Not all Power is created equal

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This article is a comment on recent observations about AC power that is supplied to the home. My work has required me to examine the power infrastructure in places where there are serious issues affecting the types of electrical equipment that can be used in the home and why sometimes it is not good enough.

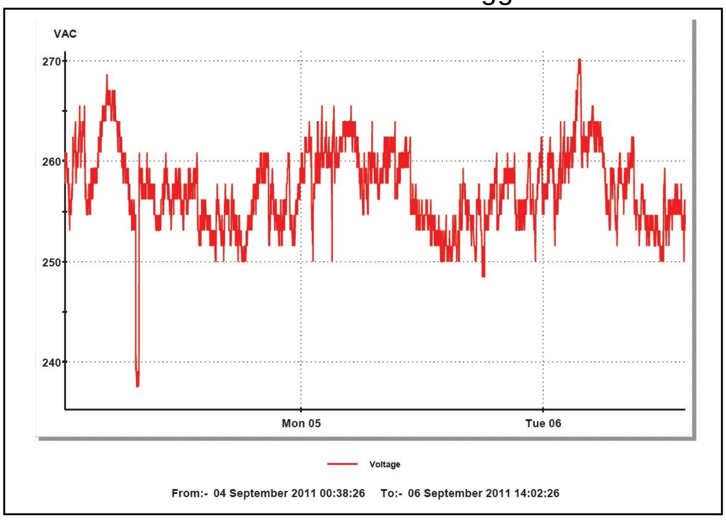
VOLTAGE MEASUREMENTS

Originally our AC supply was **240V** nominal, with **+6%** and **-10%** tolerance, which meant we should have voltage up to **254V** and down to **216V**. If it was frequently outside that range at the home, there were legitimate grounds for complaint. About 2002 the nominal voltage was changed from **240V** down to **230V** to help bring us into line with international standards, however, the tolerances also changed at the same time. They are now **+10%** and **-6%**, or **253V** and **216V**. So this meant that nothing really changed. If you were to put some meter probes into a power point, you will still read around 240V most of the time.

Lots of places don't have such a pristine power supply at their house. Many homes are running over-voltage and don't notice it. Or perhaps they do notice it in other ways. Light globes may last only a few months instead of a few years? Sometimes a heating element in an oven or cooktop will die after only a year or so of use. These can be symptoms that the mains is too high. It will fluctuate around quite a lot throughout the day, but at night, it may climb to 260V-270V in some homes. Lots of appliances around the home will fail at these levels. Switchmode power supplies in PC's and TV's don't like it. Capacitors dry out from the extra heat losses causing them to fail one day after they fall out of warranty. Most appliances now have protective MOV's in them (Metal Oxide Varistors) which absorb energy at 275V+. These explode if the volts are too high. (they literally sound like handguns going off. Very exciting)

To try and get to the bottom of this issue we have adapted the common Lascar thermal data-logger to measure AC Supplies instead, with very accurate results. Once primed via a USB port on a PC, the logger is left inside a power outlet for a week or so. It can take samples each minute for 11 days, then returned to a PC to generate a graph showing exactly what has been going on.
The image (left) shows a segment of a recording session taken at Philip Island last year where the mains bounced between 250 and 270V. The data logger tells a vivid story.

Data logger taking voltage readings



Note the brief dip to 240 volts. This site had a generator which ran for 20 minutes on Sunday mornings as a test. At least *it* was generating the right voltage.

Where the voltage is consistently over the 253V threshold, you can report this as a fault to your power provider. But be warned, if you contact the company, they may come around and pop some meter probes in your outlet during the afternoon when volts are low, then tell you that there is no problem. Apparently some companies now charge a callout fee if there is no discernable problem to be found.

These data logger units are frequently posted around Australia to different clients. Often, this has provided the essential proof needed for power companies to take notice. In the case of the Phillip Island reading, the complaint worked and the Power Company shifted a voltage tapping at a nearby pole transformer to bring the voltage down to a safer value.

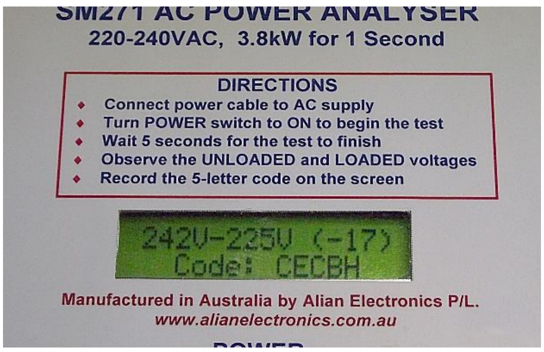
Why is the voltage so high? Well there are two reasons…an obvious one and a conspiratorial one. Firstly, supply companies like to guard against low voltage situations, so they plot the worst-case voltage drop at the worst time of day and try to set that level to around 240V. This has the side-effect that at other times of the day, particularly at night, (when there is little cooking and industrial activity) the voltage can rise to absurd levels and shorten the life of your lighting and your appliances. The second reason is money. Suppose motors and lighting at a given location draw an average of 10kw. When the mains is lifted to 260V, they are billing you for 11.3Kw instead. That's 13% extra trade for no effort by the power company. They may deny this is the reason, but they would hardly be disappointed in selling all that extra power. Of course the increase in voltage does not affect loads controlled by thermostat, as when voltage is high, a preset temperature will just be reached sooner.

POWER LINE RESISTANCE

There will always be some resistance between your appliances and the power station. Most of this will be between your house and the transformer on the power pole nearby. Beyond the local transformer line voltages are much higher, so the effects of line resistance are greatly reduced. We are fortunate in Australia in that our infrastructure means we have many pole transformers, close to our homes to help reduce losses. (take a look at this link taken by a friend to see what power infrastructure is like in Vietnam : http://www.youtube.com/watch?v=rYzsGl_ls-g It will increase your appreciation for what we have here)

The resistance generally comes from thin cables, or long cables, or (naturally) long-thin cables from the pole to your power outlet. If you are not drawing a significant amount of power, the line voltage may remain fine, but as soon as you place a large load on the circuit, you can drop a lot of voltage across this resistance. Light globes will dim, electric motors may not start. Cables will get warm from energy that you are paying for. Essentially, low resistance is good, high resistance is bad. There will be a certain resistance in the line from the pole to your switchboard, then more resistance from the switchboard to your power outlets. It became topical when some people wanted to run some machinery like a lathe or air compressor in their garage, but found that it would not work. It can be hard to convince people that the problem is not in the equipment, but in their cables. Alian Electronics now manufactures a test box to measure some limitations of building cabling.

This box has a microprocessor, an LCD display and two electric heating elements. When this unit is plugged into a power outlet and activated, it takes a voltage reading, then activates 3.8kw of heating elements for 1 second and measures line voltage again. The display then shows both the loaded and unloaded values. The voltage drop shows how good the power is at the present location and acts as a guide on what loads are possible. If you are close to your electrical switchboard, the power could be good and it may only record a drop of 5-6 Volts. After shifting the tester to the far end of the house, or to the garage and it is not uncommon to see a 20V drop.



(The display also shows 5 letters which is an encrypted version of the same information. This is provided so that where somebody is reading display values to you remotely, they can't falsify readings that appear more favourable to their situation.)

It is possible to plug these values into a calculator to provide an *Effective Series Resistance* measurement in ohms. The lower the ohms value, the better the supply quality.

For this tester, this is the formula for calculating total power line resistance:

ZX = (Unloaded line voltage - Loaded line voltage) / (3800 / Loaded line voltage)

By moving the tester to different locations around a property, you can work out where the closest good quality cable is and work out what may be needed to perform a cabling upgrade. At least then it is easier to show a client what is happening, so they don't suspect you are simply trying to talk them into a $3000 cable upgrade only because you want to own a bigger boat.

IMPACT ON SOLAR INVERTER SYSTEMS

Perhaps you will never want run a welder or air compressor in your bedroom, and perhaps you never observe the brightness flickers of your lounge room lights to let you know when the kitchen kettle has boiled and clicked off. There are other important reasons why power line resistance can affect you.

Many thousands of people now have Solar Panels on their roof and a matching grid connect inverter. The vast majority of these are in areas where supply impedance is low and they experience no difficulties. However, there are also many installations where line impedance is not so good. On a sunny day, the voltage drop issues described previously described can have an effect upon your household in the *reverse* direction. The inverters will always perfectly synchronise to the mains frequency ok, but like a battery charger, your home inverter can't make energy flow into the grid without applying a voltage that is slightly *higher* than the grid.

So if you have a long cable to the house and the tester says you're going to drop 15 Volts when consuming 3.8kw, then when the inverter tries to deposit a similar 3-4kw of energy into the Grid it would mean that it must *lift* the voltage of your switchboard by perhaps 15 Volts to achieve the desired reverse current flow. If the mains voltage at the pole is already quite high, say 260V (because your neighbours have inverters too) then conceivably your inverter may try to pump your switchboard up to 275V.

Where pole transformers are small and supply cables are long it is proving to be a big headache for the power companies, because reports from the field indicate that some inverters are burning out on sunny days as they try to track a high supply voltage.

For the average solar inverter installation company, it is hard to determine what supply integrity is like. The installers are becoming increasingly interested to testing the supply impedance at the customer location before making a commitment to the size of converter they are willing to install, as it is tough to explain why half of a new 5KW inverter system must be permanently disconnected to prevent equipment damage and side effects. These over-voltage side effects can place nearby domestic appliances at risk of failure. Because you are likely to 'own' the inverter, property damage claims caused by inverter voltage surges are unlikely to be accepted by the power companies.

It is easy to be blasé about your home infrastructure, but there is a lot going on, some of these effects are only just beginning to surface. It is a legal minefield too. Even if you don't have a solar array and you experience over-voltage damage in your house, power companies may shrug and say, "*Not our fault. If you want to pursue damages, make a civil claim against your neighbours with solar inverters*". Without definitive information, it can be impossible to prove who is at fault, with very expensive damages that must be paid by someone.

There is yet much to be written on this topic and it seems that in the rush to promote the technology, not even power companies have all of the answers.