

Evolution of the E-Panel



Hi, my name is Robin Gudgel. I'm the mechanical design engineer responsible for the designs of the products shown above. I will attempt to explain a brief history of Renewable energy (RE) breaker boxes, why they are so different, and how it all relates and has evolved into the newest entry into the RE industry; the **E-Panel**.

The AC section

Why can't we just go to Home Depot for the required over current protection and disconnect? For the AC section you can (sort of). The breakers used in the AC section of a Renewable Energy system can be standard 120VAC branch circuit rated circuit breakers. In a normal grid

connected home, there is only one source of AC power that gets distributed to many different circuits in the home. In a Renewable Energy home and some grid connected homes, there can be numerous AC sources, the grid, a back up AC generator and an inverter. This means that up to three different circuits exist for the AC source. They cannot simply be connected all together. In addition to the AC source, there are sometimes separate load circuits. Some circuits such as the hot tub or tennis court lights may want to be on a circuit that is not backed up by the inverter. Hot tubs are famous for sucking a battery bank dry in no time flat. Critical loads need to be connected to the inverter AC output. In many instances this is the entire house when dealing with an off-grid home. There are additional AC circuits that do not fit into either category. OutBack Power Systems has a unique product called the “X-240” and “PSX-240”. These auto-transformers have the ability to transfer power from leg 1 to leg 2 and visa versa. That device requires its own breakers and further complicates the AC circuit. This gives us the potential for six different AC circuits.

1. AC source: grid
2. AC source: generator
3. Non backed up AC loads such as a hot tub (may be combined with No. 1)
4. Inverter backed up loads (sometimes this is the entire home)
5. Balancing autoformer circuit.
6. AC Bypass switch

There is no standard AC distribution box available from Home Depot that can do all this. It would take several separate boxes and even then, some of them are not commonly available such as bypass switch boxes.

The DC Section

This half of the RE system is very different from the parts available from Home Depot. Your local electrical supply wholesale company does not stock the DC breakers required for RE systems. Most of the circuit breakers available at Home Depot are not rated for DC operation. Square D has the QO and QOU series that are UL listed for DC operation up to 48 volts. Some installers use the QO breakers in low voltage combiner and charge control circuits. Today’s MPPT solar charge controllers quite often operate above 100 volts input even for a 12V battery system. 48 volt systems typically charge batteries to 60 VDC so QO and QOU breakers are not suitable. As in the AC section, there are multiple DC circuits all operating at the same time. They too require independent circuits, thus eliminating the possibility to use a standard off the shelf circuit breaker box as a one stop solution. The DC breakers required do not lend themselves to the stab in type of boxes available at your local hardware store anyway. Some of the DC circuits are:

7. Inverter battery circuit breaker
8. Solar charge controller battery disconnect
9. Solar charge controller PV disconnect
10. Hydro and or wind controller output disconnect
11. DC GFP device (required per NEC soon on all solar installations)
12. DC loads such as a DC refrigerator or freezer
13. Auxiliary monitoring equipment
14. PV combiner breakers

The circuit breakers required in these circuits are generally rated for 125 VDC. The enormous amounts of fault current available from the battery bank necessitate a large interrupt capacity

(AIC) for inverter breakers. 25,000 amp interrupt is an industry standard. AC breakers are not suitable for DC operation due to interrupt rating and the lack of arc suppression. AC breakers tend to weld themselves in the closed position when subjected to high DC fault currents.

A little History

The first commercially available circuit breaker boxes made for the RE industry came in around 1989 from Photron. These boxes used paralleled breakers for added current capacity on the inverter circuit. The boxes were not UL listed but were much better than nothing. Lawrence Jennings was a real pioneer in those early days. Our industry was called Alternative Energy back then.

A little later, Ananda Power came on the scene with a fully listed AC / DC box. The breaker boxes were usually custom built for each installation though. They had standard versions, but since each installation was different, they advocated custom fitting the features to the installation. This made it almost impossible for distributors to stock the right product. The Ananda engineers built flexibility into each power center; such systems were quite complicated. They did not allow customizing in the field to any degree, so things had to be planned in advance by the installer and distributor. The retail price of this custom solution ran \$1000 or more. The Ananda Power System quickly became the industry standard due to its UL listing and lack of competition. Now customers could actually get their renewable energy system inspected to NEC compliance.



Ananda Power Center with a Trace SW and conduit box

During the early 1990's when Ananda was gaining in popularity, I was very busy at Trace Engineering doing the mechanical engineering on the SW and DR inverters. The industry standard inverter at the time was the Trace U series. I never made the U series able to accept battery cable conduit because I had little knowledge of the NEC. As it turns out, the industry was just learning about the NEC. Remember, the inverter industry was fueled by marijuana growers in Northern California and they didn't have much use for inspectors. The Trace DR and SW series inverters were the first in the industry to have this NEC compliance addressed by virtue of conduit boxes among other mechanical design aspects. Ananda boxes concentrated heavily on

DC load circuits. I figured that if you had a modern, efficient and reliable inverter, why would you need so many DC circuits? That notion was somewhat naïve on my part since I had actually never yet seen a real off-grid installation. Another aspect of the Ananda box was its high cost. It used a nice class T pull-out fuse for inverter current protection and breakers for all other circuits. The high cost, I figured, was due to the custom nature of this product as well as low quantities that have always plagued our industry. It seemed that there should be a code compliant solution to address the inverter battery over-current protection and disconnect that was affordable. None existed, so I began designing the Trace DC250, (1994 or 95).

Pulse and Connect Energy

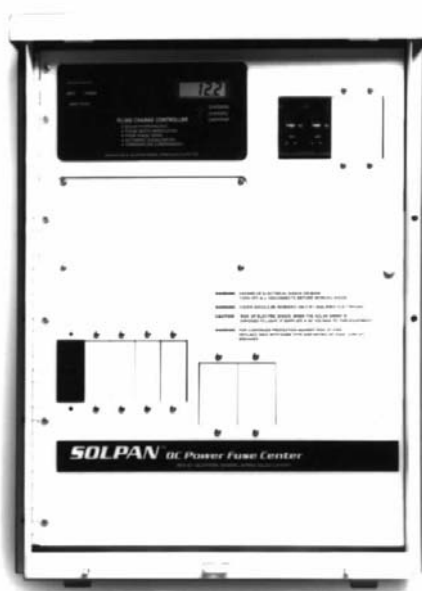
In the late 1990's, Pulse Energy was formed from the now defunct Ananda Power Technologies. They changed the color of their circuit breaker box to match the Trace line of inverters. Pulse as a company did not last long however. A short time later, Connect Energy was formed from the ashes of Pulse. The products of all three companies are essentially the same, (good stuff). It all stemmed from Ananda Power Technologies designs of the 1990's. Building a sound profitable company in this industry is difficult.



Pulse PC250



Connect Energy PC500



Heliotrope Solpan 30

HelioTrobe

While I was working on the DC250, Heliotrope came out with their SOLPAN system. It was very similar to the Ananda box but eliminated most of the DC load circuits. The Solpan was meant to be a lower cost alternative to the Ananda power Center. A basic Solpan system with inverter breaker and charge controller could be purchased for as little as \$600. Heliotrope was very well known for their PWM charge controllers at a time when Trace Engineering was still making relay based controllers and Ananda used Mercury displacement relays. Heliotrope was years ahead of everyone else with their excellent charge controllers. The Solpan breaker

box included a 60 or 120 amp charge controller as well as DC over current protection and disconnects.

The inverter breaker was an option, but a 500 amp shunt was standard. These boxes did not incorporate any AC circuitry. The Heliotrope units were ETL listed and a good value. Sam Dawson (owner of Heliotrope) was forced to close the doors of Heliotrope after a fire ravaged the factory, but I hear he is still involved in solar swimming pool equipment.



Trace DC250

The original concept for the DC250 was to use a fused pull out similar to Ananda until John Wiles steered me to the Heinemann GJ1 Series breaker. A breaker made a lot more sense because those pull outs were often difficult to actually pull out. The UL specs have guidelines to follow for minimum bending room and I cut it down to the bare minimum. Allowing for more wiring room would have made the boxes larger and more expensive. It was a couple of years later that I actually wired up a dual SW power panel with 4/0 cable. That experience was a real eye opener for me. The DC250 was a bare bones box built for DC only. There was one DC load breaker for a DC refrigerator or power shed light. Later on requests came in for more breaker slots, so I added three more DC breaker positions. I still did not fully understand the significance of disconnects for PV controllers, but the additional breaker slots seemed to satisfy this requirement. It seemed odd to have breakers protruding out the

sides, but that was the only option available at the time. In ten years there have been no problems with this arrangement that I am aware of. The DC250 also has an optional tin plated machined block of aluminum for connection of negative conductors. It also had a 500 amp shunt as an option. Since Trace was an inverter company, we made the inverter breaker standard and the charge controller with its breakers optional. This was just the opposite of Heliotrope. The Trace box originally sold for \$295. It may have been basic, but it was priced right. I still believe the success of the DC250 had a lot to do with the demise of Ananda and Heliotrope. It is interesting to note that the same DC250 is still sold today by Xantrex.

Trace Power Panel



I had seen only a couple of real installations by the mid 1990's. Remember, I'm located just North of Seattle. The sun doesn't seem to work up here very often. There was one particularly nice installation on a mountain top in Ukiah CA that Doug Pratt was kind enough to show me. I was amazed at how well all the different boxes had been connected together using conduit and gutters. It was also obvious to me at this site that every single installation in the industry was a custom one-off design. A

year or so later after having created the Trace C-40 solar charge controller, there were finally enough Trace components to build a standardized system.

Enter the 400 pound gorilla, the Trace Power Panel. There was a fair amount of risk in developing the Power Panel. The industry certainly needed something that was standard, but we worried that professional installers would feel like they were being cut out of some value added income. In reality, they made profit on the Trace wiring simply from price mark up. Recently I reassembled my old Trace dual power panel for the picture at the front of this article. NEVER AGAIN! It didn't get any lighter and I didn't get any younger.

The only non Trace product on the Power Panel was the AC bypass switch made by Square D. In 1997, I began building a house in Arlington near the Trace factory. I thought that it might be wise to use an inverter to provide all the power during the construction phase just to see how our customers lived. During the construction phase I learned a few things about the Power Panel that needed some attention.

1. There was no way to hook up the Trace 240 volt autoformer in a clean tidy manner.
2. The back plate should have been made up of two pieces so it could be sold as a separate piece and shippable via UPS. This also meant that the back plate needed to be made from a lighter gauge steel. The 12 gauge steel back plate was very heavy all by itself.

Trace AC box / T-240



Well, the house got built and the Trace AC box / T-240 did in fact make it into the Power Panel, but I have the only Trace split apart back panel in existence! Trace decided not to offer the back panel as a separate piece. The AC box as it was called when mounted on the Power Panel also had room for the T-240. This box had room for two AC bypass switches as well as AC input breakers and the T-240 breakers. The T-240 was used only for single systems as it was for step up or step down only. One thing we did when converting the old

T-220 into the new T-240 was to get rid of all those taps. I never did figure out how to wire the T-220, so the new T-240 got rid of all the wires that weren't really necessary. I also never figured out why Trace would not sell the AC box without the autoformer?

A few more years go by, a few more inverters are designed and then on July 31, 2000 the new owners of Trace, (Xantrex), decided to lay me off. As you can imagine, I was not pleased that Xantrex had laid off their chief mechanical engineer in Arlington, especially since I had paid for and owned about 1% of the company.

The very next day while filing for unemployment I decided that there were still too many good ideas swimming around in my head, so I was just going to have to start my own company and compete with Xantrex. **Enter OutBack Power Systems!**

The first ten months was spent in my home office designing sheet metal boxes to go with the FX inverter as well as the Trace DR, SW and Vanner RE series inverters. The OutBack inverter was still two years away from production, but the mechanical design was being worked on. By the

time I rented a building in June 2001, the FX inverter mechanical design was virtually done. It would still be another 18 months before it worked well enough electrically to ship.

The OutBack PSAC and PSDC were designed during that first six months of solitude in my home office. I had the chance to start with a clean slate and therefore was able to address some industry shortcomings that needed attention. The first thing to address was to allow ample room for wiring. Compare the size of the AC and DC boxes between the OutBack Power Panel and the other popular breaker boxes. Big difference! There were a host of other improvements too. The Quad stack is the most versatile power center ever developed, but if you do not need all that capability, OutBack did not have a smaller solution. The OutBack enclosures use breakers that previously were not used in the AE industry. Square D breakers did not always fit the bill due to size, cost and DC voltage limitations, so new sizes and styles were in order. The decision to expand on breaker styles has been a good thing for our industry. We now have good small and inexpensive breakers rated for 125VDC. The AC equivalents are also small and economical.

OutBack PSAC, PSDC, PSMP



To address the size, weight and cost issue of the quad stack, I developed the OutBack PS2 system about a year later. This has grown to be the industry standard for dual inverter systems.

OutBack PS2 System



While the PS2 system enjoys great acceptance in North America, it is virtually non-existent in Europe, Africa, Australia and New Zealand. There are a couple of reasons for this. It is physically too large for European homes. It uses breakers not available outside of North America, it is expensive and it looks too American.

MidNite Solar, Inc.

A few months after having resigned as president of OutBack Power Systems (March 2005), the urge to design something overcame my daily routine of yard work and house maintenance. I started with a new approach to solve what seemed to me to be the last issue for RE circuit breaker boxes. My goal was to make a modular breaker box that could expand as required and yet take up the smallest footprint on the wall. The design breakthrough that allowed the small footprint was to incorporate a hinged door to which the inverter would mount. This task turned out to be easier than I thought. We were all a little concerned about the strength of the door since it was going to have a 60 pound inverter mounted to it. Thank goodness for UL standards. They require a test to cover just this issue. ETL now has pictures of two guys (300 pounds) standing on the inverter mounted to the door, and the door is open! The hinged door allows the installer to bolt the inverter to the door while the door is laying flat on a table. Once bolted together, simply hang the door on the chassis. Anyone that has had to hold an inverter up in the air while trying to screw it down will appreciate this feature. The installer no longer needs three hands and a back of steel to mount an inverter.

There is a certain amount of room required for breakers, terminal blocks and such so putting the inverter directly over these items made the footprint extremely small. Since the inverter was taking up the entire face of the new E-Panel, there was no place to put the circuit breakers but out the sides. This side exit allowed the depth of the E-Panel to be half that of previous designs. Din Rail mount breakers were selected due to their low cost and small size. In all of the tens of thousands of these Din Rail mount breakers I've sold in the past, I am aware of only one single Din Rail breaker that had a problem. This was just one more good reason to select these breakers for the E-Panel. The 63 amp 125VDC breakers used for charge controller disconnects cost half as much as other styles used today. CBI in South Africa who makes these breakers has graciously made changes on my recommendations to have the DC breakers re-tested to 125VDC. The industry has benefited from this change. They are now in the process of having the MidNite DC-GFP breaker assembly UL listed. This will finally allow DC-GFP assemblies to be priced as they should be, (affordable).

The more we got into the design features of the E-Panel the more real world features kept on growing. It was decided to pre-wire the AC bypass switch and generator/utility input disconnect breakers. We also decided to provide the inverter cables with the E-Panel to help make installation a snap. The installer has enough to do with solar panels, batteries and generators. The pre-wired E-Panel will make the installation go a little smoother and quicker, thus reducing overall cost. The fact that the E-Panel handles AC and DC circuits cuts hundreds of dollars out of the bill as opposed to the larger boxes offered today. A complete list of features is included at the end of this paper for your review. Comments are always welcome too.

The evolution of the E-Panel was the toughest of any breaker box I have done, but it has been worth it. There have been hundreds of hours and thousands of dollars spent in the design of the E-Panel. I've learned over the years that in a product like this, you need to actually build some,

wire it up and especially get feedback from the people that will be using it. It took four different prototype runs to get all the features right. A big thanks goes out to all the industry people that helped in the development phase. The E-Panel is now ETL listed for the US and Canada and will commence shipping in November 2005. Following right behind the introduction of the E panel will be a version to work with Magnum Energy inverters too, "The MagNite". The people from Magnum also get their roots from Trace Engineering. They will be a welcome addition to the RE industry providing needed competition.

There are but a few optional parts to consider for E-Panels.

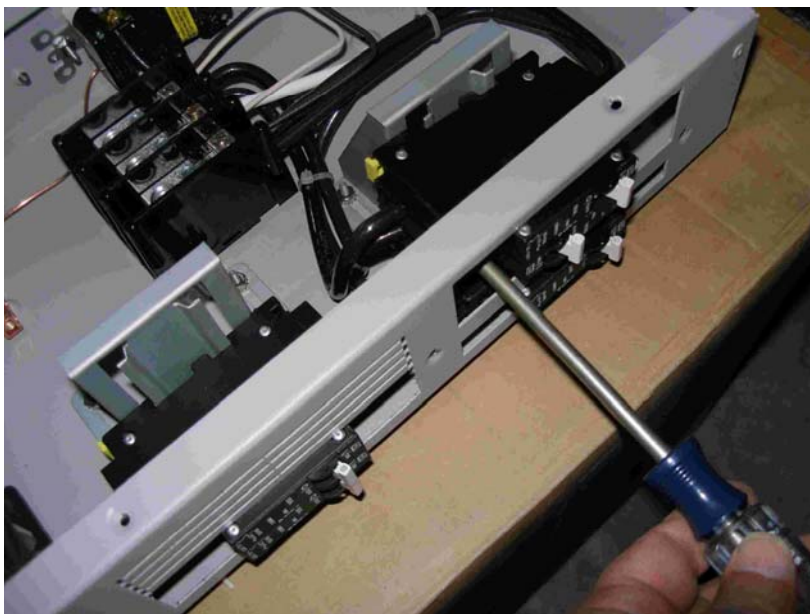
E-Panels stack vertically right out of the box. This vertical configuration also takes up the least amount of floor space. Some people will want to stack two inverters horizontally in order to keep things all at eye level. You would need a left hand hinged door for the left hand unit in this case. Each Left hand hinged door also comes with a right hand charge control bracket. You then will have a right and left charge control bracket and will be able to mount two charge controllers in between E-Panels as shown below.

The E-Panels are available in both the gray powder coated steel as well as white powder coated aluminum. Aluminum E-Panels will be popular in salt laden environments like Hawaii.

One of the only options to the E-Panel is a left hand hinged door. This door will be used when stacking two inverters horizontally. Hinges open like an old Lincoln Continental with suicide doors.

Two other options are available from MidNite. A 63 amp 125VDC breaker is available to use as charge controller disconnects input and output. (MNEPV63).

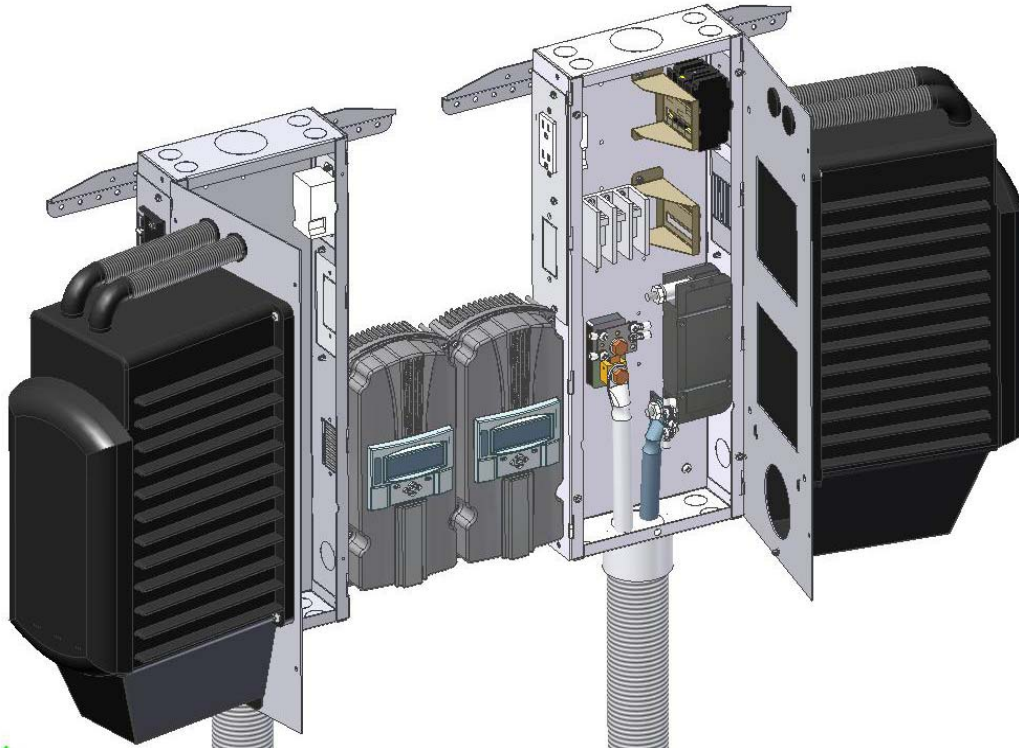
A DC-GFP assembly is also available for roof top mounted solar in order to comply with NEC. Present day NEC requires this device only when Photovoltaic panels are installed on the roof of your dwelling. Future code will require this device on all installations. The MidNite DC-GFP will help take the sting out of this requirement due to lower cost.



This picture shows the installation of Din Rail mount breakers. Notice that there is good access to everything.



E-Panel (1st version)



Features:

- ✓ Small size compared to existing products
- ✓ Pre-wired to save time, money and mistakes
- ✓ White powder coated aluminum or gray powder coated steel
- ✓ Easily expands to accommodate up to four inverters with no interconnecting conduit
- ✓ Six slots per unit for 13mm wide Din Rail mount breakers; PV, Wind, Hydro and AC distribution or three 19mm wide breakers
- ✓ 500 amp 50mv shunt for battery status monitoring systems
- ✓ Pre-wired 50 amp 240VAC inverter AC bypass switch (120VAC 60Hz or 240VAC 50Hz circuits)
- ✓ Pre-wired 50 amp 240VAC AC input disconnect (120VAC 60Hz or 240VAC 50Hz circuits)
- ✓ Mounting hardware for inverter and charge controller
- ✓ Snap in plastic conduit for AC, Mate and RTS wires
- ✓ Wall mounting brackets to aid in one person installations
- ✓ Heavy duty 175 amp AC distribution block
- ✓ ETL listed to UL and CSA standards
- ✓ Right hand hinged door to mount inverter
- ✓ Knock outs for AC and DC conduits
- ✓ Charge control bracket (CCB)
- ✓ Cut outs for two North American style GFCI outlets
- ✓ DC inverter battery breaker
- ✓ Internal inverter DC cables
- ✓ Battery minus bus bar for additional circuits
- ✓ Battery plus bus bar for additional circuits
- ✓ Ground bus bar