Transverter T13X

The Motivation. The Transverter system is designed to have a maximum of 12 power modules that are 2 KW each. They can all be controlled and automatically regulated individually with any phase relationships required. If you dedicate individual power modules to dedicated loads then you can do a lot of amazing things with the real time mathematical modeling and control features built into the power modules. However, it's costly and an inefficient use of all of your system's resources if you have to use an entire power module for each dedicated load.

It is typical for a home or business to have only two power modules for a total of 4 KW of power while having a grid connection of 24 KW for 100 amp service. They really have a need to monitor and manage all of the grid power and some of the larger loads like air-conditioning and heating without having to run it through a power module.

The major move to the Smart Grid really wants to replace the power meter with a smart digital power meter that can integrate with smart load management and renewable energy. This has all lead to the development of the Transverter T13X.

The Product. The Transverter T13X has connections for 4 line voltage sense lines and inputs and outputs for six 30 amp relays. It has a Cat5 cable connection that goes to a small connector module which connects to up to four snap on current sensors for the 100 amp main grid inputs. It also has a

RJ45 connector named UP and another one named DOWN. This allows it to be connected simply at the end of the last power modules. This allows continual communication with the entire Transverter system information bus. The T13X gets its power for its internal electronics either from the 50 volt rail on the power modules or from whichever of the four AC in lines that are active. You can even have a system that includes a T13X and a remote panel but no power modules. Typically line 1 and line 2 would be connected to the split phase mains from the grid. Alternatively, lines 1-3 could be connected to 3 phase grid power. Lines 3 and 4 could be connected to a second grid service or could be connected to the mains of a generator which would be typical of a commercial UPS system. The voltage and current of each of these lines is analyzed in real time for full oscilloscope functions as well as power factor, true RMS voltage, current and also, real power. The T13X logic analyzes all four lines and defines the first line with acceptable voltage as phase 1 and phase locks to it. Then all of the other lines are represented in relation to the phase one line. You can get true graphical analysis of the phase relationships of all of the voltages and currents. The frequency of phases 1 and 3 are measured to an accuracy of .002 Hz.

There are six isolated relays which are typically connected to the various outputs on the breaker panel which go to various key loads that need to be individually analyzed and controlled. The relay is connected to the actual individual loads. When the relay is open the voltage across the relay is analyzed to determine if a load is there and which phase it will be. When the logic tells the relay to close, the current through the relay produces full oscilloscope analysis with power factor and RMS current as well as real power. If the current rises above the defined maximum limit then the relay automatically opens. For split phase 220 volt loads the relays are used in pairs and for 3 phase loads the relays are used in sets of 3. A pair of 30 amp relays used for a 220 volt load will support 6.6 KW. For larger loads the relay simply provides current to the coil of larger contactors (relays) which can be 2 or 3 phase. This way one 30 amp relay could control a 100 amp 3 phase contactor. When you do this then the relay current waveshape sensor only senses the current of the contactor coil (which is of no interest) but you can use one or more of the external line1-line4 clamp-on current sensors to sense the entire current of the controlled load.

These six relays can also control and analyze DC circuits. They could be used to manage high voltage strings of solar panels and each relay could typically control and analyze 6 kw of high voltage solar panels. This way we can bring the modern data analysis and communication of the Transverter to existing grid tie systems and pave the way for easy integration to battery backup, community energy storage and UPS.

Load Management. The T13X allows for complete load management where large loads like an air-conditioner, could be selectively turned off or cycled to help with peak loading issues with the grid. With the USB interface on the remote panel, a program is run on the PC that can communicate with the grid in real time via the internet and adjust loads in real time. With a stand alone or battery backup system this load shedding could be used to greatly extend battery run time by selectively shedding lower priority loads as the batteries become discharged. Since the Remote panel contains a real time clock that is automatically updated via the USB connection to a computer which is, in turn, synchronized by the internet then real time scheduling of loads can be applied to automatic lighting, water pumping, refrigeration, etc.

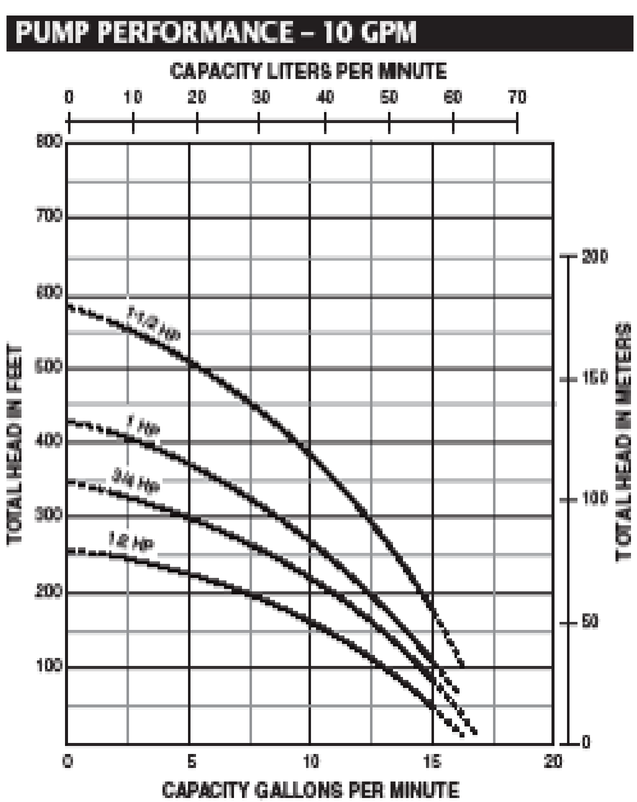
Load, Grid & Generator Protection. When the grid voltage dips repeatedly, it can cause damage to some inductive motors, particularly in refrigerators and other compressors as well as pumps. Since we monitor this voltage, we can automatically disconnect when the voltage dips and wait for it to become stable again to re-connect. If it is a refrigerator or compressor, we can wait a predefined time before re-connecting to allow the pressure to bleed off the compressor making it much easier and less stressful to start the motor. In the case of a domestic refrigerator it is not even possible to start this motor until the pressure bleeds off and almost all refrigerators simply try to start and fail making the over current protection device in the refrigerator heat up and disconnect and retry again in a few minutes. This typically can go through 3 or 4 tries before it is successful placing undue stress and aging on the refrigerator compressor.

When the grid voltage dips it usually means that it is overloaded so this automatic load shedding, when we have enough systems installed, will have a dramatic effect on improving the grid. For even finer tuned, faster response, protection we can use the early warning system of the grid frequency dipping slightly and use that to disconnect. See <http://availabletechnologies.pnl.gov>

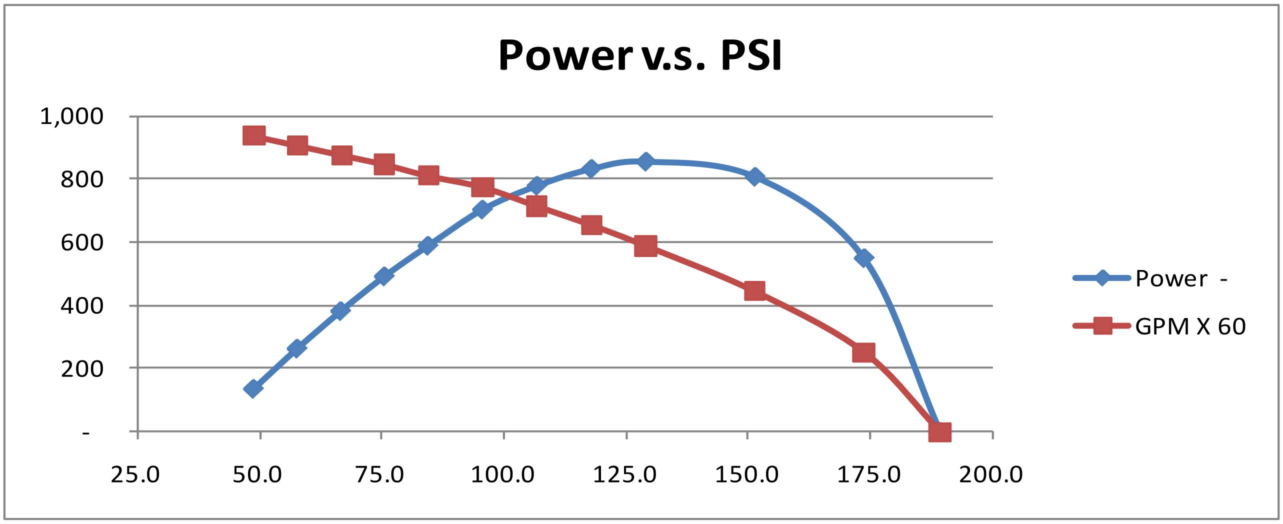
With many systems, particularly commercial UPS systems, there is a generator connected. All of the loads that are controlled with the T13X relays will wait until the generator has come up to speed and stabilized and had a chance to start all of its other loads before connecting the relays. The individual relays will even stagger their start up so that the generator doesn't have to bear the burden of starting all of these loads at once. These large relay controlled loads will often be inductive motors (like air-conditioners) which require large surges to start, often bogging down the generator and compromising the other loads, so staggering the start up is a big deal. For a large commercial UPS system it isn't really critical for the air-conditioner to never miss a few minutes or even an hour. Imagine an office with 100 amp service and a 24 KVA backup generator. You connect one relay to a 100 amp contactor for the grid and another relay for another 100 amp contactor for the generator and another relay for the automatic start circuit for the backup generator. When the grid fails, the air-conditioner does not work and everything else is running off of the Transverter power modules. When enough time has gone by for the batteries to start to get low or the building is getting warm enough to need the air-condition then the automatic generator start relay closes and the generator starts. After the generator has come up to speed and stabilized then the 100 amp contactors close and the Transverter power modules start to smoothly integrate the generator power into the system. After this has stabilized then the individual load relays (like the air-conditioner) close and the building begins to cool while the batteries are being rapidly charged. The battery charging automatically is interrupted every time the air-conditioner starts. After the building cools down the air-conditioner thermostat shuts it off and the T13X can, at that time, disconnect the generator contactors and shut down the generator. While the generator was running it charged the batteries so that you are now running on generator energy that was stored in the batteries. After a preprogrammed time or when a sensor or a human says that we need to cool the building again then it goes through the whole generator startup sequence. This phased generator operation could often cut generator run times drastically along with reducing fuel consumption. With Katrina, Sandy and many other power outages from disasters, all of the generators for hospitals and data centers ran continuously until they ran out of fuel and then shut down until help arrived, sometimes for weeks. The Transverter power modules automatically insert any solar or wind power that is connected into the equation and further reduce or even eliminate generator run time. With this system, it is often possible to have 24 hour power while only running the generator for an hour a day. This auto genset capability would also be implemented in many homes, RV's and boats. When the grid does come back on, the T13X analyzes it and when it has had a chance to stabilize, it opens the generator contactor and then closes the grid contactor and shuts the generator down. Then the Transverter power modules smoothly integrate the grid power back into the system and then the controlled load relays start to phase in staggered to reduce their start-up impact on the grid. This is a major improvement with regards to grid and generator stability and a major simplification of the installation.

<u>Inductive Motors.</u> When the AC voltage running an inductive motor increases or decreases the current then also increases or decreases giving the impression that the power consumed is also increasing or decreasing. But the inductive motor is phase locked to the frequency of the grid so it is spinning at exactly the same speed so the physical work or output power of the motor cannot change. At first this seems like a contradiction, but if you use an oscilloscope to look at the voltage and current wave shapes you will see that the current lags the voltage by some angle which automatically adjusts itself so that the actual output power is always the same even though the volts times amps is changing. The real power divided by the voltamps (volts times amps) is called the power factor. This is one of the advantages of the Transverter system, including T13X, having full built in real time oscilloscope functions. Any device that does not consider waveshape can never really analyze and effectively control AC power.

<u>Water Pumping.</u> The most common and most efficient water pumps are generally submersible pumps. A typical pump system consists of the submersible pump, a pump starting box, 3 electrodes to sense water level in the well, an electronic water level sensor to connect to the electrodes, a contactor with current sensing to protect the pump and a pressure switch if the pump is filling a pressure tank or a level sensor for a tank if the pump is filling an open tank. In addition there may be a timing device to schedule pump operation. This makes for a fairly complex system to purchase, install, troubleshoot and maintain.



Pump manufacturers supply pump performance data similar to the graph on your left (for a 1 hp Sta-rite pump). The engineer for the water system tries to get a pump that has the correct number of stages and horsepower to provide the required flow rates for the pressure range needed. If you are filling a pressure tank, the actual operating pressure of the pump usually fluctuates about an operating point with a difference between the cut-in pressure and the cut-off pressure of about 20 psi. As the level of the water in the well goes up and down the operating point changes but this difference range of 20 psi remains the same. Because we are monitoring real consumed power throughout the waveshape we can actually determine with high accuracy the actual power consumed by the pump. From this we can deduce a wealth of information.



This is a graph, which is easily determined from the information provided by the pump manufacturer, (or easily determined experimentally), which shows the real electrical power in watts supplied to the pump vs. the real pressure in psi. The red line shows the actual gallons per minute delivered at that pressure. The idea is that it is complicated and costly to hook up a bunch of sensors and so we use mathematical modeling and the physics of the system to actually determine, with high precision, more actual information without even having the sensors. Here are a couple of examples.

Pump filling a pressure tank. This is the most common system in the US. We could try to determine the water pressure in the tank from the power on the pump but this power only gives you the total pressure from the water level in the well to the pressure in the tank. Since the water level in the well can change drastically with seasons and weather and drawdown this isn't such a good idea (not to mention the fact that just knowing the power gives you two possible pressures). A better way is to have a normal pressure switch (usually the least expensive part of the system) and connect it between line1 or line2 and line 4. This is just a way of letting T13X know the state of the pressure switch. When the pressure in your tank drops to 30 psi the pressure switch turns on and, depending on what ever set of rules you want to follow about your entire energy situation, turns on the pump. You can see from the graph that the blue line has a maximum at about 130 psi. As the pump runs for a short time you can see the power either increase a little or decrease a little. This can be used to determine which of the two points on the blue line for that exact power that you are on. For example, imagine that the device is consuming exactly 800 watts. Then from the blue line on the graph you can see that the pressure is either 110 psi or 153 psi. If, after running for a short time, the power increases a little then you know that it is the point on the left, 110 psi. If, however, the power decreases then you know it is the point on the right, 153 psi. Since you know the tank was 30 psi when the pressure switch closed you just subtract from the total pressure that you now know and you know the exact level of the water in your well. Looking at the red line on the graph for that pressure you also know how many gallons per minute you are pumping. After a while the tank pressure comes up to 50 psi and the pressure switch turns off. The module sees this and subtracts 50 psi from the total pressure and we again know the exact water level in the well. It then turns off the pump and waits until the pressure switch tells it that the tank pressure has dropped back down to 30 psi. Since we have tracked the gallons per minute the whole time the pump was running we know how much water was pumped and comparing the water levels in the well we know what the drawdown was. Then, when the pump comes back on and we again get the water level in the well we know how fast the well is recovering. This is incredibly valuable information that nobody has right now with the current state of the art systems. You also know how far down your well your pump is so you can know when to turn you pump off to protect it from running dry and ruining your pump. As an added protection, we have the pump cut off if the power level ever gets below, say, 400 watts which indicates that it is essentially un loaded meaning that it is either at a very high pressure or sucking air, both situations that require turning off the pump. If the water in the pipe freezes between the pump and the pressure tank then this blocks the flow, raises the pressure to the pump then T13X detects this and turns off the pump rather than just run the pump and raise the pressure to a point where you might break a pvc fitting or pipe (and alerts you to the fault condition). You can also tell how much water you are using a day and even graph your water usage over a long time making it obvious when you develop leaks. If you develop a serious leak the pressure will drop and you will see it with the pump power. This can develop a reported fault condition and we can operate under a different set of rules until you fix the leak where we only run the pump for 6 minutes for every hour throughout the night or something like that. This can have an enormous energy and water conservation impact worldwide.

The pump system doesn't need the contactors or the over current protection because that is included in T13X and they also don't need the electrodes in the well nor the electronics that connect to these electrodes. When Tesla developed the inductive motor it was for 3 phase power. Many submersible pumps today are single phase but they are actually 3 phase with the third phase being kind of faked with an AC run capacitor. To get the motor started they have a thermal relay connect another, higher capacitance, capacitor to use just to get the motor started. These things can eventually fail and if the thermal relay keeps the starting capacitor connected for just a little too long it blows up and makes a big stinking chemical mess. Also, if the grid is coming on and off every couple of seconds the starting capacitor doesn't have enough time to cool down and self destructs leaving you with no water in your system. The module already prevents this rapid on-off-on situation but it can actually just use another of its relays to become a super intelligent pump starter just by adding the capacitors (eliminating even another part of the system). When a field technician checks out a well he can test some things with a meter without removing the pump from the well (which is a big project). The T13X can selectively do diagnostics by connecting only one of the 3 wires to the pump at a time and seeing what current flows through the system which will detect broken or damaged wires or connections, shorted connections or damaged insulation. Since this is shared with the entire Transverter information bus, including the remote panel, and the remote panel can be connected to a computer on the internet, it means that these diagnostic tests can be done remotely over the internet without even having the technician come to the farm.

Pump filling an open tank. This is the most common system on large farms on hilly terrain particularly outside the US. These systems usually just run until the tank overflows wasting enormous amounts of water and energy. The better systems have level sensors in the tank and wires that run from the tank to the pump controls to turn the contactors off and on. These level sensors frequently fail and the tank is often hundreds of meters away from the pump meaning long electrical lines in conduit that are frequently damaged. With the T13X system you simply put an inexpensive float valve in the tank and when it starts to close the pressure goes up making the power go down (look at the graph) which makes T13X turn off the pump. Since we have already measured the elevation of the tank then we know the water level in the well when the pump is running. These float valves wear out and get particles of grit clogged in them so they don't close completely but this doesn't matter since we just need it to restrict the flow enough for us to detect the pressure and hence power difference. Then, after a preprogrammed time, the T13X starts the pump again until the float valve closes again. Again, if water freezes in the pipe the pump automatically turns off. Simple, easy to install and pretty much fool proof.

Both of these systems drastically reduce the installed cost and the complexity of the system while giving higher reliability and valuable information about the condition of the well as well as water usage. Even if you only bought the T13X and the remote panel for controlling a pump, it would be a great deal.

<u>Other inductive motors.</u> Just like the pump example, there is a whole world of applications, analysis, models, rules and fault modes for air compressors, refrigerators, heat pumps and air-conditioners.

<u>Renewable Energy Sources.</u> With some wind and hydro generation systems it is desirable to have a shunt load to apply to load the generator down when you do not need the energy. One of the relays can be used for this purpose.

There are some wind generators like Southwest Windpower's Skystream as well as some sola micro-inverters (like from Enphase) which include synchronous inverters and are designed to hook directly to the grid. These can be connected to Transverter power modules AC outputs via one or more of the relays. This way the power module can automatically insert this power into the grid or use it to charge the batteries. When there is no grid present and the batteries are charged and there are not enough AC loads to use this wind or solar power then the relay opens and then closes again when the energy is needed. The Skystream automatically applies an electronic brake when the relay opens and the turbine blades do not even turn, preventing undue wear and tear on the wind generator.

With standalone renewable energy systems you are often trying to increase the functionality without increasing the price, particularly in the developing world. The typical system design in the US where you just add up all of the loads and that dictates inverter size can be improved upon with T13X. Each relay on the T13X can power the coil on an external relay or contactor that is double pole meaning it has a normally closed contact as well as a normally open contact so you can switch between loads. For example, we have a system with two refrigerators and a 220 VAC pump. The pump needs to run for 30 minutes each day. We have the normally closed contacts of the external relay connected to one refrigerators. The normally open contacts of the external relay are connected to the pump. It doesn't matter that the refrigerator doesn't run for 30 minutes each day and the power modules don't have to bear the burden of running the refrigerators while they are running the pump (both devices requiring large startup surges). In this case, the entire operation is totally automatic and the pump is run while the sun is shining and after the solar panels have charged the batteries pretty much. This guarantees that there is plenty of energy available to start the pump and minimizes the use of the batteries, extending their life.

Smart Grid Power Control. With a complete Transverter system with the Remote panel connected to a computer on the internet the T13X completes the picture for the smart grid. If you look at a typical breaker panel for 100 amp service and add up all of the breakers you will see that they total way over 100 amps. This is no big deal since all the individual circuits don't run at the maximum at the same time usually but it is possible to exceed 100 amps which would trip the main service breaker and make everything go out. The T13X monitors the total current and if it approaches 100 amps then it starts cutting things out according to priority rules and can even cycle things so circuits take turns to keep the total under 100 amps. If you have the air-conditioning, a hot water heater and a bunch of other stuff and you are in the shop with a compressor running and someone is using the table saw and you decide to start using the arc welder then you could exceed 100 amps the T13X will automatically turn off the hot water heater or the air-conditioner until your load lightens. If the grid communicates through the internet that it needs you to cooperate and limit your energy usage then the T13X can lower the maximum level to 50 amps or whatever is needed and apply whatever set of priority rules you want. The Transverter system automatically takes into account your local generated renewable energy so you only limit what actually comes in from the grid.

For large RV's and boats they sometimes have 100 amp service for their home hookup or a fancy campground or marina but when they travel they get whatever is available T13X could automatically give them the best functionality by making loads take turns when they only have 50 amp or 30 amp service available.

If you do not have an active internet connection to the grid these grid current limiting features could still be implemented via communications by the grid modifying the frequency. The T13X has such high precision frequency monitoring built in that virtually any sort of communication plan based on frequency could be implemented. You could actually have a code based on frequency variations like super slow FM communication. The Sunnyboy Island already does this in a very crude way and the T13X can easily be compatible with their system.

Future Versions. This first version is set up to be added to existing installations and bring all smart grid and smart meter functionality. This uses external clamp on current sensors that can be applied to the mains without ever disconnecting anything. Future versions will be set up as the grid's power meter with all of the current going through the device much the same way it goes through existing smart grid meters like the Shark 100-S. These future versions will have the mains current sensors internal and the only external wiring will be for the 6 relay controlled loads. All the specifications and functionality will be the same. It will probably have some simple LED or LCD readout on the front much like the Shark 100-S.

SPECIFICATIONS

Length	9”
Width	10.4”
Height	1.8”
Weight	1 lb.

6 load control relays 250 VAC, 30 amps normally open
Line1 – line4 current sensing either 100 amp or 250 amp

Communication all optically isolated the entire Transverter and T13X data set is updated 35 times per second. Since this is normally repetitive data this is essentially real time data and control.

Data Accuracy:

Line1 – Line4	voltage ±.024 volts rms	current ±.012 amps rms
	Power ±1.2 watts	
Relays	current ±.004 amps rms AC or DC	power ±.4 watts

Pump related information for 1 hp Sta-rite series 2000 submersible pump. Accuracy varies somewhat with pump selection. The accuracy goes up with the number of stages in the pump.

Pressure	±.6 psi
Head or water level in well	±1.35 feet
Water flow	±.11 gpm

Heart Transverter
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