Schneider Electric 1MW PV Station Design

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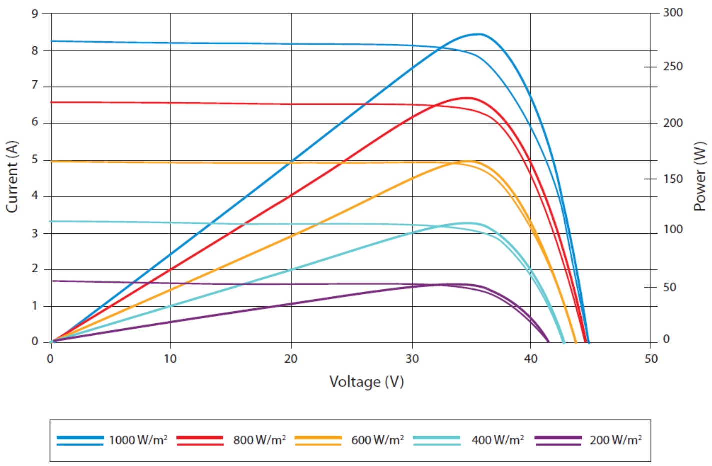
Quick Facts

- In operation since May 2011
- Converts solar radiation to electric power
- 3,456 individual PV modules
- Rated maximum DC power 967,680W @ 1000 W/m^2 irradiance, 25°C ambient
    - Divided into 8 octants, each rated 120,960W
- Selectable 600/1000V DC operation
- Solidly-grounded, ungrounded, bipolar re-configurable DC grounding
- Flexible inverter configuration for testing/operation of multiple inverter types

Basic PV Design Principles

- PV modules act as current sources
- Short-circuit level of modules is only slightly above load
- Short-circuit current is used to size DC infrastructure (specific requirements in NEC 690)
- PV modules are arranged in strings, with maximum open-circuit voltage limiting the size of a string.
- Multiple strings operate in parallel
- Ambient temperature is taken into account using temperature coefficients of PV modules
- Inverters convert the DC from the PV modules to AC, typically operating as current-source inverters.   DC voltage is controlled to keep system operating close to maximum power point

Current-Voltage & Power-Voltage Curve (STP 280 - VRM -1)



Temperature Characteristics

Nominal Operating Cell Temperature (**NOCT**)	45±2°C
Temperature Coefficient of Pmax	-0.44 %/°C
Temperature Coefficient of Voc	-0.33 %/°C
Temperature Coefficient of Isc	0.055 %/°C

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The Design Challenge

- Dual Role -- Operational PV field w/payback, and with capability to serve as a test bed for inverters
  - Dual 600 and 1000V DC operation capability
  - Reconfigurable grounding arrangements
  - Capability to mount different inverter configurations, in both indoor and outdoor environments
  - Capability to back up anti-islanding provisions in prototype inverters
  - Capability to support multiple inverter sizes and AC output voltages
  - Infrastructure to support remote monitoring
- 1000V DC was not a common option for PV fields at the time the installation was designed
  - Challenge with availability of full-range fuses, disconnects, cabling
  - Challenge with NEC requirements written for 600V DC application

Non-Electrical Design Challenges

- Grading
- Storm water Runoff
- Field Surface Selection
  - Trade-off – maintenance requirements vs. runoff
- Anchoring of PV racks
  - Soil characteristics and rock content
- The above comprised a significant portion of the cost for the project

Safety

- With reconfigurability comes additional safety requirements
- Means of de-energizing reconfigurable elements and lock-out/tag-out are critical
- This installation includes additional disconnecting/isolation means means vs. a typical PV installation

Design Criteria

This is not an exhaustive list!

- PV Module Selection and Number of Modules
- PV Module Mounting Angle and Physical Arrangement
- Shading
- PV String Size
- Cabling specification and sizing
- Raceway specification and routing
- Grounding arrangement
- DC and AC circuit protection
- Disconnects required for enhanced safety
- Racking and Rack Anchoring design
- Required number of transformers
- Need for control building vs. outdoor mounting of AC and control infrastructure
- Utility requirements for metering
- Reconfiguration of incoming Utility 25kV overhead line
- NESC requirements for setback of control building from 25kV line
- Lightning protection/abatement
- Etc…

First Step – Hierarchical Organization of the DC Circuits

- (6) Modules per series string – connected at racks
- (18) series strings connected to a String Disconnect Box (SDB) – provides isolation capability for each string and connects (12) of the 6-module strings into (6) 12-module strings.
- (6) 12-module strings + (12) 6-module strings form an Array, connected into an Array Combiner Box (ACB). Voltage is configured for 600V or 1000V DC operation in the ACB.
- Each Array is connected to an Array Disconnect Switch (ADS). The ADS provides isolation for the Array.
- (4) ADS's connect to a Master Combiner Box (MCB). The MCB parallels the Arrays and provides overcurrent protection for each array.
- Output of each MCB forms an Octant, which is equipped with an Octant Fuse (OF) and Octant Disconnect Switch (ODS)
- The field contains (8) Octants

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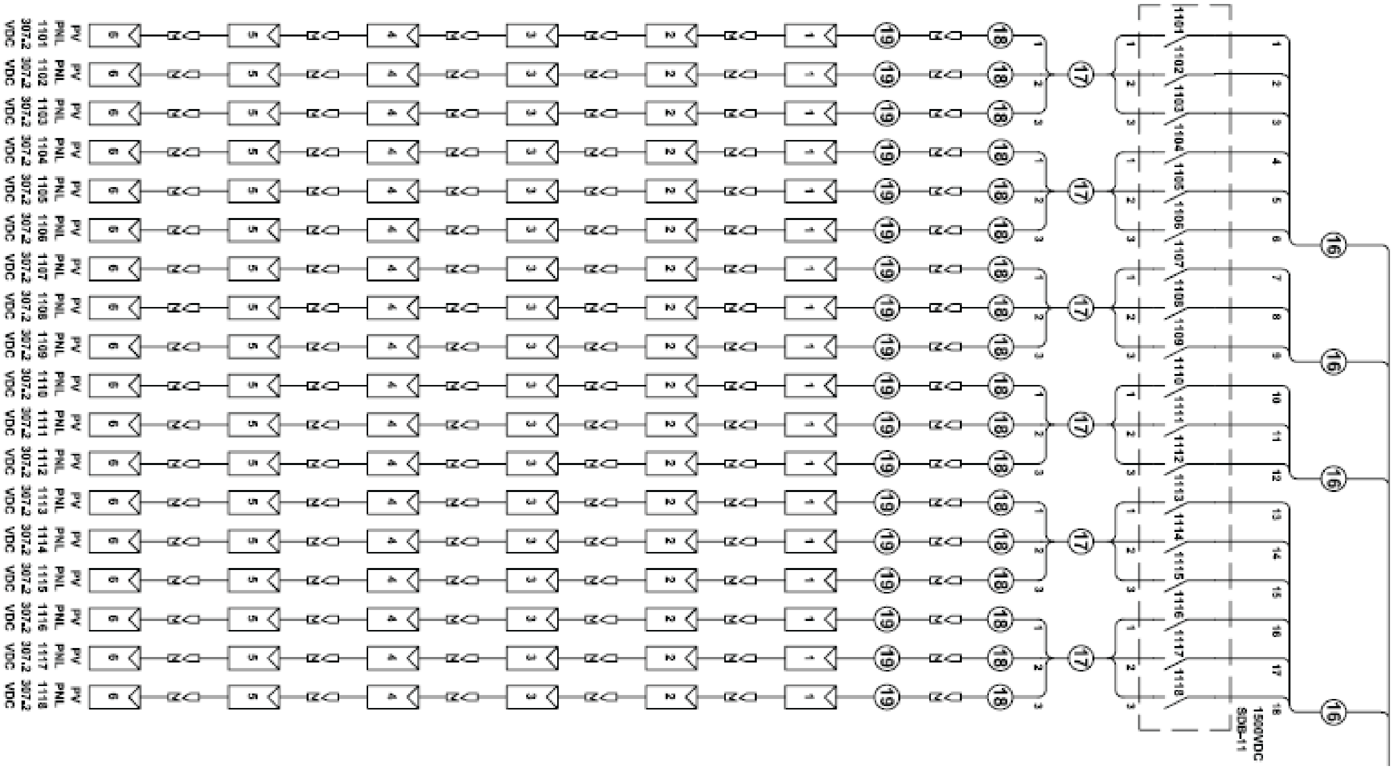
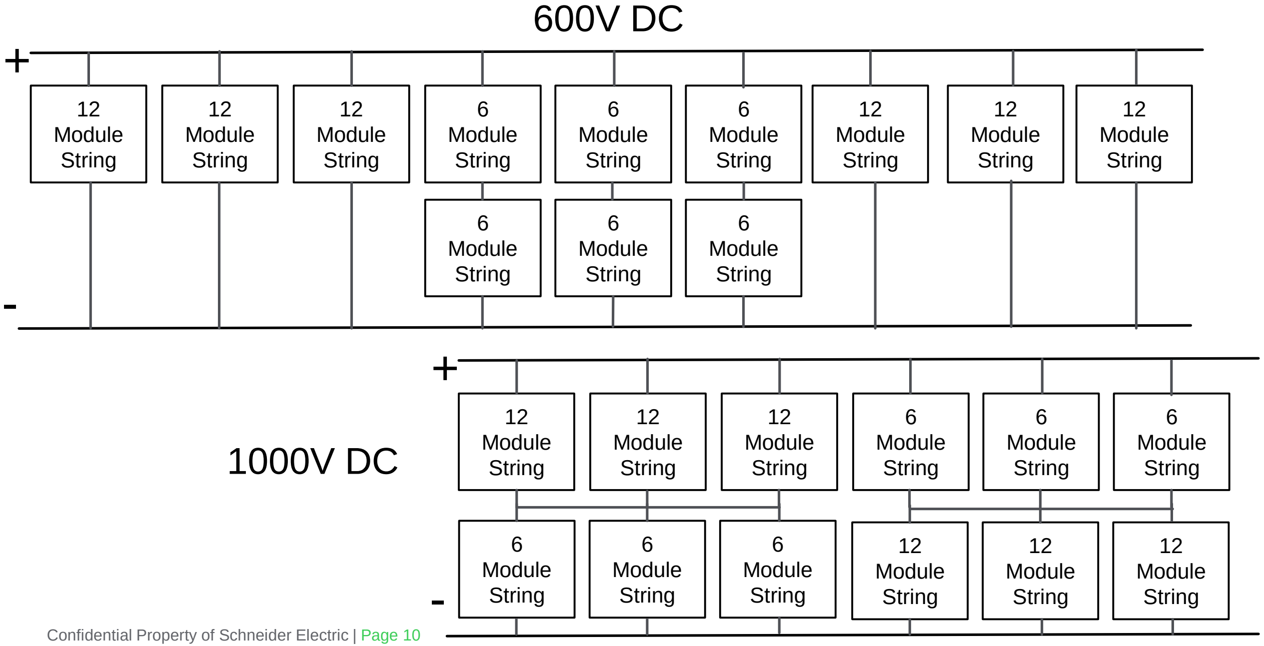
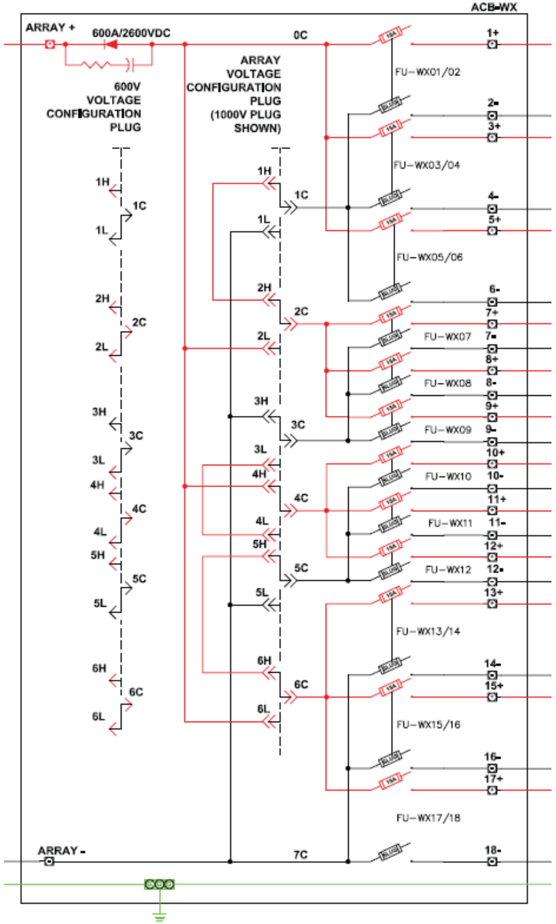
PV Strings



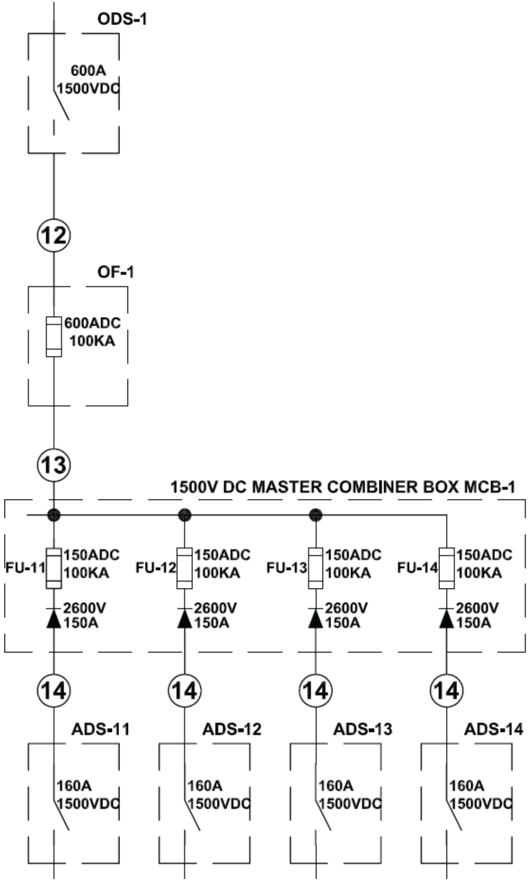
Dual Voltage Operation

- 600V DC: 12 modules per string
- 1000V DC: 18 modules per string
- Connections established by 600V and 1000V "configuration plugs"





Octant DC Master Combiner



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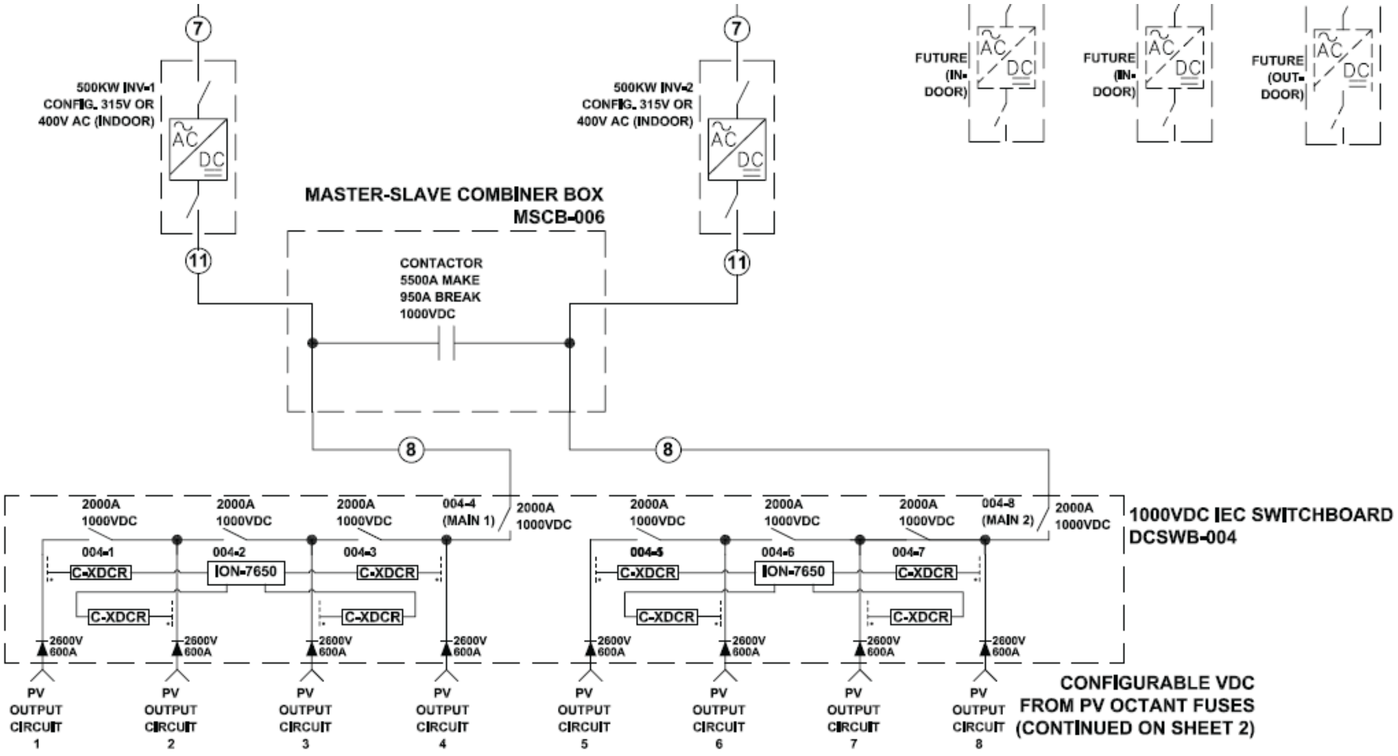
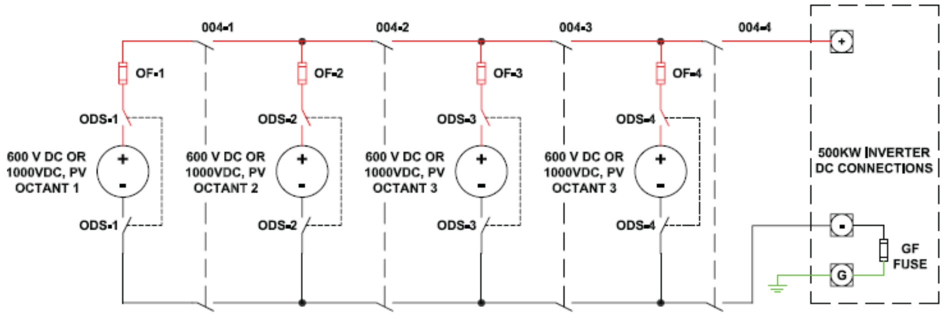
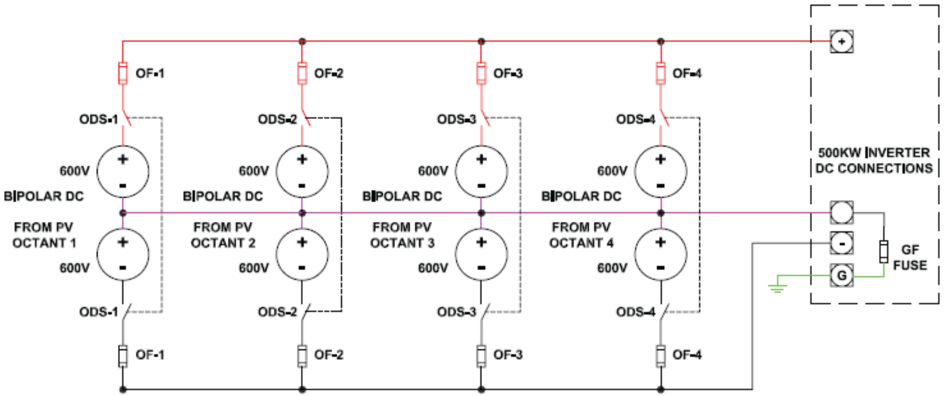
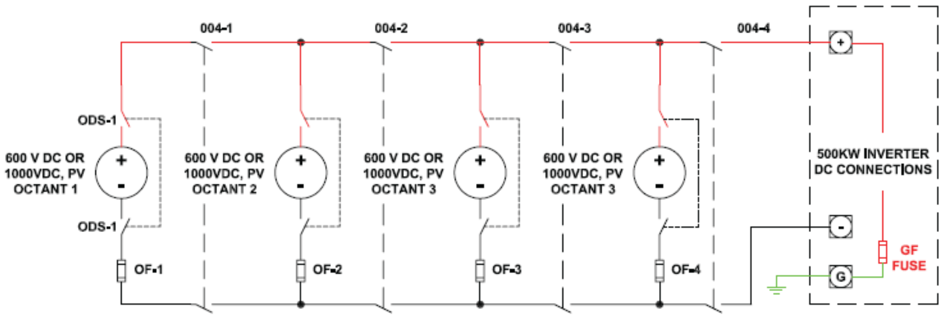
DC Switching and Inverter Arrangement



Re-Configurable DC Grounding







AC PHASE A
AC PHASE B
AC PHASE C
AC NEUTRAL
GROUND
DC POSITIVE (+)
DC NEGATIVE (-)
DC NEUTRAL/CENTER TAP

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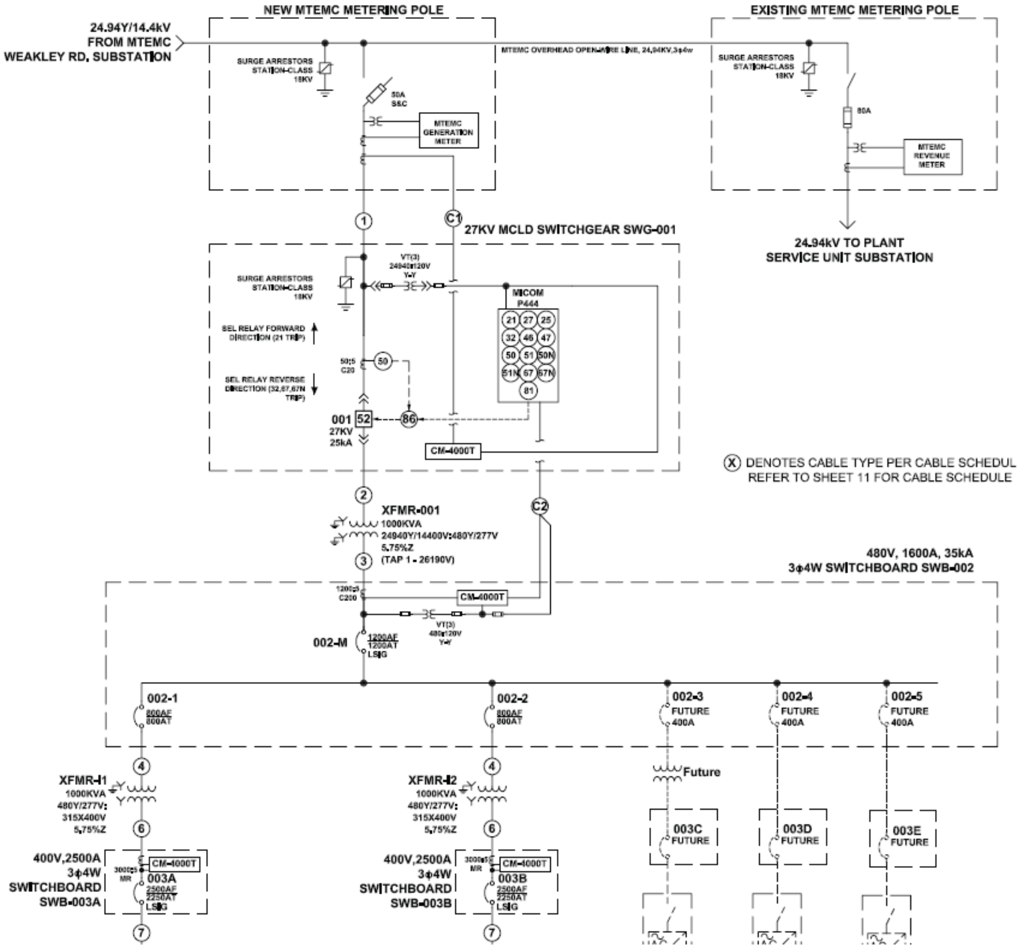
AC Arrangement



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