07 May 2013

From: Daniel Hellerstein
To: Albert Nunez (Capital Sun Group)
Re: Statement of work

Hello Albert.

As I stated in my email of 6 May, I would like to more forward – with a cap of $9503. A statement of work and timeline are required, after which I can sign a contract and give you the downpayment.

Just in case you misplaced it, the following is the outline of a statement of work.

The following lists my view of the job requirements. Actually, some are requirements, and some are “optional” – their achievement may depend on how much time and $ are left over after doing the required portion is, or how willing will I be (if the need arises) to exceed the cap.

**Requirements**

a) Fix the problem with the non-performing 5 panel string.

I speculate: this might require obtaining a replacement Helios PV panel (using warranty).

b) Install battery backup system.

This involves mounting existing batteries in battery enclosure, connecting batteries to Magnum inverter, and connecting inverter to existing critical-loads sub panel (the “GenTran” transfer switch”). And any inspections and paperwork required by Pepco, MoCo, etc.

- Note that the GenTran contains a transfer switch that allows use of an outside (manually started) generator. This capability, of using a generator to run critical loads during outages, **must** be maintained.
  - I assume, as a layman, that this can be achieved by connecting the Magnum's output to the “utility” input of the GenTran. Thus, upon job completion:
    1. Magnum AC input from main circuit breaker panel
    2. Magnum AC output to “utility” input of the GenTran.
       - This replaces the current connection from the main breaker panel to GenTran “utility” input
    3. Generator remains connected to “generator input” of the GenTran
    4. Magnum DC input from batteries in enclosure …

Perhaps this is not code or is otherwise unacceptable? If so, we need to consider alternatives.

- Currently the AC input to the GenTran is 240v x 50w =12kw; while the Magnum steady output is 4.4kw (with greater peaking). This may be seen as an underpowering of the critical loads. I don't think it is, since the only real draws are a microwave and a toaster oven which are rarely on simultaneously for an extended period.

        - Perhaps  adding a circuit or two would be helpful, if it allowed movement of some heavy draws off of circuits connected to the critical loads panel.

- A midnite sun MNBE-8D2x2 DELUXE battery enclosure is on order, and should arrive around May 9.
    - http://www.midnitesolar.com/productPhoto.php?product_ID=398&productCatName=Battery%20Enclosures&productCat_ID=12&sortOrder=2
    - To save time and $, I am willing to assemble this. If, in your judgment, it would be less risky for you to assemble it (in terms of minimizing risk of making dumb mistakes), I can be convinced to not do it.
    - If code permits, I would like for this to be installed underneath the current location of the Magnum inverter. This will probably require repositioning the magnum – it should be raised 6 or so inches. As we both observed, this should not be a problem.
        - Note that this is a logical spot for the enclosure, as it minimizes cable length from batteries to inverter
        - Note that I have a mixture of heavy “battery” cables on site (left behind by the prior contractor). Perhaps these can be used (thereby avoiding ome expense).
        - Note that the enclosure comes with 250A battery breaker, and 3 cables for interconnecting batteries (see link above)
- During outages, the Magnum should automatically provide AC power to the critical loads sub panel. The Magnum contains a transfer switch, so during outages there should be no chance of backflow into the main breaker panel.
    - Is that sufficient, or does code require an outdoor cutoff for AC output from the Magnum? Note that “removing” the outdoor meter would cause the Magnum to invert battery power and supply it to the subpanel... so I would not be surprised if strict code requires an outdoor cutoff for AC power supplied by the Magnum.
    - There are several cutoffs on the Magnum mounting panel, perhaps those are sufficient (though they are obviously not accessible from outside).

**Important note:** if dealing with the hassles and expenses of implementing this “most of house UPS” battery backup system  become sufficiently large, I would  give up and sell the equipment rather than jeopardize the functionality and timeliness of the PV install. My current generator-only backup kind of sucks, but it is useable.

IOW,  careful thinking about how to do this is needed (rather than charging forward and burning bridges as you get to them).

c) Install DC optimizers.

The following assumes a Tigo solution (25 maximizers, 1 Gateway, 1 MMU)

- The MMU contains an emergency DC cutoff.
- You suggested that it is sensible to install the MMU outside, near the current AC disconnects, rather than inside near the Aurora inverters. That makes sense to me.
    - I have an ethernet cable running from my LAN switch to the basement corner containing the inverters. It should be easy to extend this to a MMU mounted outside (near the current AC disconnects)
    - There is an AC outdoor receptacle  within 2 feet of  the current AC disconnects

    - Although this receptacle can be used for the MMU (I believe the MMU requires AC power), it might be nice to pig tail an additional plug, or directly wire the MMU, so as to not lose an outlet. But this is not a requirement.

d) Adjust position of 8 panels on flat roof.

There are two rows of 4 PV panels on the flat roof, tilted up to face North. In March and early April, before noontime, I noticed that the front row shades the bottom 5% or so of the back row.

- Lowering the front rows upper end several inches would eliminate this shading, but would reduce the tilt of the front row
- As an alternative, you suggested raising the back row (both front and back ends of the panel) by several inches. This strikes me as a much more cumbersome job – it would require replacing the front and back vertical support bars, whereas lowering the front row would just mean trimming the size and drilling a few holes in the existing back vertical support bars.
- I can be convinced either way – is the efficiency gain from maintaining the tilt of the front row worth the expense/hassle of raising the back row?

e) Dealing with permits and other paperwork for Pepco, MoCo, etc.

As I noted, the Pepco paperwork seems to have been filed and accepted. I would like to believe, but have no actual proof, that the MoCo paperwork has been filed.

- Note that the copy of the MoCo paperwork I forwarded to you is wrong in many details. I have no idea if that matters.

f) Paperwork for MD rebates.

At least tell me what forms to fill out!

g) SREC application

At least point me to an appropriate aggregator.

h) Job completed within 4-6 weeks of downpayment

Unavoidable delays due to official (i.e.; Pepco and MoCo) tardiness will not be subject to this deadline.

**Optional**

The following are optional, whose completion depends on the time and $$ required to complete the above.

a) AC coupling

The original design of this system presumed an AC coupling solution. While I may be incorrect, I believe the architecture would be:

- Output from one of the Auroras (“Auroroa B” – the Aurora inverting the 11 panel string) would be backfed into the GenTran.
    - Actually, the GenTran is full (all breakers are in use). However, an additional sub panel can be easily chained off the GenTran. Thus, the Aurora would backfeed a second sub panel, rather than directly into the GenTran.
- During normal operation, this would be no different (in concept) than backfeeding to the main panel.
- During outages, the Magnum engages its internal transfer switch (to isolate itself from the main panel), and begins providing AC to the critical loads panel by inverting from batteries (rather than drawing utility power from the main breaker panel). Thus, loads on the critical loads panel see only a short (15ms) disruption in AC.
- The Aurora B would continue to see AC, hence would continue to provide inverted AC power from the PV panels (it might do a 5 minute wait, due to the 15ms switchover time).
- AC power backfed from the Aurora, into the Magnum, would be used to bulk charge batteries. If batteries are fully bulk charged, the Magnum should (if Magnum's literature is to be believed) modulate the frequency of its AC power. This should register as a fautly grid to the AuroraB, causing it to cease production of AC power from the panels.
    - My understanding is that this protects against overvoltage condition, since the batteries can no longer absorb excess voltage once they are bulk charged.
    - As a safety backup, if the batteries become overcharged (too high voltage), the Magnum is supposed to disconnect from the batteries. This will stop AC to the critical loads panel, hence to the Aurora. Obviously, this is not good (no power to the critical loads), but it does prevent overvoltage.

I understand that this is a clumsy architecture. A more elegant solution would incorporate a battery charger running in reverse, that dumps excess power to a resistor. Or, the Sunny Boy integrated solution. I decided to adopt this clumsy solution to save money, given the infrequency of outages.

If feasible, I would like this architecture to be enabled. However, I wonder if it will satisfy code.

- The GenTran has a 50A bus, but the breaker in the Magnum mounting panel is 30A. Given that 2000W (@240v) is a probablemax output from the AuroraB, are there capacity constraints (on backfeed amperage through the subpanel and magnum).
- Will MoCo just not like this odd architecture, and figure out a way to say no?

Thus: if implementing this AC coupling feature proves problemmatic, I would rather forget about it than spend an inordinate amount of time and money implementing it. That is; treat the Magnum/batteries as an independent system, with no direct connection to the PV panels. If this means this portion of the job does not quality for federal solar tax credit, so be it.

b) Connect AC battery charger to batteries

I purchased a PowerMax 18A, 48V AC charger. The idea is to use this to charge the batteries from the generator during outages. I can imagine two installatons

1. Connect the PowerMax to a circuit connected to the critical loads panel. When

the generator is being used, the Magnum will be disconnected from the GenTran. Thus, weird backfeed issues (i.e.; power from the generator and from the Aurora B) will not occur.

2. Splice a 120V receptacle into the line from the generator BEFORE the connection to the GenTran.   Thus, the batteries could be charged simultaneously by the AuroraB and by the generator.
   - An advantage of this is that the critical loads panel would see power from the Magnum, which is MUCH cleaner than power from the generator
   - Would there be backfeed issues into the generator? I would expect not, since the only connection to the generator is through the PowerMax

Actually, even if the AC coupling is not attempted, solution 2 has some appeal. It allows the Magnum to be used as a filter for the generator – at the cost of limiting useable power from the geneator to be about 1kw (but a constant 1kw).

IOW: I am open to suggestion as to how this should be implemented. But some means of charging batteries from a generator is a very sensible thing (assuming one wants a nicer solution during outages). Frankly, if I had to choose between AC coupling and the ability to charge batteries from a generator, I would chose the latter.

c) Redesign string architecture

An issue is that each Aurora input is clipped at 2kw.
Why is this a problem?

- The 9 panel string has STC output of: 9x 260=2340
- The 11 panel string has STC output of: 11 x 260 = 2860

– which means that under ideal situations, the output of the strings would  be clipped.

In particular, the 11 panel string is subject to clipping, even under NOTC conditions. But the  11 panel string connects to an Aurora that only has one input being used. Would it make sense to break this string into two other strings?

- It also seems like a waste to not take full advantage of the having 4 separate MPPT inputs, especially for the 11 panel string (that has a mixture of panel orientations)

Actually, I suspect that this kind of re-stringing is not worth the trouble: clipping is unlikely (see tables below) and taking advantage of the extra MPPT of an additional input (going from 3 to 4 strings) may not be worthwhile, especially given the installation of the Tigos.

For example, I took some measurements at 1 PM today, under a mostly clear sky (some upper atmospheric haze), and air temp of around 60F (15C),

For 9 string panel (STC and NOTC values are from the Helios 260T spec sheet.):

| | STC/panel | NOTC/panel | Measured | Per panel |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Voltage | 30.8 | 27.7 | 260v | 28.8 |
| Amp | 8.5 | 6.8 | 7.7A | |

For 11string panel (260W panels):

| | STC/panel | NOTC/panel | Measured | Per panel |
|---|---|---|---|---|
| Voltage | 30.8 | 27.7 | 338V | 30.7 |
| Amp | 8.5 | 6.8 | 6.8A | |

This suggest that under the current layout, clipping isn't going to be a problem. But, if Tigo's succeed at upping power output, maybe clipping will be an issue?