Report on the Inverter Shootout at SEER '90

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Seer '90 at Willits, CA was probably the very first time that this industry had just about everyone in the same place at the same time. A perfect opportunity to place different brands of inverters in exactly the same system and compare their performance under a variety of loads.

The Test Inverters & People

Just about every inverter manufacturer got into the act. Inverter manufacturers present were (listed alphabetically) Heart, Heliotrope, Photocomm, Statpower, and Trace. We were only able to test the 600 Watt inverters (Heart 600, Statpower 600, & Trace 600) because of system limitations. So the larger (>1 kW.) inverters made by Heart, Heliotrope, Photocomm and Trace were not able to be tested, but in all fairness they were ready and willing. The reasons why we couldn't test the larger inverters was voltage loss through the system's cables, fuses, switches, circuit breakers, shunts and connectors. More on this problem below.

The testing was organized by the fine fellows from ATA, Johnny Weiss and Ken Olsen. The testing was conducted on Sunday August 12, 1990 in front of a live audience of more than 50 fairgoers and the tech reps from the aforementioned inverter manufacturers. The whole show was video taped by Paul Wilkins of The Photovoltaic Network News (PVNN).

The Test System

The test system contained eight Trojan L-16 lead acid batteries configured as a 1,400 Ampere-hour battery at 12 Volts DC. The system contained lots of other gear like eight PV models on a Zomeworks tracker, regulators, controls and instrumentation. We hunted through the crowd and were able to find three Fluke 87 Digital Multimeters to take accurate test data. All inverters used the same set of heavy weight copper cables for connection to the system. A large board of 100 Watt incandescent lightbulbs served as loads. Other loads tried were an approximately 650 Watt Microwave oven and a medium sized (about 400 Watt) circular saw. These last two loads were used to measure the inverter's performance under inductive loads.

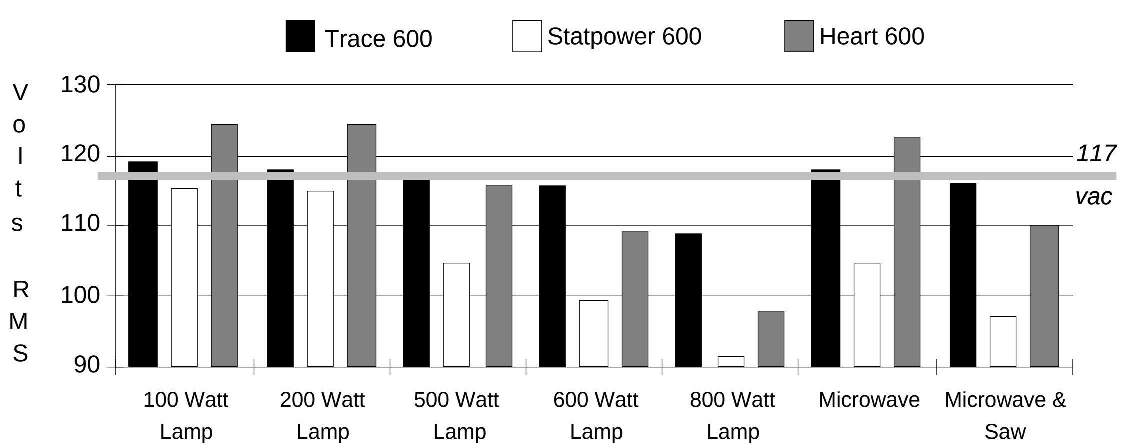
The Data

The table and chart below give the data just as it was taken. All inverters were run into exactly the same loads. The most meaningful data was the output voltage of the inverter under a variety of loads. We measured RMS voltage and peak voltage of the inverter's output. We also measured battery voltage, amperage, and inverter frequency. In terms of battery voltage and amperage, it became apparent early on in the testing that the instrumentation was not accurate, so I have omitted this data from the table and chart. In terms of frequency, all the inverters were so stable and close to 60 cycles that the data was trivial. Copies of the data were supplied to all the manufacturers of the inverters immediately after testing.

In order to match the output of the commercial electric grid, the inverter should have an RMS voltage output of 117 volts ac. RMS voltage on the grid commonly varies by about six volts RMS or about ±5%. Peak voltage of the commercial power grid is 162 volts peak. Since inverters don't really make sine wave power, their peak voltage is different from that of sine wave grid power. The peak data is, however, accurate and provides a basis for relative comparison of inverter performance. What really counts in the inverter test data is how close the inverter was able to keep its output voltage to 117 volts RMS under a variety of loads and within its specified operating range of 600 Watts.

600 Watt Inverter Shootout, Willits, CA on 12 August 1990

120 Vac Loads	TRACE 600 Vac RMS	TRACE 600 % High or Low	TRACE 600 Vac PEAK	STATPOWER 600 Vac RMS	STATPOWER 600 % High or Low	STATPOWER 600 Vac PEAK	HEART 600 Vac RMS	HEART 600 % High or Low	HEART 600 Vac PEAK
100 Watt Lamp	118.9	2%	141.2	115.2	-2%	148.0	124.4	6%	148.0
200 Watt Lamp	118.1	1%	136.8	115.0	-2%	148.8	124.2	6%	140.8
500 Watt Lamp	116.7	0%	125.2	104.6	-11%	137.6	115.8	-1%	122.8
600 Watt Lamp	115.8	-1%	123.2	99.3	-15%	130.8	109.2	-7%	115.6
800 Watt Lamp	108.9	-7%	116.8	91.5	-22%	122.4	98.0	-16%	104.0
Microwave	118.0	1%	140.8	104.7	-11%	141.2	122.6	5%	221.6
Microwave & Saw	116.0	-1%	181.2	97.0	-17%	142.4	110.1	-6%	191.2



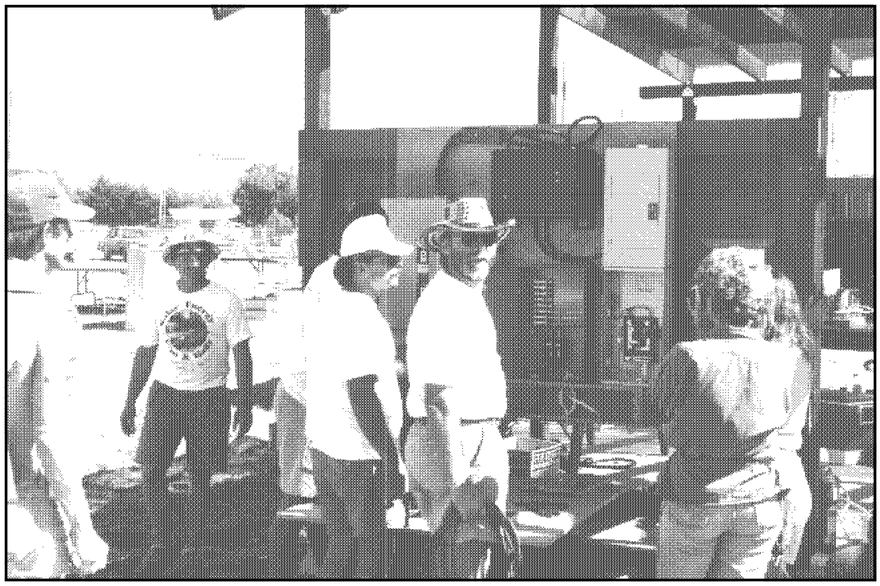
Conclusions from the data
I am content to let the data speak for itself.

Now this test system was set up according to Code. This means that it had all the fuses, circuit breakers, fused disconnects, and other paraphernalia required by the National Electric Code (NEC) in addition to the cables and connectors necessary to move the power from the batteries to the inverter. The major problem we had testing the larger (over 1,000 Watt) inverters was voltage loss. By the time all the code required safety devices added their individual voltage losses, we couldn't move much more than 100 Amperes of current into the inverter. At amperages higher than this, the accumulated voltage loss of all the components in the inverter's low voltage supply lines was about 2 Volts. This meant that the larger inverters were shutting themselves off because of low voltage at their terminals.

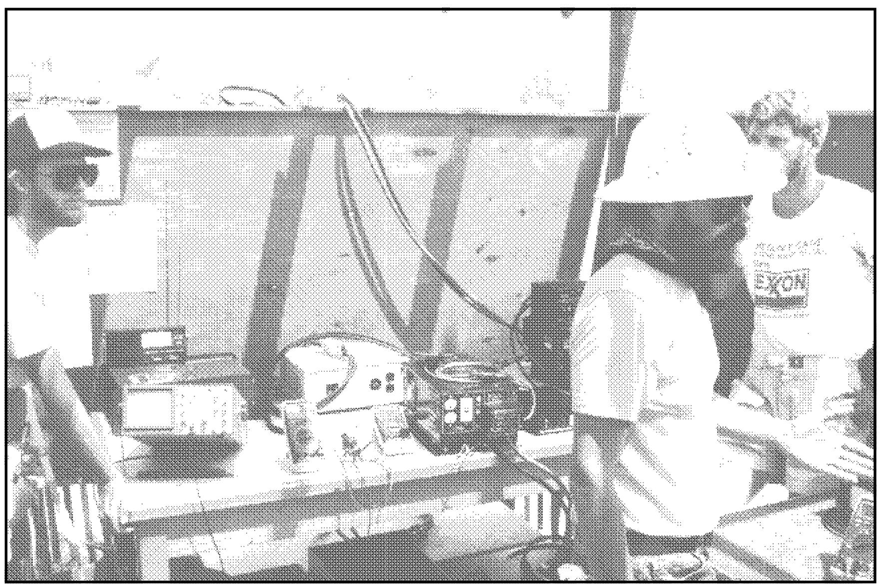
And this is perhaps the most important thing we learned from this testing. Large inverters are capable of drawing surges of well over 1,000 Amperes from the batteries. They are capable of consuming over 200 Amperes during normal operation at their power limits. In order for a low voltage line to move this much current without excessive voltage loss, the line much have very, very low resistance. The inverter lines at SEER '90 had a resistance of about 0.02 Ohms. This was too much resistance to operate an inverter larger than 600 Watts. Today's inverters commonly put out over 2,000 Watts. In order to have these larger inverters work well, the electrical lines feeding them must have very low resistance (less than 0.0015 Ohms). This means heavy copper cables of between 0 gauge for cables totaling less than 6 feet, to 0000 gauge for longer cable lengths. Every series connection and device in this low voltage line adds some resistance. Every fuse, fuse holder, mechanical connector, circuit breaker, switch, and disconnect adds some resistance.

I appreciate that the NEC is concerned for our safety and the safety of our systems. My concern is that by the time they've made us safe enough, our system will be crippled by the accumulated voltage losses in all the protective devices. Please understand that I am all for safety and agree that we need protection in low voltage lines. I respectfully submit that the NEC needs to spearhead the development of safety devices (like fuses, fuse holders, disconnects and circuit breakers) that have about ten times less loss than those they are now proposing. The NEC and the electrical products industries are used to working with 120 vac where a volt or two loss doesn't make much difference to performance. In 12 Volt systems, however a volt or two loss is the difference between working and not working. If low resistance protection devices are not developed, then we are faced with two choices: 1) running an outlaw system, or 2) sitting safely in the dark.

ACCESS
I am happy to communicate with anyone about inverters, systems, batteries, etc: Richard Perez, C/O Home Power, POB 130, Hornbrook, CA 96044 • 916-475-3179.



The ATA guys, Johnny Weiss (in the SEER T-shirt and Solar Balaclava) and Ken Olsen (in the cowboy hat) oversee the main power panel of the Solar Demo House at SEER '90. This power panel interfaces with eight L-16s and a tracked rack of eight PV modules. It contains all NEC stuff like disconnects, circuit breakers, fuses and distribution panels. The power center also has a 2 kW. wall mounted Heart inverter.
Photo by Paul Wilkins



The 600 Watt inverter test setup. All inverters were tested on the same set of cables connected to the same battery. All measurements were taken with the inverters under identical loads. Instruments used were three Fluke 87 digital multimeters and an oscilloscope.
Photo by Paul Wilkins