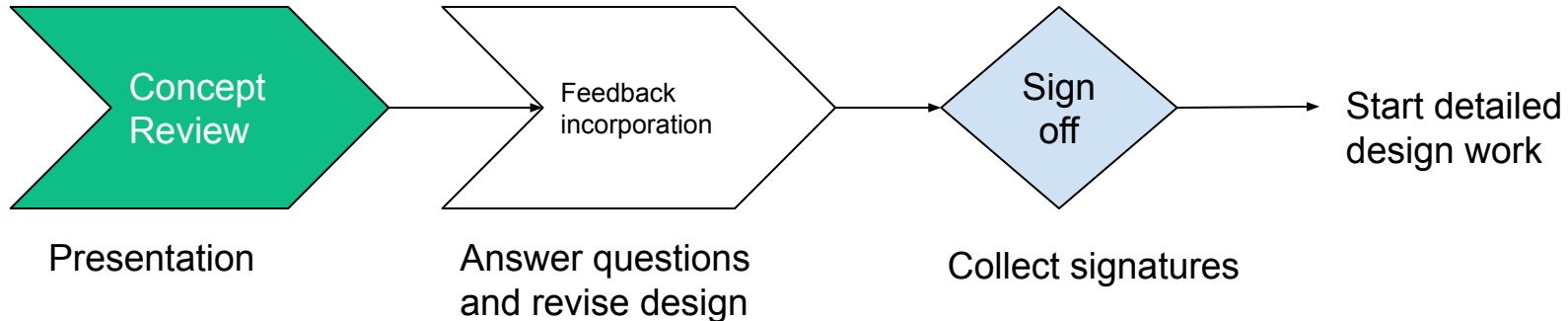


Grid Interface Panel Concept Review



Concept Review Goal

- Align engineering and leadership, so that we are on the same level of understanding of the risks moving forward with detailed design work (Design Review)
- Collect feedback in [form](#)





What is our Grid Interface Panel?

Lunar's Grid Interface Panel:

- Automatically detects the status of the grid and seamlessly transitions from grid power to local power and back during a power outage.
- Has breaker slots for the inverter and other relocated loads
- provides monitoring of house loads for solar self-consumption and time-based controls, either directly or with remote CTs

Why are we doing this in addition to the Meter Socket Adapter?

- 80% of California installs are meter integrated & SunRun has the majority of its business in CA.
- 90% of non-CA installs are non-meter integrated. Overall Lunar sees its business approx 50-50 meter-integrated and non meter integrated



Key Grid Interface Panel Specifications

Electrical Specifications

AC Connection	240 V Split Phase
Current Rating	200 A
Survivable Short Circuit Current	12 kA (limited by K246 relay)
Overcurrent Protection	Optional 200 A breaker
Overvoltage Category	Category IV
Wired Connectivity	Hardwired comms, PLC (G3)
Wireless Connectivity	900 MHz (802.15.4g)
Internal Power Supply	OV CAT IV, both line and load
External DC Input	15 V, 2A w/ eFuse and OV protection
Metering	ANSI C12.20 revenue grade, 0.2%
Firmware Update	Yes

Mechanical Specifications

Dimensions	Flush mount between two studs
Internal Panelboard	8 breaker slots min, 200A max (for up to 4 Lunar inverters)
Mounting	Wall mount or flush mount
External Connections	LV DC Input Power - 16-24 AWG Wired comms - 16-24 AWG Optional 2x external CT or 2x Rogowski coil
Operating Temperature	-40 to 50 °C
Enclosure Rating	NEMA 3R, IP 56 (IP 67 Electronics)
Warranty	20 years
Certifications	UL 1741, UL 869A, ANSI C12.20
Emissions	47 CFR Part 15

RWA: This has been deprecated. See:
<https://lunarenergy.atlassian.net/wiki/spaces/PRODUCTS/pages/3705020770/Grid+Interface+Panel+Landing+Page>



Requirements - Listing Scopes

- UL1741 - Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- UL 67 - Panel boards
- UL 869A - Standard for Reference Standard for Service Equipment
- UL 916 - Standard for Energy Management Equipment
- FCC Part 15 - Radio Frequency Devices
- ANSI C12.20 class 0.2 - Electricity Meters



Short circuit requirements

- Limited by K246 relay
- 12 kA / 66.7ms
- 7kA peak / 100ms

*Higher short circuit rating can be achieved with upstream fuse or breaker

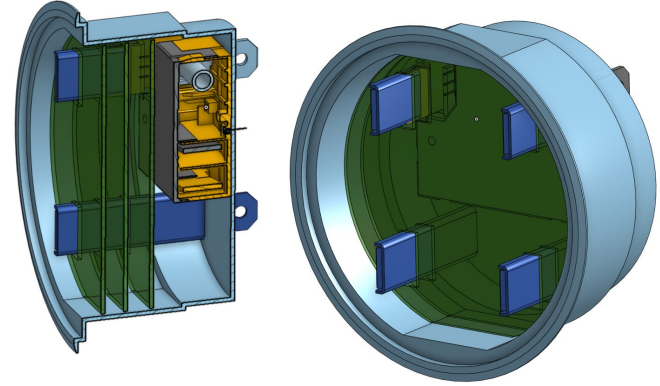




Comparison to Meter Socket Adapter



Meter Socket Adapter and Grid Interface Panel



	Grid Interface Panel	Meter Socket Adapter
Relay	Custom K246 relay	Custom KG K255
Power entry/exit	Lugs (L1, L2, N, PE)	Meter terminal (L1, L2) + neutral reference
Firmware	Same	Same
Communications	Same	Same
Breakers	Yes	No
Metering	ANSI C12.20 class 0.2	ANSI C12.20 class 0.2
External Current Sense	Two external CT/Rogowski	None
PCBA	TBD	2 or 3x concentric disc

- Goal of shared firmware and schematics between MSA and grid interface pane.
- PCBA/Layout sharing will depend on mechanical design.
- Shared resources allow a grid interface panel & MSA project to launch on similar timelines

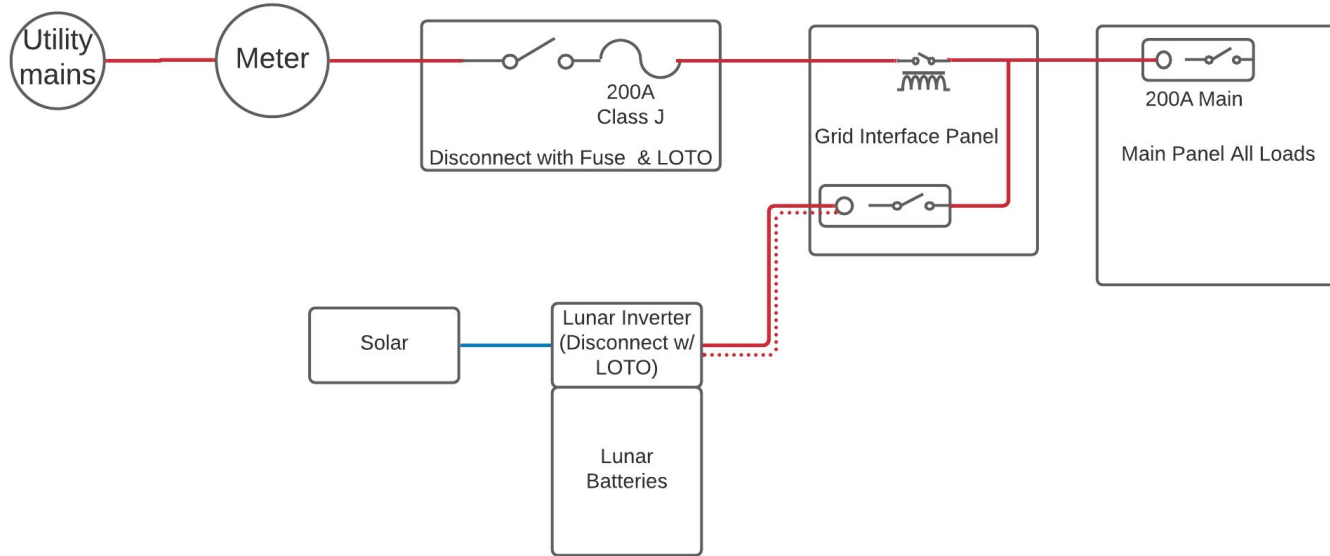




Installation Scenarios



Whole Home Backup, Grid Interface Panel



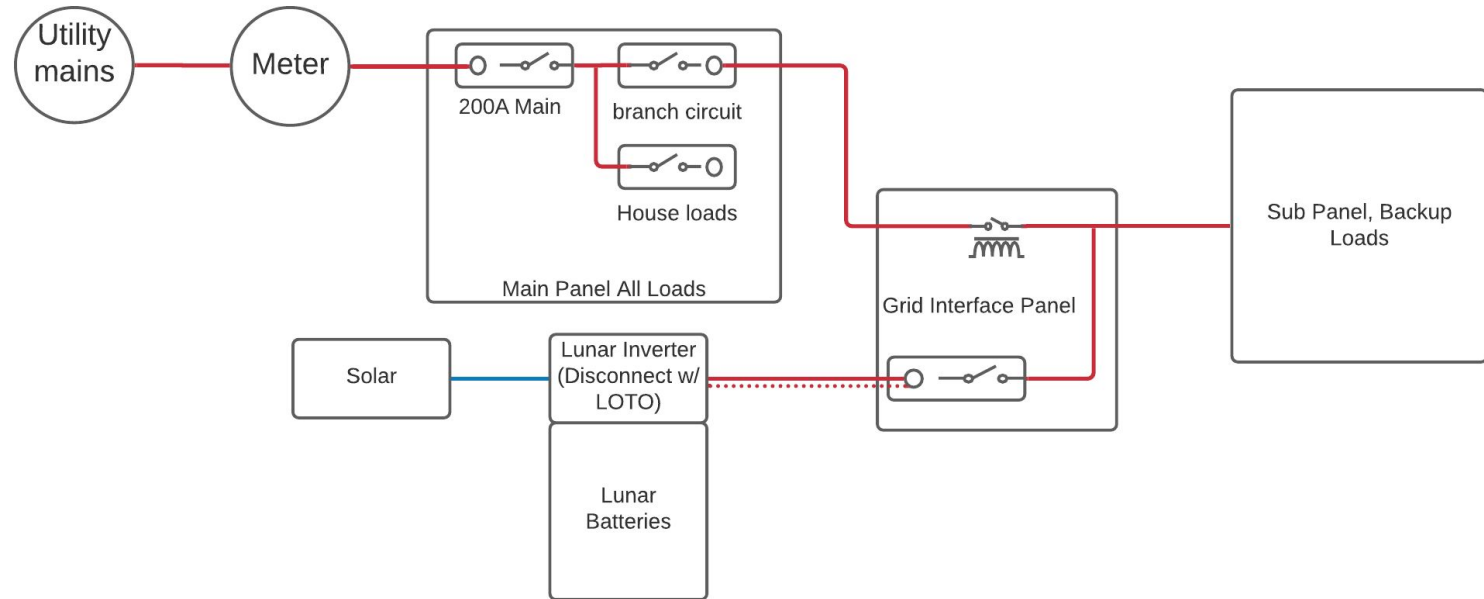
..... = up to 3 additional Lunar inverters and breakers

LOTO = lock out tag out

ne whole home has some number of load shedders



Partial Home Backup, Subpanel



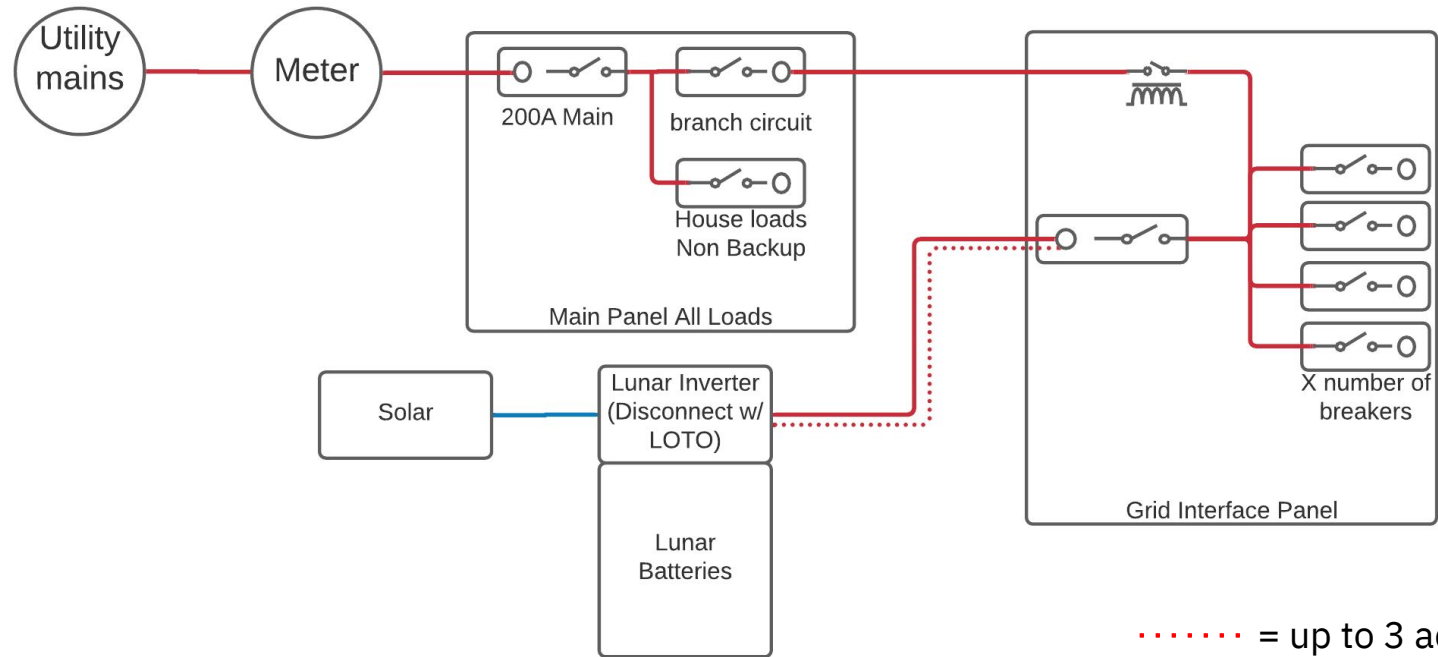
..... = up to 3 additional Lunar inverters and breakers

*Assume whole home has some number of load shedders

LOTO = lock out tag out



Partial Home Backup, No Subpanel



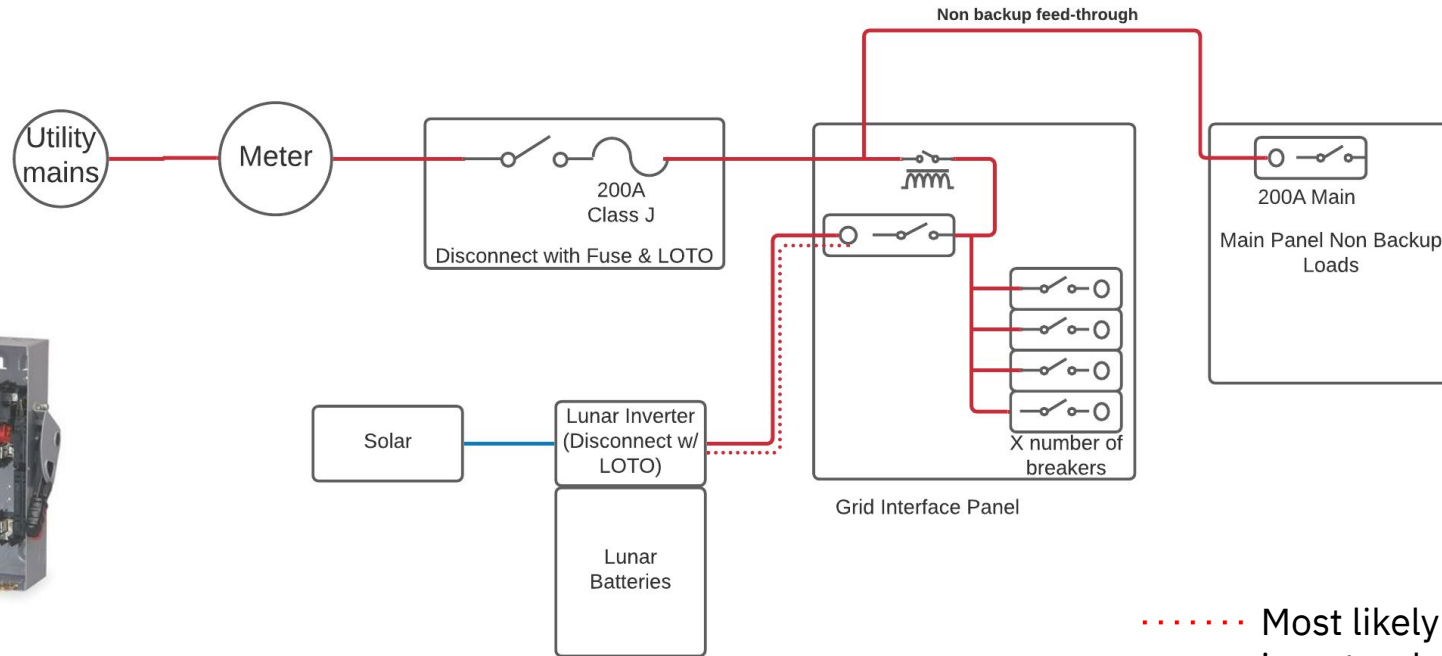
..... = up to 3 additional Lunar inverters and breakers

LOTO = lock out tag out

*Assume whole home has some number of load shedders



Partial Home Backup with Feedthrough (no subpanel)



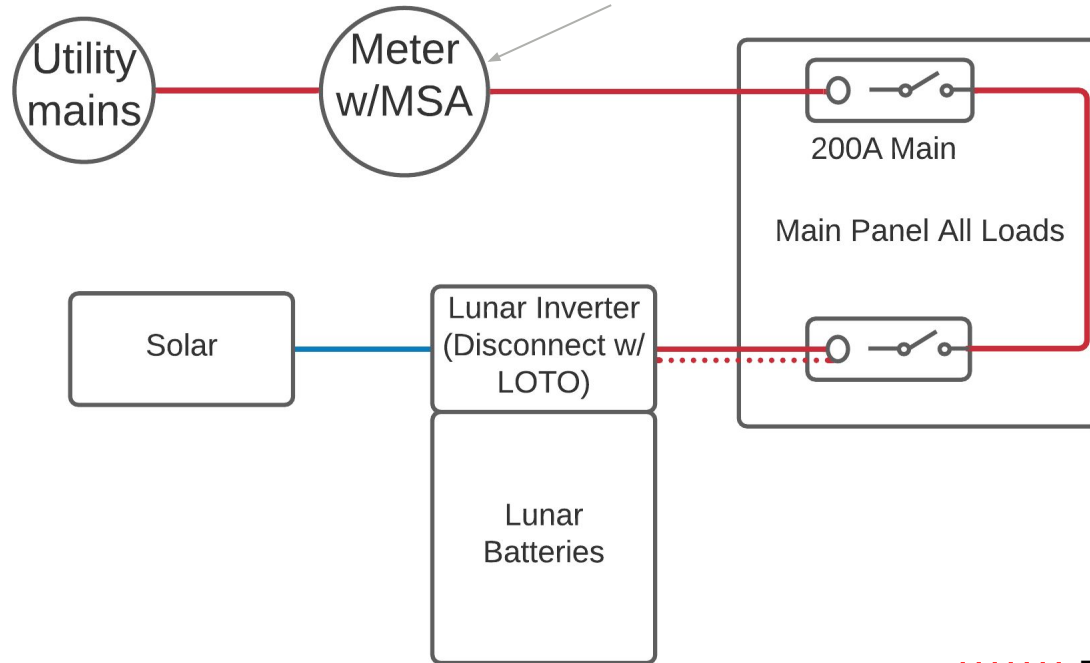
..... Most likely just 1 Lunar inverter due to small loads

LOTO = lock out tag out

*Assume whole home has some number of load shedders



Whole Home Backup, Meter Socket Adapter



..... = up to 3 additional Lunar inverters and breakers

LOTO = lock out tag out

*Assume whole home has some number of load shedders



Mechanical Assembly

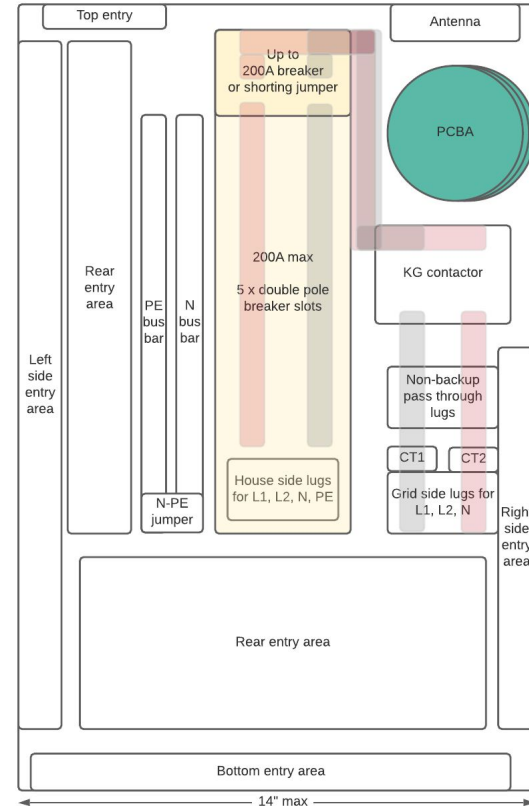
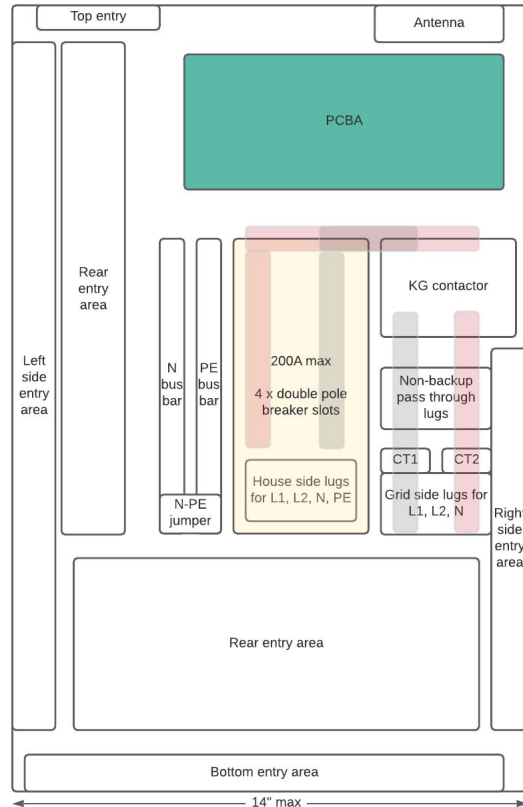


Detailed Mechanical Requirements

	Grid interface panel
Overall width	Flush mount between two studs
Overall depth	< 6 inches
Bend radius	For 200A AL wire (250 kcmil dia)
Knockouts	Top, Side, Bottom, rear
Top entry	Compatible with Eaton or Square D (match breaker) - water tight
IP Rating (Overall Enclosure)	IP56 for main enclosure/IP67 electronics
Service/Installation	Wall mount/flush mount
Install location	Indoor/Outdoor
Cooling	Passive
Dead front	Yes, (removable using tool)
Feed through	200A, non backup
Enclosure Material	Plastic (preferred), Metal (based on code/requirements)
Antenna window (metal enclosure)	For 900MHz radio



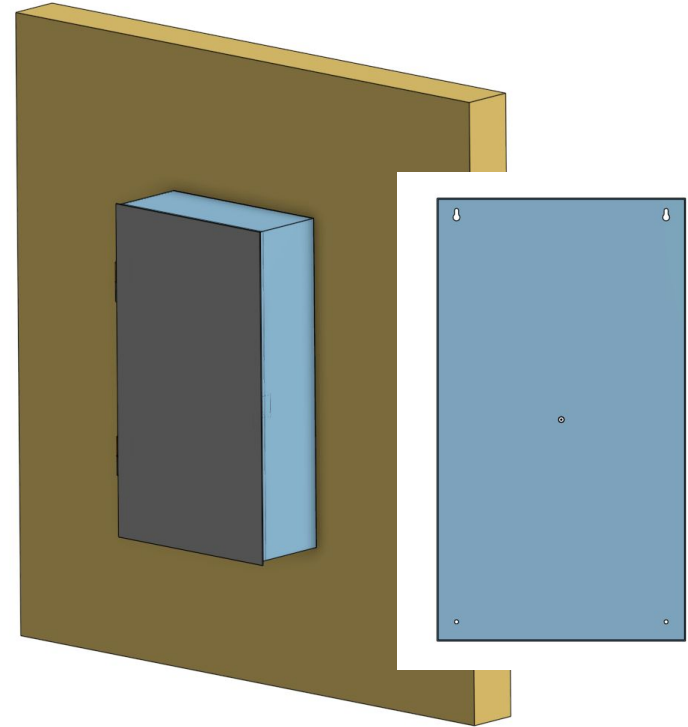
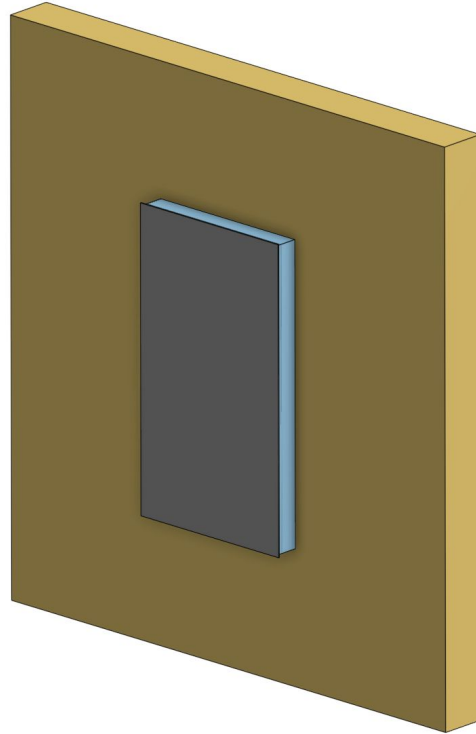
Grid interface panel layout





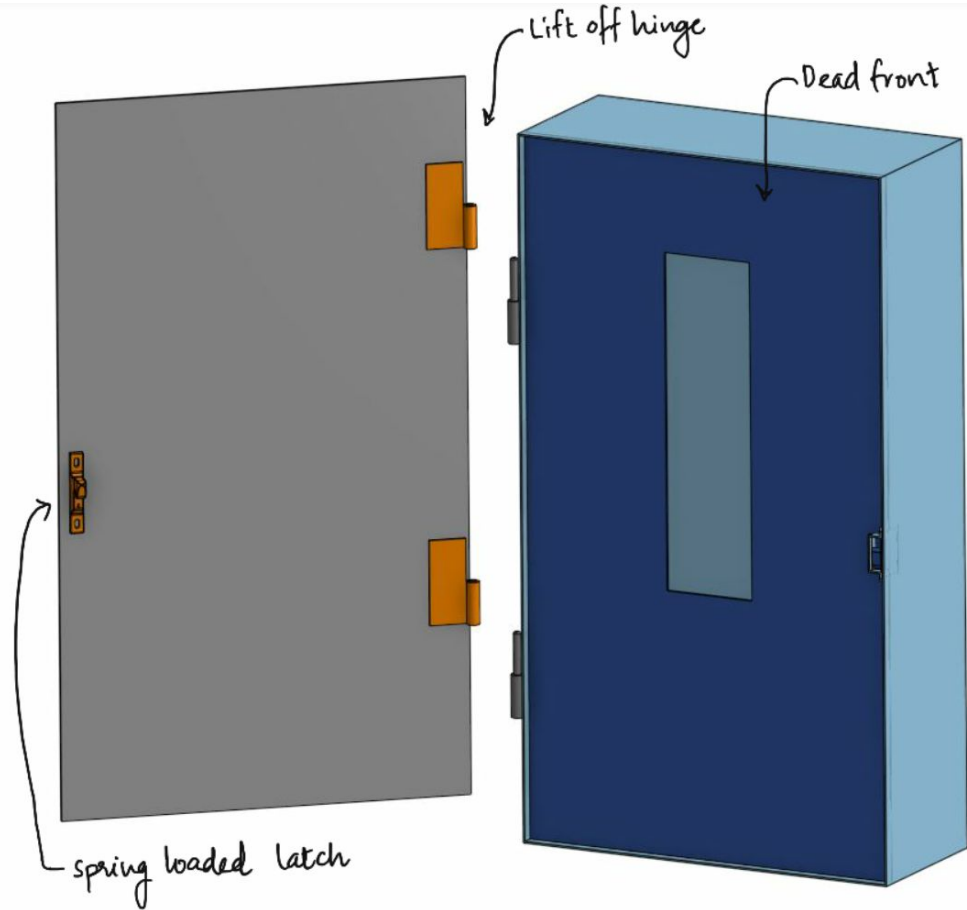
Mounting Strategy

- Wall mount - stud mounting, intended not to be required due to low weight
- Flush mount - between two studs (highly preferable)
- Screw dimensions TBD



Door Hinge & Latch

- Removable front panel - This is a requirement for installers
- Lock out, tag out capable





Grid Interface Panel Mechanical Dimensions

	Width (mm)	Height (mm)	Area (m ²)	Links
Tesla Gateway 2	411	660	0.27	Datasheet
LG ATS-Box	338	622	0.21	Datasheet
SolarEdge Backup Interface	352	523	0.18	Datasheet
Enphase Enpower	500	916	0.46	Datasheet
Generac ATS	343	762	0.26	Datasheet
Lunar Grid Interface Panel	~350	~650	~0.23	



Electrical

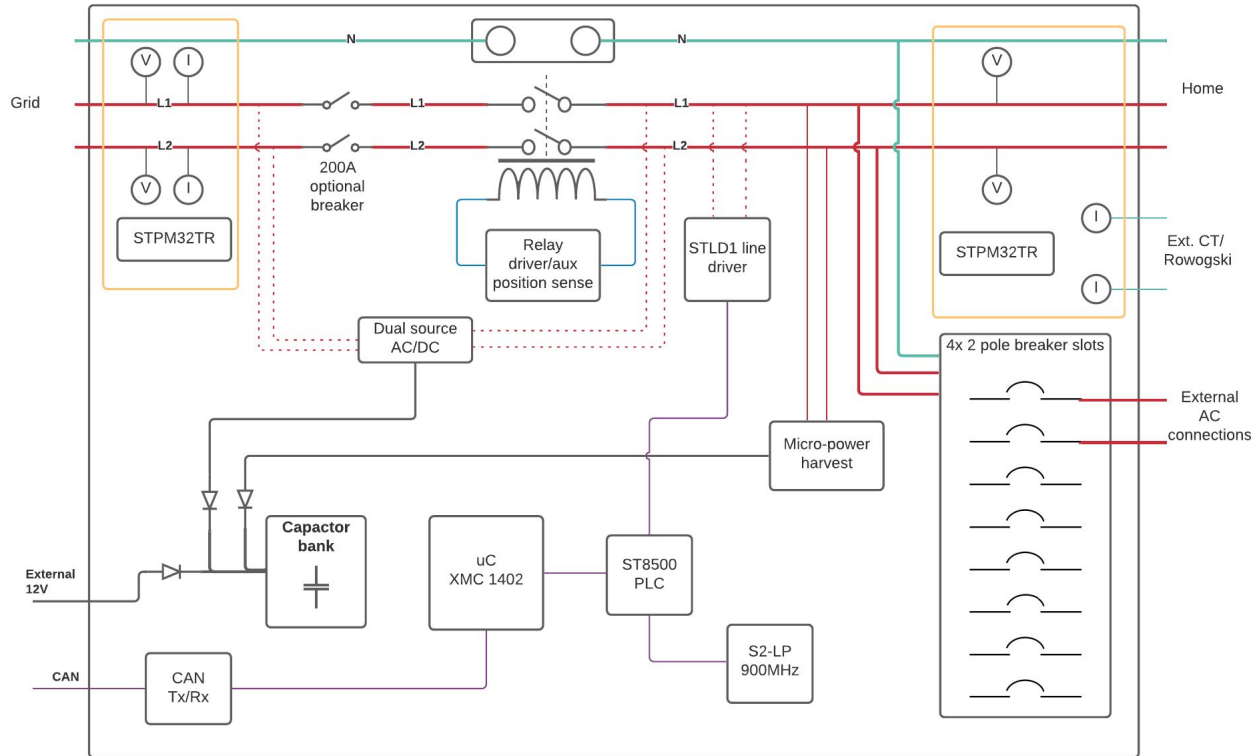


Key Electrical Requirements

	Grid Interface Panel
AC voltage (Nominal)	120/240V, 60Hz split phase, OV CAT IV
Maximum Input Short Circuit Current	12kA (limited by K246 relay)
Disconnecting relay	200A split phase relay, latching
AC meter	ANSI C12.20 revenue grade, 0.2%
Primary Connectivity	PLC/900 MHz, Wifi (for B-sample)
Backup Connectivity	Wired (CAN or RS-485)
Internal Panel Board	8 breaker slots min, 200A max (for up to 4 Lunar inverters)
Additional current sense	2 x CT or Rogowski coil
Lifetime	20yrs
Temperature Range	-40C to 50C full sun
Certifications	UL 1741, UL 67, UL 916, ANSI C12.20 Class 0.2
Dark start	No user input dark start capable



Electrical Block Diagram for B sample



- Certified latching relay
- Revenue grade metering chip
- Power line communications & 900MHz radio
- Isolated external comms (OV CAT IV)
- Hold-up Capacitors



Breakers

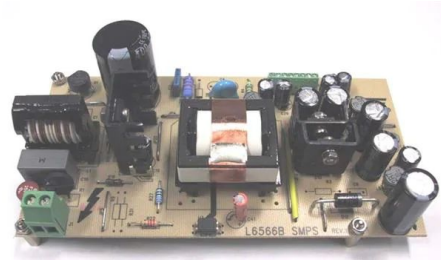
- Will ship without main breaker or breakers for the panel board
 - Main breaker will have jumper by default - removable if installer wants to install a breaker there
- Breakers will either be compatible with Square D or Eaton (but not both), based on feedback from Sunrun.
 - We will make decision during detailed design
 - Top entry conduit cap's manufacturer will also match breaker manufacturer





Power supply

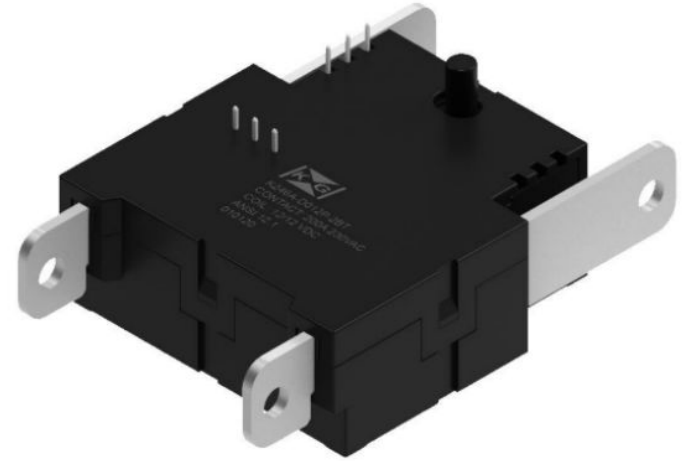
- Overvoltage category IV rated
- 20 year life
- Dual input source (from grid and home)
 - Can we use two full wave rectifiers for one DC bus?
- 216 to 264V (+/- 10% of 240V nominal)
- 15V, 2A (30W) max, rough estimate
 - Actual number could be much lower due to hold up cap
 - Need at minimum some headroom above comms + microcontroller
 - Once power tree is made, we can have much lower and accurate number for power





Relay actuation

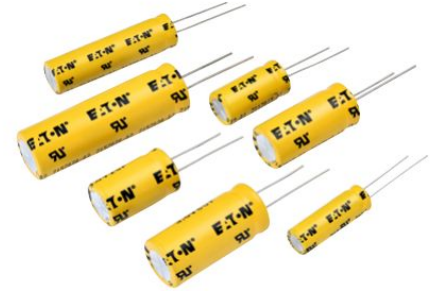
- Relay coil voltage: 9.6V to 14.4V
- Use H-bridge for relay actuation
- 12 ohm coils
- Current of actuation ~1A



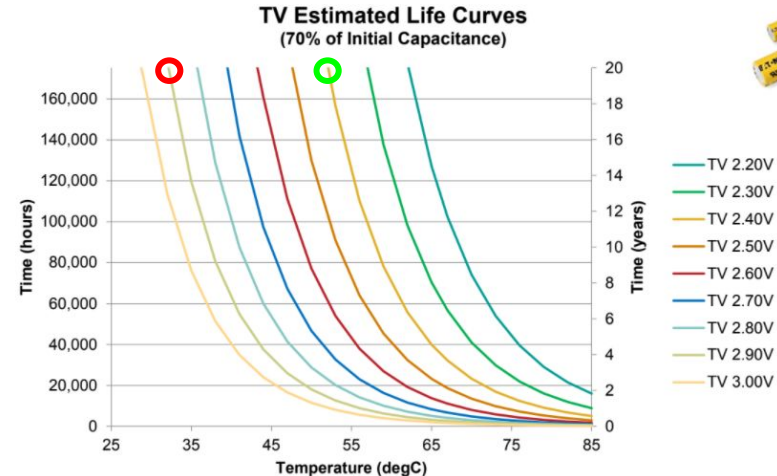


Capacitor hold up for grid transition

- KG K246 relay:
 - Working voltage: 9.6V to 14.4V
 - Minimum pulse duration: 50ms
 - Recommended pulse duration: 200ms
 - 12 ohm coil
- Supercapacitor design:
 - 20 year life - Eaton is one of the only ones that has data for 20 year life.
 - **6 cells in series, 2.4V per cell. 6.3 Joules (green circle)**
 - 5 cells will drop max average temperature requirements to 35 deg. C - unsure if we can hold this with sunload + T rise from contactor
- Cap bank at 14.4V can throw the relay:
 - 2 times using recommended pulse
 - 13 times using minimum pulse
 - Previous experience with relay shows relay motion stops at about 30ms after initial pulse



TV Family Estimated Life Curves





Metering / non-export

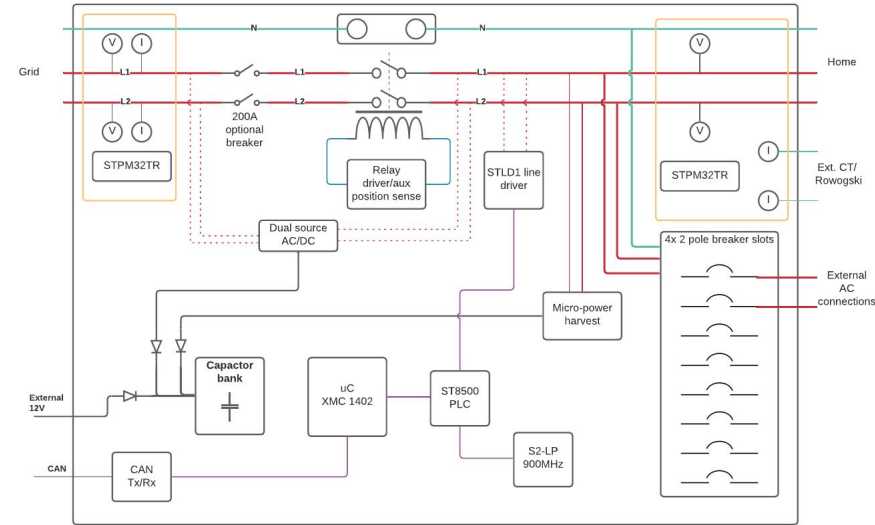
- Requirement: grid interface panel to deliver non-export functionality
- Metering
 - CTs and sense resistors for synchronization, non export is same cost for revenue grade vs non revenue grade
 - Lock step with inverter and meter socket adapter hardware to avoid additional cost/time during cert. If revenue grade metering causes any non-trivial timeline slip, we will put metering on pause.
 - Target: 0.2% revenue grade, ANSI C12.20
- Use Weco 4330 for metering metrology
 - 0.01% energy accuracy





Voltage and current sense

- Voltage sense via resistor divider
- Current sense from
KG-MCT010/200(240)A100mA-0.1
 - \$0.88/pc at 88k per year quantities
 - Burden resistors on PCBA
 - **Need custom housing to fit CT through bus bar - one time tooling cost of \$1800 is required.**
- STPM34TR for revenue grade metering ASIC
 - ~ \$0.94/pc at 50k pcs/year
 - Two voltage sense and two current sense
 - Class 0.2 revenue grade





External current sensors

- 2x external current sensors
- Non revenue grade
- Can be open clam shell CT or Rogowski coil
 - CT would have built-in burden resistors





Microcontroller selection

- XMC1400 family - same as PV optimizers
- Needs to support OTA via PLC/900MHz
- Need 3 SPI channels
 - 2x metering ASICs
 - 1x PLC/ST8500 comms

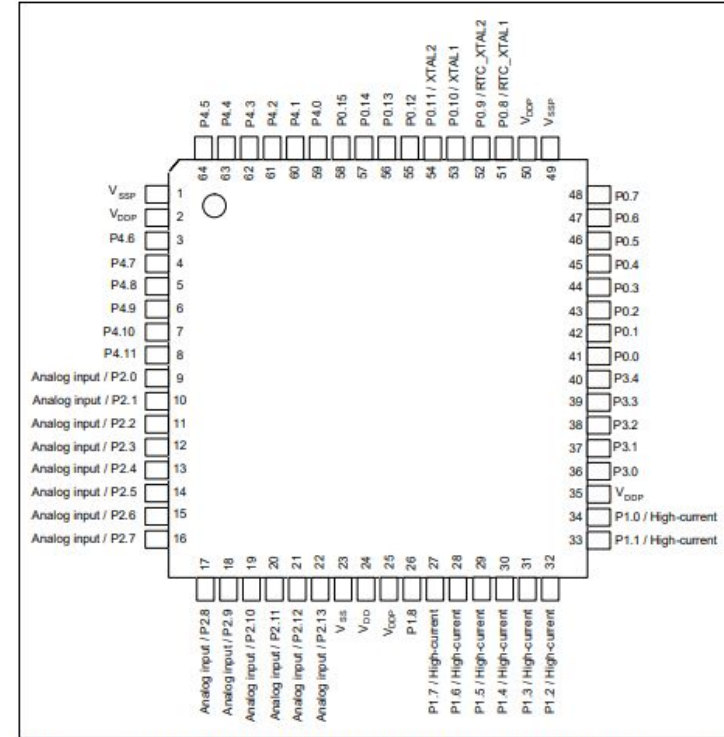


Figure 9 XMC1400 PG-LQFP-64-26 / PG-VQFN-64-6 Pin Configuration (top view)



Wired communications and power

- Recommend using CAN bus
- Connector for power/comms
- spring loaded Phoenix type connector (as preferred by Sunrun)
- Wire sizing:
 - 16 AWG to 24 AWG
 - Hold up cap can allow thin wire to be used for power
 - Make robust against CAT 5 wire installations

	CAN	RS-485
Distance	250k @ 250m	~2M @ 250m
Speed	10k to 1M	100k to 10M
Hardware auto-retry/CRC	Yes	No
Automatic arbitration	Yes	No
Shielding required	No	Yes in many cases
Stochastic vs Request/Reply	Stochastic	Request/Reply
Max packet length	8 bytes	Indefinite
Software for plotting traces	Multiple	Sparse





External communication - non wired

- Use PLC/900 MHz for communication
- ST8500 SoC
- STLD1 line driver for power line communications
- S2-LP 900MHz radio + Skyworks power amplifier
- Will need small window for 900MHz antenna



Dark start strategy - wired/micro power harvest

- Wired power provides energy for relay position sense
- AC or DC micro power harvest for non-wired relay position sense
 - B-sample at least



Backups



Grid Control Panel Temperature Range

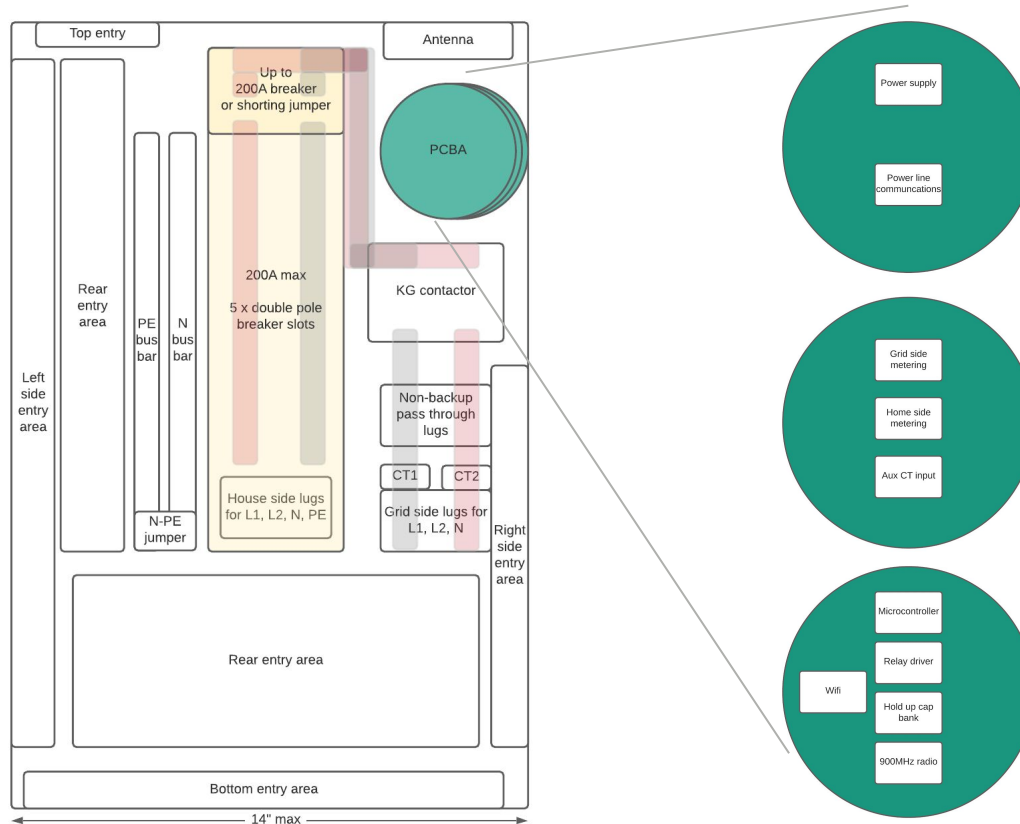
	Nameplate Ambient Range	Same As Battery	Links
Tesla Gateway 2	-20°C to 50°C	✓	Datasheet
LG ATS-Box	-25°C to 40°C		Datasheet
SolarEdge Backup Interface	-40°C to 50°C		Datasheet
Enphase Enpower	-40°C to 50°C		Datasheet
Generac ATS	(Not listed)		Datasheet
Lunar v2	-40°C to 50°C		

Because of the lack of content in our Grid Control Panel it seems like we could be listed to -40°C to 50°C without driving much more cost.

If that premise if false Lunar could follow Tesla's path and use the same temperature range as the battery/inverter system



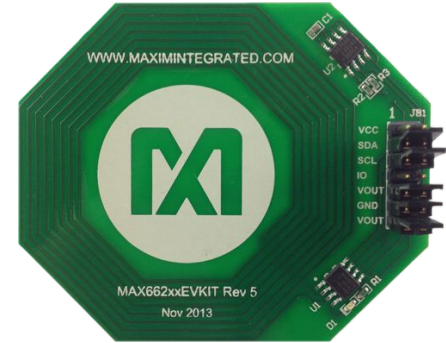
Circular PCBA Board Layout





Dark start strategy - NFC

- Use self powered NFC reader to check for relay status (current candidate: MAX66242)
- Standalone circuit - nothing else gets powered
- Dark start sequence:
 - User connects smartphone to Home Controller's access point
 - Battery SOC sufficient for dark start
 - Customer requests dark start - app notifies user to scan phone by NFC reader
 - Customer scans NFC reader at grid interface panel, confirms relay open
 - App sends "clear to start" signal to Home Controller
 - Inverter starts outputting power in voltage source mode
- For those without smartphones:
 - Can buy optional "NFC reader" with Wifi, NFC that's powered by AA batteries





Dark start strategy - solar (Michael Starman)

- Use solar cell to harvest power for micro-burst communications
 - Charge solar via sun or flashlight from customer
 - Flashlight might only be a smartphone (around 50 lumens)
 - Solar cell of 25x25mm for charge time of 5 seconds (typ. smartphone)
 - Behind main cover, on dead front
 - Will need clear panel to allow solar input
 - Also might need DC/DC, MPPT
 - Will need to isolate non-essential devices from essential devices
- Cypress Energy Harvesting PMIC - S6AE101A (\$1.50 in volume)
- Dark start sequence:
 - User connects smartphone to Home Controller's access point
 - Battery SOC sufficient for dark start
 - Customer requests dark start - app notifies user to shine light on solar cell
 - Customer shines light at grid interface panel, waits for X seconds, confirms relay open
 - Grid interface panel sends "clear to start" signal to Home Controller
 - Inverter starts outputting power in voltage source mode



Knockouts

- Location?
 - Top, sides - top and bottom sides, bottom, rear
- Size?
 - Options for 1" or $\frac{3}{4}$ "
 - Are all of them capable of going to 2.5"?
 - Are there multiple per side?
 - How do we seal knockout when not used? NEMA 3R gaps, or smaller?
- Top cable entry - is this a Lunar part or a off the shelf part?

Replace with detailed diagram here



Water drainage strategy

- Premise: water ingress can and will happen through conduits - installation never perfect for all sites, water can come in
- Desire: to be tolerant of dripping water coming from any knockout location

Replace with preliminary concept image



Materials

- Need non-metallic opening for antenna
- Needs to be able to withstand weather for 20+ years
- Needs to be able to be mounted securely and withstand seismic loads
- Want to be durable and resistant to scratches/damage during installation
- May need to contain high kA short circuit testing loads
- UL panel spec - UL 1741, UL 50



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Connectorized wire feed?/ not possible

- No installer access to inside of enclosure needed; just plug 200A connectorized wire to side of grid interface panel
 - Same for external comms/power
- Questions:
 - How does this work with conduit requirements?
 - Unused 200A input locations? Plug them up with watertight seal?



Main heat sources

- KG relay
- PLC modem(?)
-



External electrical connections

- Comms
 - CAN
 - DC power
- House wires
 - 200A line wires
 - Neutral
 - Ground(?)
- Circuit breaker wires
 - Max gauge(?) and number(?)
 -



Sealed (?) electronics assembly

- Insects shouldn't get in
- Water droplets shouldn't get in
- Massive dust shouldn't get in, but a little is okay
- Feedback from Chris Todd?
- What type of connectors on PCBA and what type of ingress protection is offered?
 - CTs, voltage sense, external CT/Rogowski coils
 - External comms/power
 -



Grid interface panel layout

- Need to have:
 - Same schematic as MSA
 - Grid L1, L2, Neutral
 - House L1, L2, Neutral
 - Earth is required
 - Breakers (good to have, TBD) - Kunal (min 4 double pole + more depending on CAD)
 - Current capacity? 200 A
 - Knockouts
 - Antenna(s)
 - Relay
 - Two current transformers
 - External wired communication
 - 200A feed through - non backup
 - Ability to strap ground to neutral (if we are a panel)
- Where do we want grid side and load side lugs to be? (depends on the layout)
- Replace this with diagram