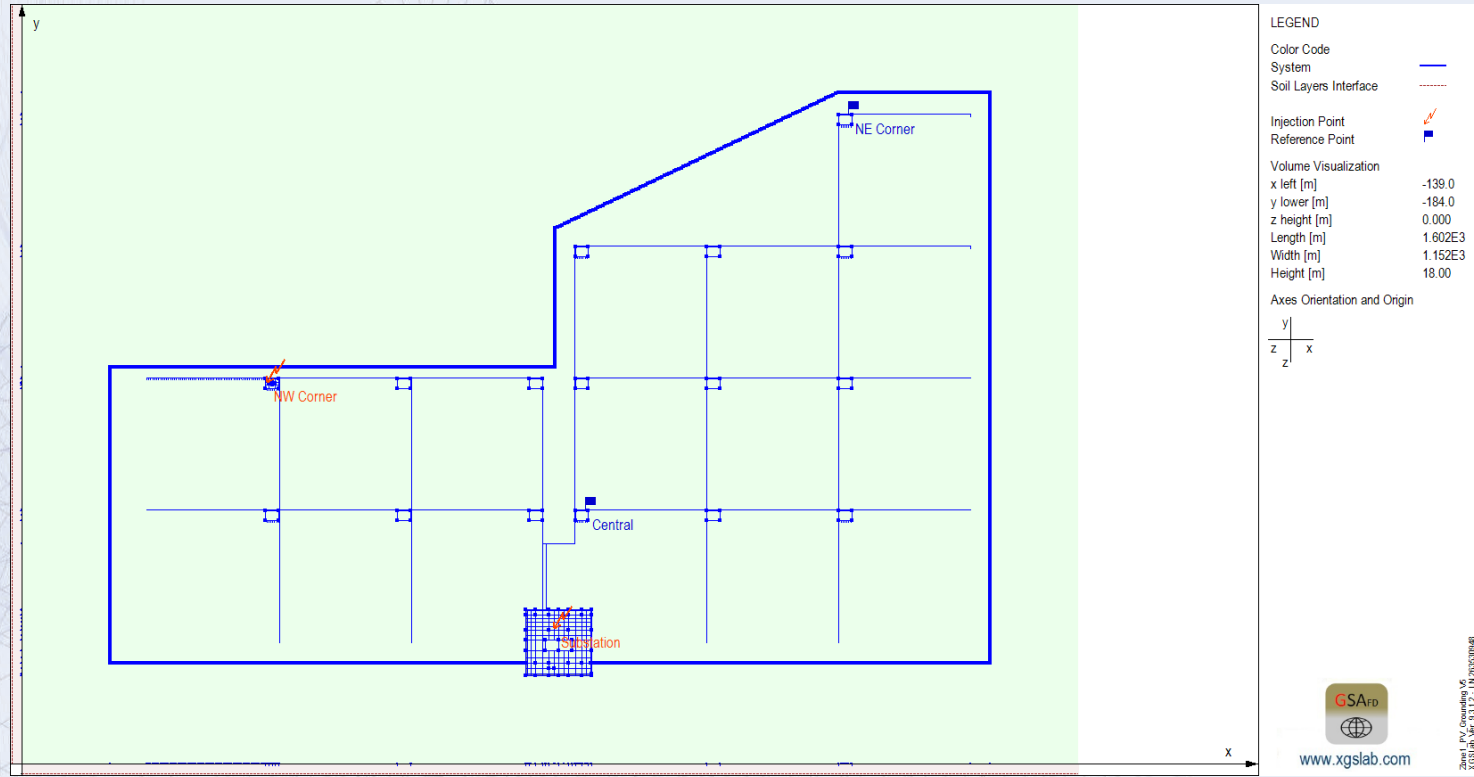
Zone 2:		
Top	130 Ω -m	30 m
Bottom	40 Ω -m	∞

Zone 3:		
Top	300 Ω -m	4 m
Middle	130 Ω -m	25 m
Bottom	40 Ω -m	∞

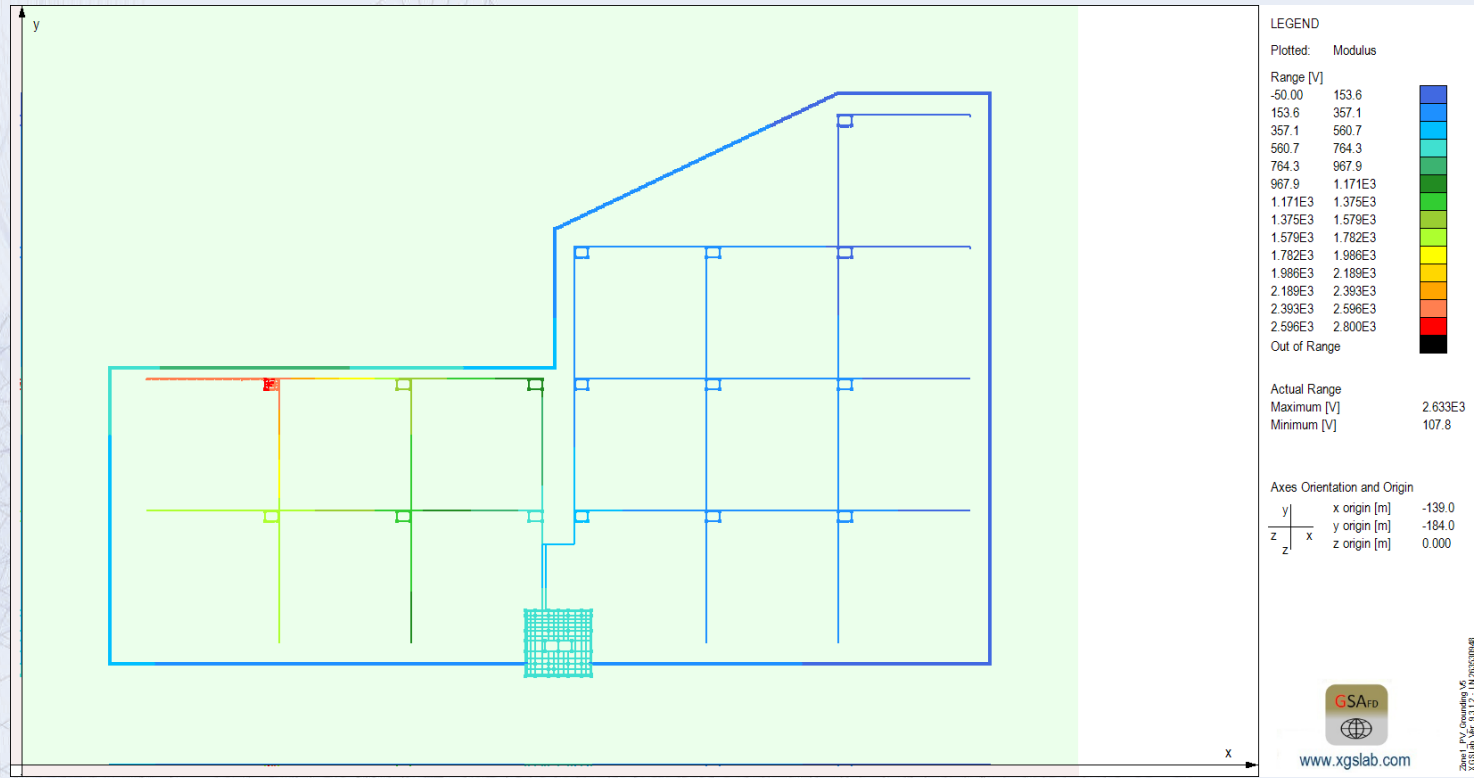
Fault Data Location		Total SLG (KA)	Delta Contribution (KA)	Clearing Time (sec)
34 kV	INV1	23.363	4.930	0.3
34 kV	INV2	17.862	3.769	0.3
34 kV	INV3	17.691	3.731	0.3
34 kV	INV4	14.931	3.151	0.3
34 kV	INV5	14.335	3.022	0.3
34 kV	INV6	14.053	2.966	0.3
34 kV	INV7	16.274	1.434	0.3
34 kV	INV8	11.351	2.398	0.4
34 kV	INV9	13.782	2.909	0.4
34 kV	INV10	10.501	2.214	0.4



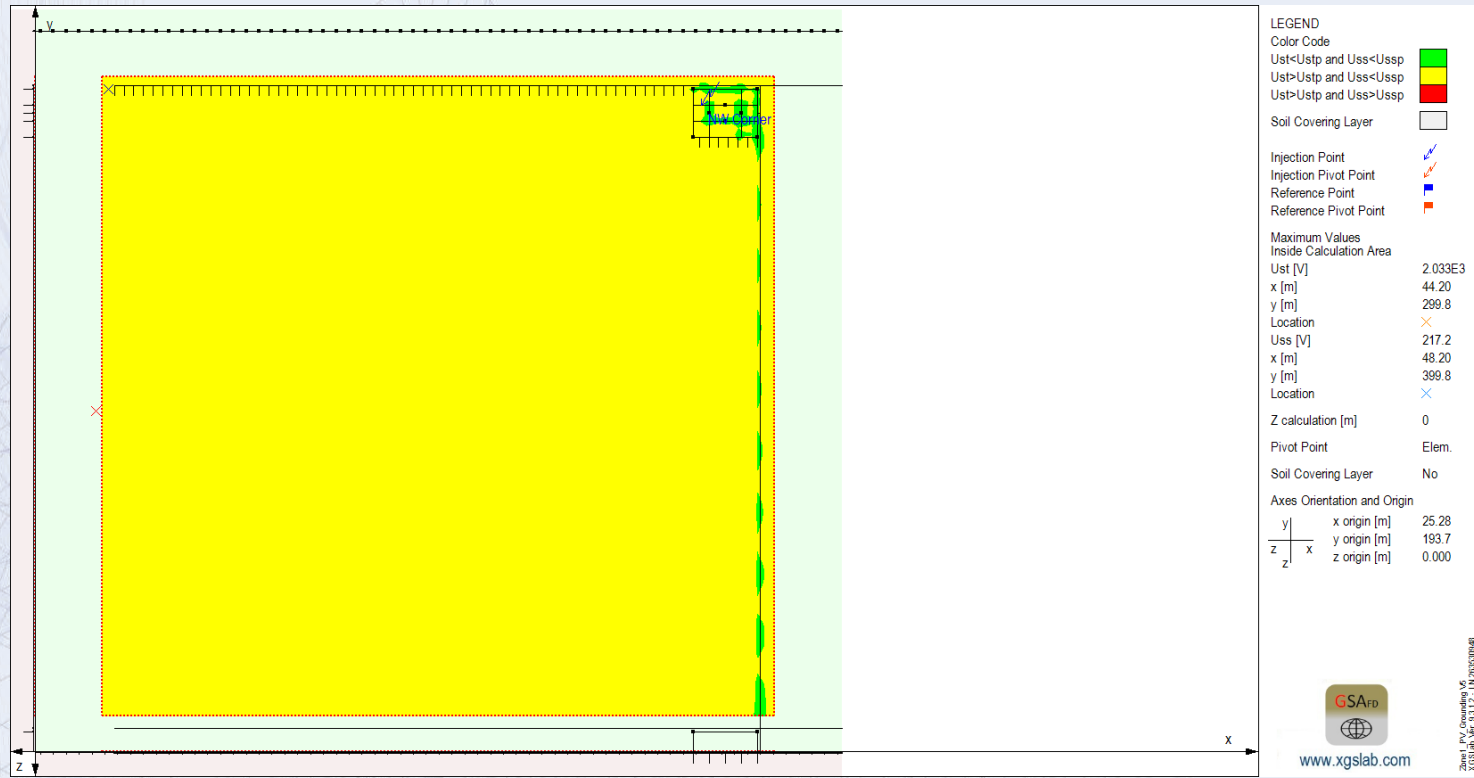
Base Model



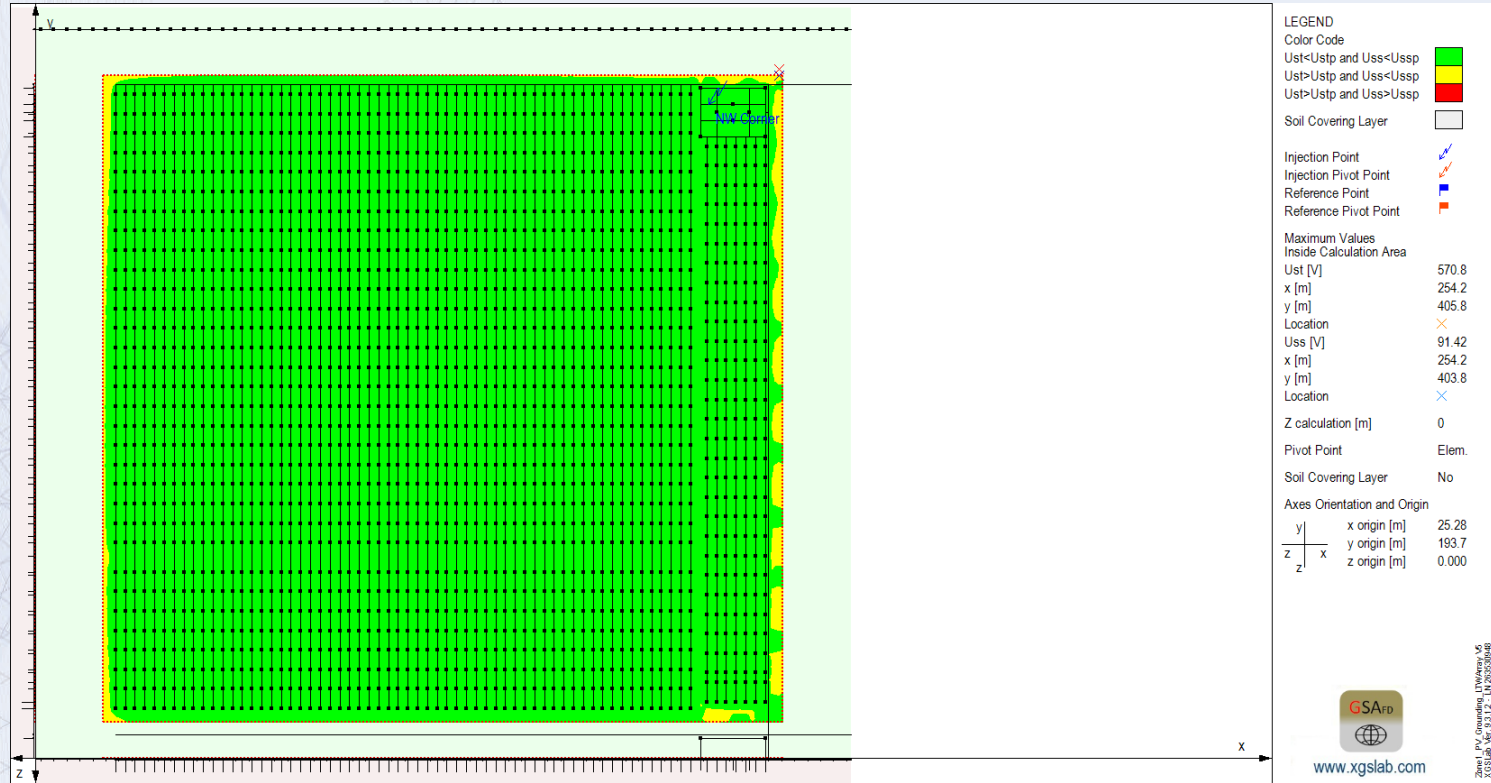
Metallic Potential NW Corner Fault



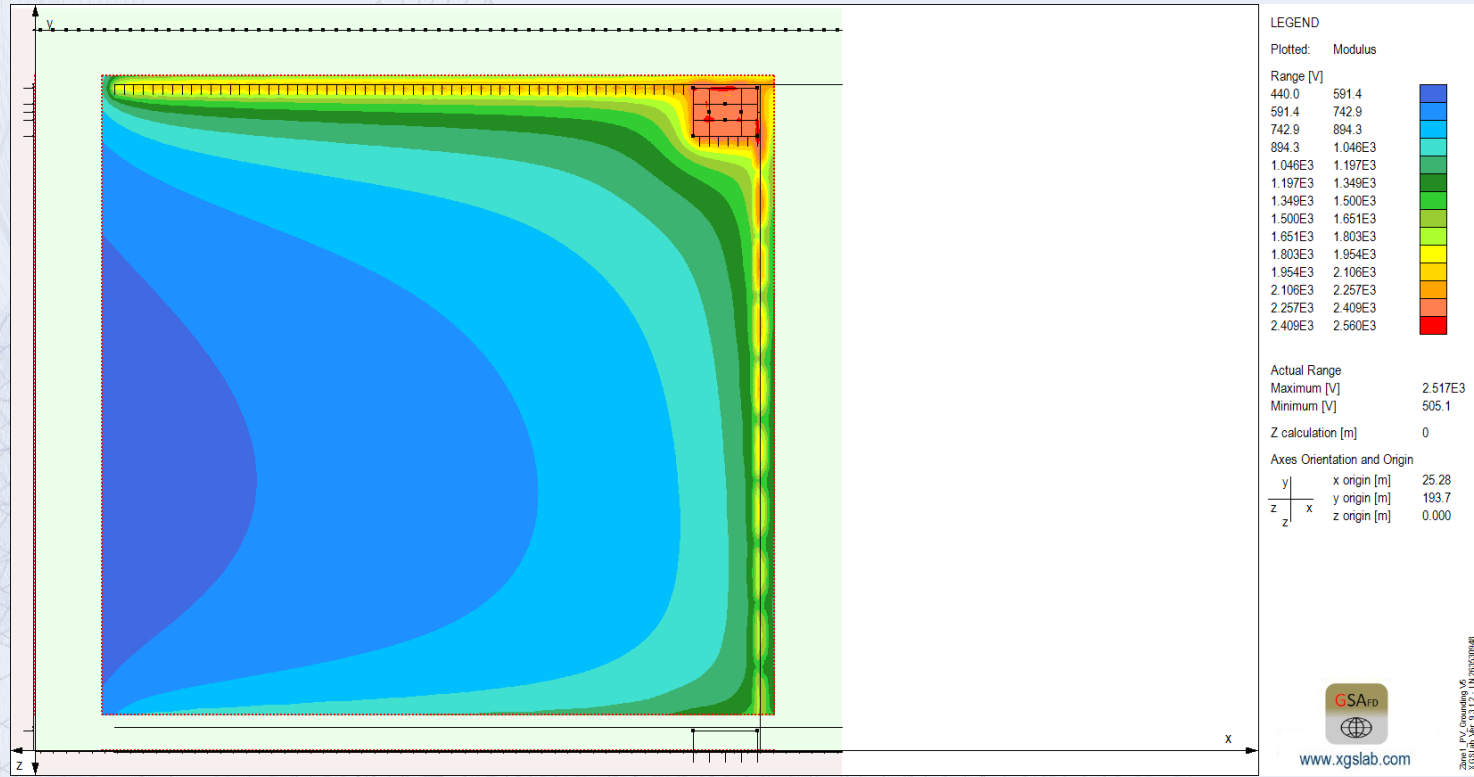
Permissible Touch & Step Voltage



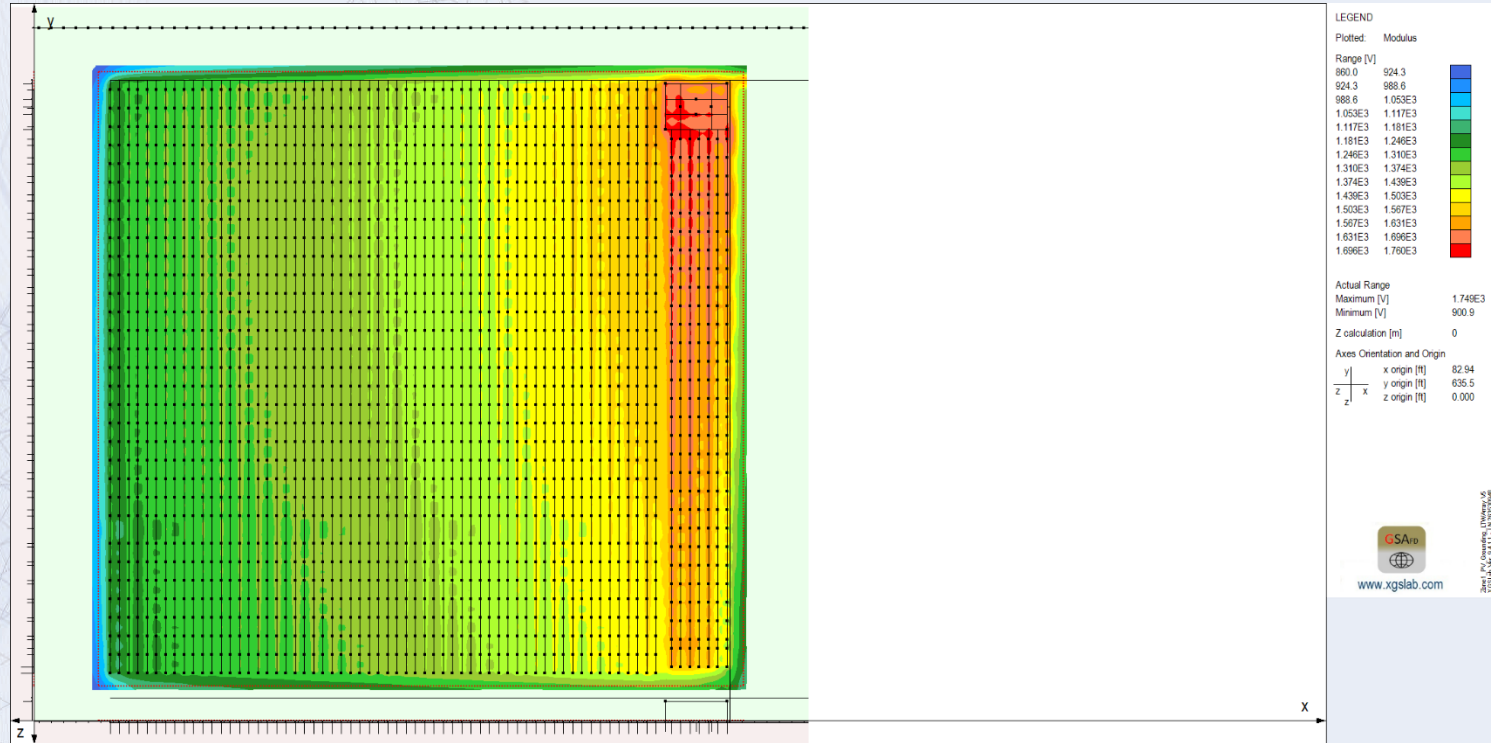
Permissible Touch & Step Voltage



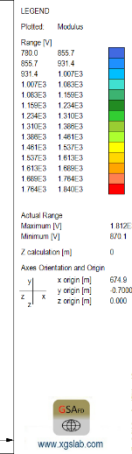
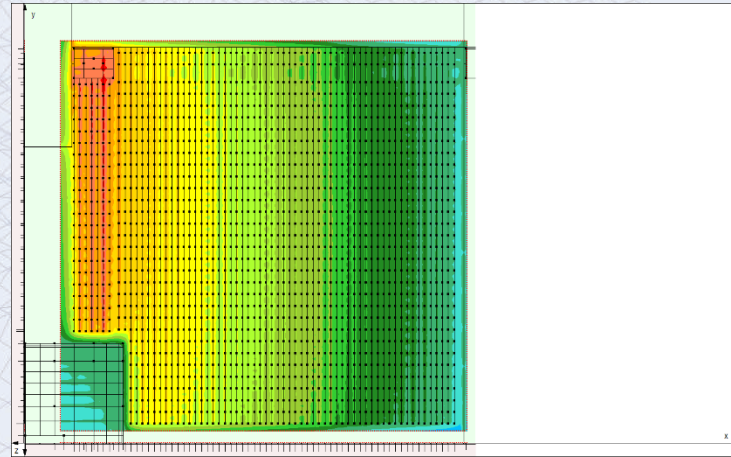
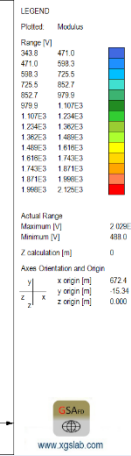
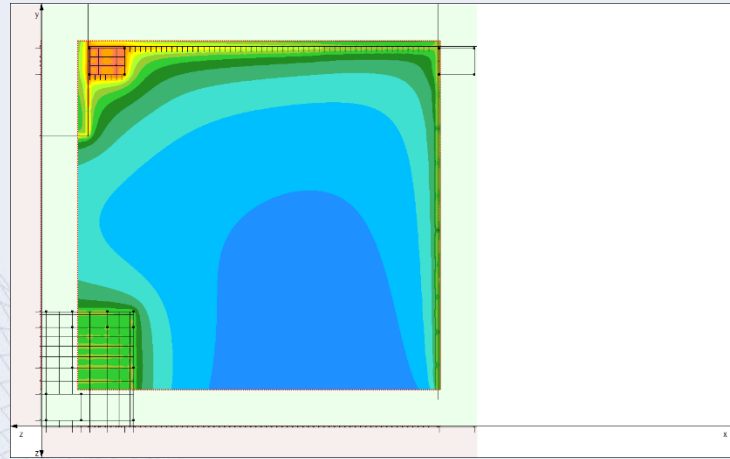
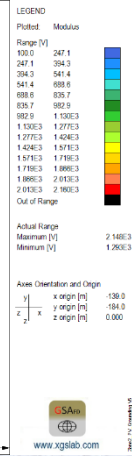
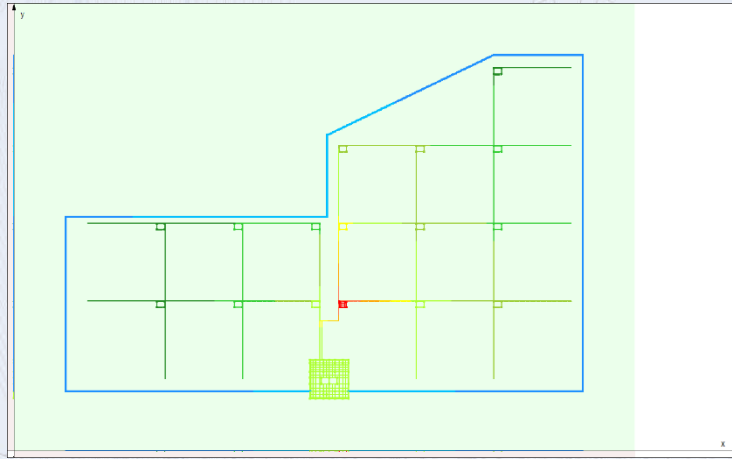
Ground Potential Rise



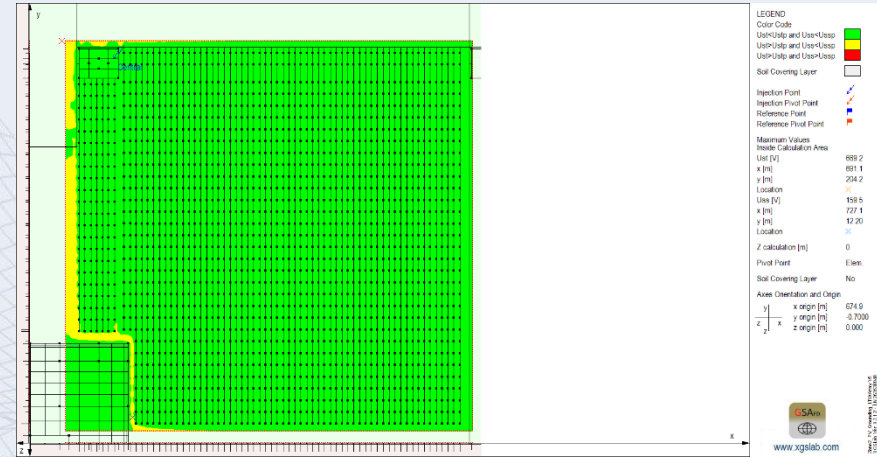
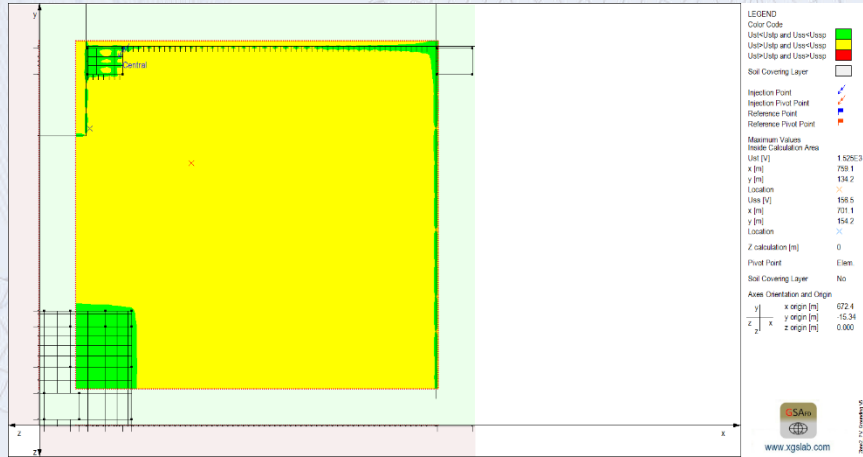
Ground Potential Rise With Posts



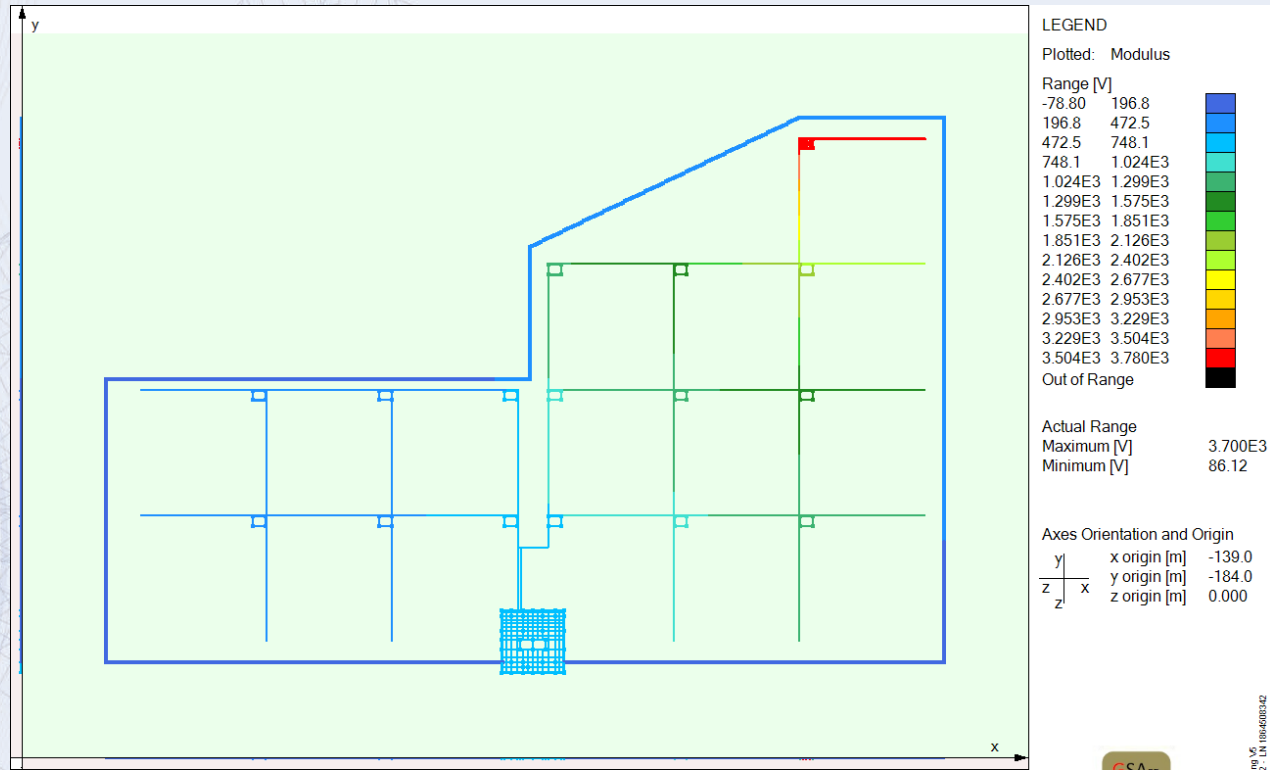
Central Fault



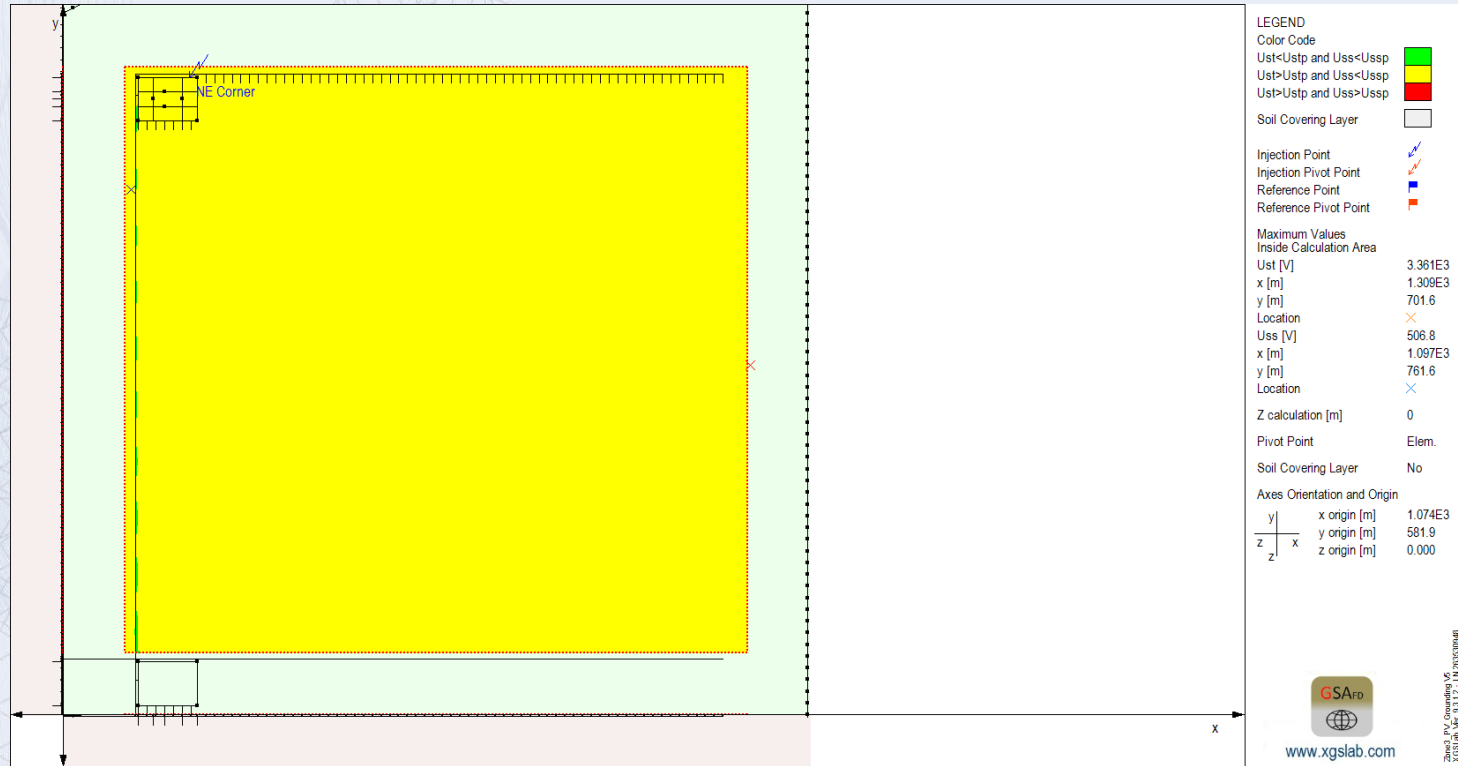
Permissible Touch & Step Voltage



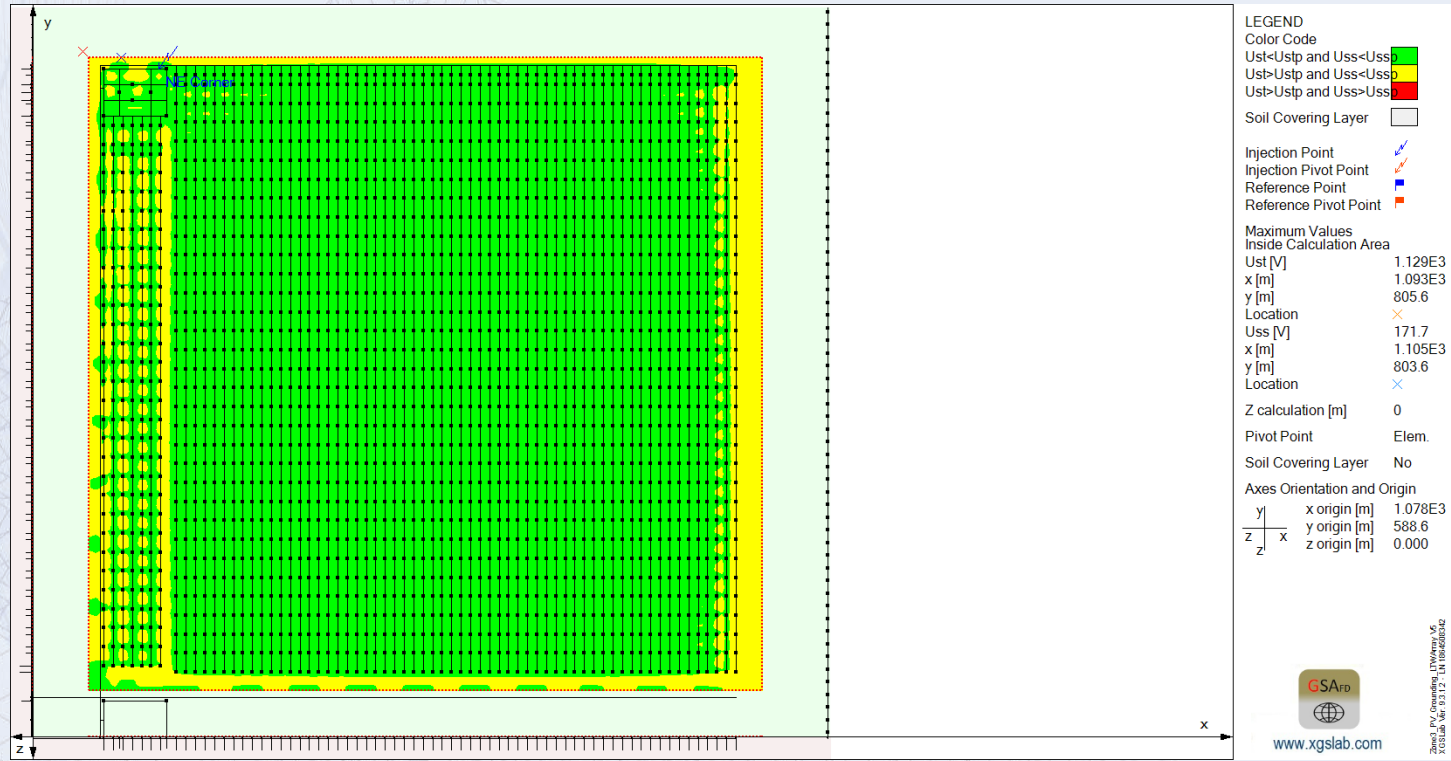
Metallic Potential NE Corner Fault



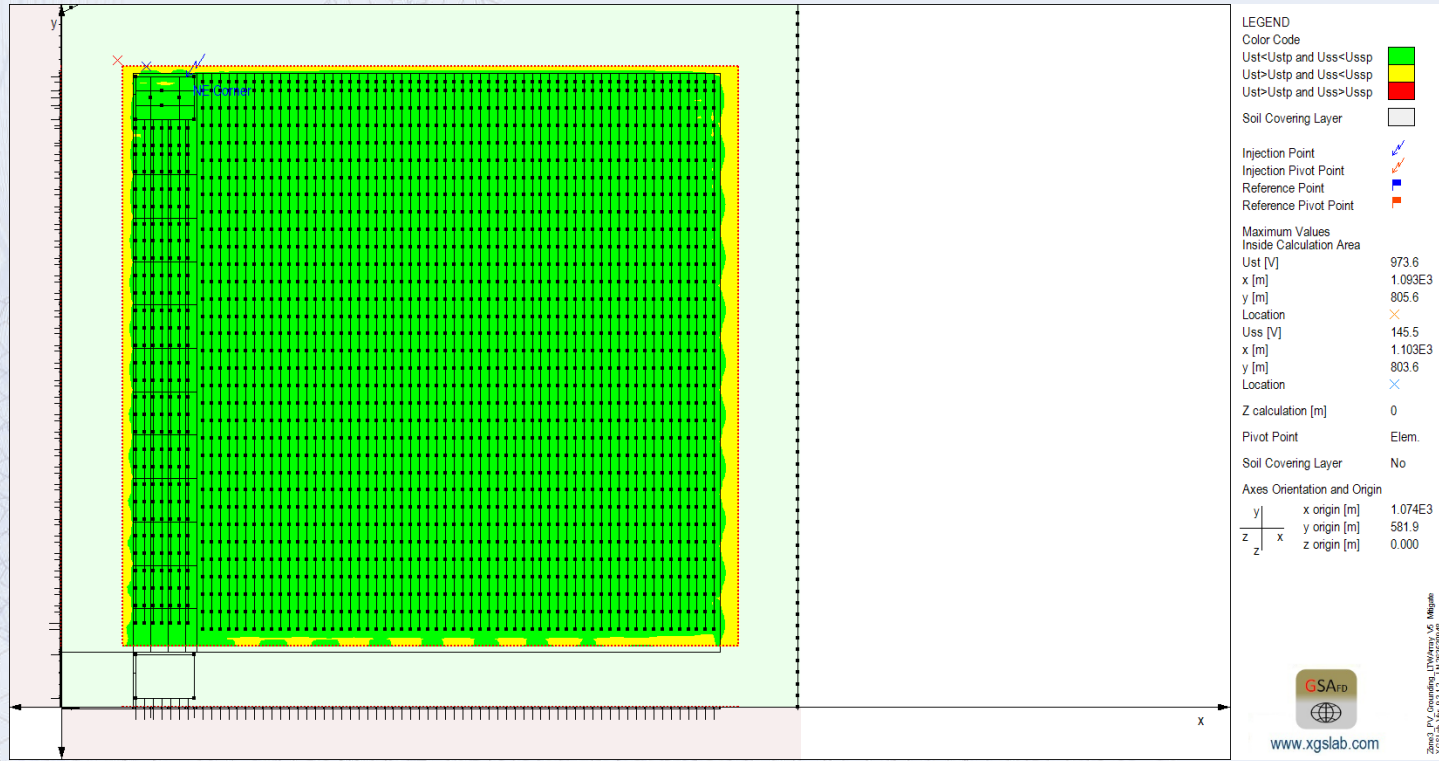
Permissible Touch & Step Voltage



Permissible Touch & Step Voltage



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Questions?

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