REDUCING ELECTROMAGNETIC INTERFERENCE IN PHOTOVOLTAIC SYSTEMS

Reducing Electronic Interference in Solar Electric Systems

This information is mainly aimed at reducing or eliminating radio, TV, cell phone, and other electronic noise and interference in photovoltaic and other DC powered systems and from equipment used in PV systems, but much of it applies to anything or any equipment with EMI (electromagnetic Interference) or RFI (Radio Frequency Interference).

WHAT IS EMI AND RFI?

EMI and RFI are similar and often have the same causes and solutions. RFI is interference or noise that is radiated - essentially, radio waves. EMI includes RFI but also includes non-radiated interference, such as line noise coming in from power or control lines. From here on we will use only EMI, as treatments are basically the same.

EMI can come from many sources. Almost everything in your home or car emits some EMI, including fluorescent lights, TV's, cordless phones, electric tools, auto ignition, etc. In solar and DC systems you often have additional sources, such as switching power supplies, charge controllers, DC light ballasts, and inverters (especially modified sine wave types). There are dozens of digital devices in use nowadays, and digital - especially power circuits - emit more EMI than analog (AC).

FCC PART B

One of the major problems with solar and DC power equipment is that almost none of it meets the standards for FCC Section 15, Part B. Nearly all appliances and electronic equipment sold today for consumer use in homes must comply with FCC part B - which regulates the maximum amount of EMI that devices (such as TV's) can radiate. That is why you don't get a lot of noise from your microwave and coffee grinder. But nearly all DC and solar equipment is exempt from Part B. Which means that they can put out a LOT more EMI and still be legal.

MAIN SOURCES OF NOISE

Any digital electronic equipment produces at least some noise. And nearly all equipment now used in PV systems is digital. The most common real problem equipment is charge controllers, DC lights, and some modified sine wave inverters. Nearly all charge controllers do not send a steady voltage/current to the batteries, but are pulsed. And high power digital pulses are one of the worst EMI sources.

How to Get Rid of EMI

The most common ways of reducing noise are:

- *Shielding*
- *Cancellation*
- *Filtering*
- *Suppression*

Shielding

Almost any metal will offer some shielding. A shield basically blocks the noise, just as the name implies. Metal enclosures are common for inverters and some other equipment. But metal conduit will also act as a shield. Shielding is effective but not always possible, and will not do much to stop any noise carried on the wiring to and from the device.

Cancellation

Cancellation might not be the best term. But it is very simple to do and pretty effective in some cases. It is basically just a matter of twisted wire pairs. Noise in twisted pairs tends to cancel itself out at each twist. It does not work in all cases, but is so simple, cheap and usually easy to do, so that is often the first method to try.

We sell some cables - mainly for such things as shunt signal wires - that are shielded twisted pairs. That type cable is very effective in keeping noise in or out of wires. But shielded twisted pair wire in larger sizes can be hard to find and very expensive.

Filtering

Filtering has been around since electronics was invented. The most common method is to use capacitors across a signal line or wire to ground to get rid of the noise. Inductors are sometimes used also, but they have some frequency limits and can also get pretty bulky and expensive. One limitation of using capacitor filters is that you usually must have a good ground nearby for one side of the capacitor. If you have long leads between what you are filtering and ground, you could even make the problem worse.

Suppression

This is relatively new and often the most effective. The most common method uses Ferrite chokes, cores, and beads. Ferrites are powdered molded metal powders cast into various shapes and sizes. Ferrites are actually a type of molded ceramic . They are usually made of powdered Iron Oxide (Fe_2O_3), along with Zinc, Copper, Zinc, and other metal oxides. The EMI portion of the filtered spectrum is converted to heat within the ferrite core and dissipated.

We sell the snap-on chokes, which can be simply opened up and snapped around the wires or cables. You can stack as many as you want and stack different types if you have severe problems. You don't need one for each wire unless you have really fat wires - they work just as well if snapped onto a pair or bundle of wires. The are non-conductive so can be used almost anywhere, including on 115 volt power lines and battery or inverter cables.

INFORMATION FROM EXELTECH

Below is a good basic outline of noise caused by DC powered equipment, written by one of the engineers at Exeltech Inverters:

Interference from inverters will always be an issue. It's a difficult topic for many to understand .. and equally difficult to reduce. Note you can reduce .. but not eliminate the interference.

To complicate things, the farther a radio is from the transmitter, the more difficult this issue will be to resolve.

Here's why...

To achieve the highest efficiency possible, inverter power circuits today transition from off to on in an extremely short time, as in totally off to totally on in microseconds .. or even nanoseconds. Internally, within the inverter, even "sine" wave models use square waves at various points. Why? Solid state devices operate with the least energy loss when they're completely off .. or turned on in a strongly "saturated" mode - meaning turned on to their maximum possible level with the least possible resistance. The transition from off to on is commonly done in one step, from zero to max .. then back again.

Micro-processor clocks also operate in this fashion, as do the signals within the processor, and any related communications circuits.

Square waves are a composite of a sine wave, plus all odd harmonics (odd integer multiples) of the original sine wave frequency. To create a 100 kHz square wave, we start with a 100 kHz sine wave and add sine waves of 300 kHz, 500 kHz, 700 kHz .. and so forth, up into the many Mhz region. The number of harmonics added is astonishing.

As a consequence, these harmonics radiate into the AM broadcast band .. and far beyond. To make matters worse, the circuits in inverters are not "linear", which is to say they don't faithfully reproduce the exact waveform put into them. It's done by intent, but with a side-effect. This non-linearity turns the circuits into "mixers". Mixers are a part of every radio and television. We use mixer circuits to combine two frequencies and obtain others. When non-linear circuits are fed a large number of signals, they add and subtract all the various combinations of signals to create still other frequencies .. and so it goes.

Radio frequency interference ("RFI") originates from many different aspects of an inverter. If the inverter is battery-based, you'll have many hundreds of amps being switched on and off very rapidly by the inverter "front end". To handle the hundreds of amps, the input resistance ("impedance") of the inverter must be very low .. on the order of a few milliohms.

String inverters connected to a series array of PV operate on the same principals, but at lower currents and higher voltages than their battery-based counterparts.

RFI filters work on the basis of a voltage divider, posing a very high impedance to the interference (blocking it), but a very low impedance to the DC that must flow, minimizing loss at DC. This is a very difficult challenge due to the high amperages involved.

The same is true of inverter AC output circuits. AC output is more easily addressed because the current is much lower than the DC input (battery based systems only). Conversely, inverters connect to AC circuits in the home, turning every inch of the house wiring into an antenna that radiates the interference.

As mentioned earlier in this thread, it's best to reduce the interference at the source - in this case, the inverter.

First step is to try to determine where the bulk of the interference is originating. The DC leads? AC leads? Inverter case? All the above? Each has its own set of possible steps to reduce RFI. Leads are the most likely culprit. A battery-operated shortwave radio with a signal strength indicator can be an invaluable tool here. If you have one, you're ahead of the game. If you consider buying one .. ensure it also receives the AM broadcast band. Most do.

Basic rules:

1) Keep the DC leads from the battery to the inverter as short as practicable.

2) Twist the DC leads together if possible. If not possible, keep them as close together as you can. The goal is to have the RFI magnetic energy from each lead cancel the RFI magnetic energy in the other. As was also pointed out, it may be helpful to run each DC leg in metal conduit and then GROUND the conduit to an earth ground - the shorter the better. Failure to ground the conduit will simply turn the conduit into another antenna. An RFI ground is separate from the earth "protective" ground. If you use the AC "ground", it too becomes an antenna unless it's kept short, and you've got a good connection to the grounding electrode conductor with highly conductive earth. It's tough to achieve all three together, but it can be done in some locations.

Someone suggested a "filter capacitor" be connected across the DC leads. This won't hurt, but isn't likely to be effective given the very low impedance of inverter input circuits.

3) Ferrite cores may be slipped over the length of each cable, and placed at the point where the cables exit the inverter. Toroid cores or similar may be of help, but you'll need many of them, and they'll need to extend at least two to three feet starting at the inverter. More is better, and keep in mind .. when many are used .. they're heavy.

Do not install them at the battery end. Installing at the battery end, and leaving some cable exposed at the inverter allows the exposed conductors at the inverter to act as antennas.

Select the proper type of ferrite. Surprisingly, various formulations of ferrite react differently depending on the frequency range in which they're used. For example, some ferrites are good for 100-500 Mhz, and would not do a good job blocking RFI that interferes with AM radio. For AM radio RFI, select ferrite that's rated to work from 250 kHz up to 2 Mhz or more.

4) AC EMI/RFI filters are also available, and may be installed on the AC output circuit at the inverter. These are made by Corcom, Tyco, and others. Select a unit rated for the output voltage AND current of the inverter. RFI filters will be UL/ETL/CSA recognized. If you find some that aren't .. don't buy them.

5) As was suggested, a radio with external antenna may help, especially if the antenna is fed with coaxial cable, which can act as a shield until the cable is well away from the house and/or inverter. Keep the radio antenna as far from the inverter and house wiring as you can.

6) A battery-operated radio is also an option. This too was mentioned earlier in this thread. Even well-filtered inverter AC output always carries with it some level of interference. A weak radio signal will still be affected by a weak source of interference.

7) Ground the inverter housing in accordance with the manufacturer's instructions. All inverters today are required to meet certain levels of FCC interference criteria. Actions of internal RFI filtering circuits may be improved if the inverter is properly grounded.

8) Ever drive into a parking garage while listening to the radio, and the radio station gets very weak or disappears altogether?? Same thing happens when we drive through long highway tunnels.

We can make use of that trait. It's caused by the reinforcing steel bars ("re-bar") acting to block the radio signals from getting to the antenna on your vehicle. The same characteristic that keeps signals from getting to your radio, also works to keep interference IN.

In addition to all the above, you may have to construct a screen around the entire inverter, then connect the screen itself to earth ground. This screen should NOT come into contact with the inverter housing. To do so would defeat the purpose of the screen. However, properly filtered DC and AC leads may pass through it.

In this case, you'll be constructing a "Faraday shield", which will keep interference inside. Surprisingly, this can be ferrous or non-ferrous metal. I'd recommend ferrous (such as chicken wire with small openings), for ease of soldering. Build a "box" around the inverter, including the back of the inverter. To do this, you'll need a board or other means to keep the inverter enclosure from contacting the wire.

Once you've constructed the box .. connect the box to its own "RFI" earth ground. This will be similar to a standard protective ground.

Next, add a bond wire from the RFI ground to the system protective earth for the system. This RFI-ground to safety ground bond wire should be outside if you can .. and buried in the soil if at all possible. Adding this bond wire avoids opportunity for AC ground loops or other issues. Keeping it in the soil also slightly reduces the opportunity it will become an antenna for the interference. If all the above are done properly, they won't impact the effectiveness of the box you've just constructed.

Reducing radio frequency interference is, at best, a snipe hunt. The strength of the radio/TV station signal itself can and will vary, and is dependant on a variety of variables. This can give the impression something you've done had an effect on the interference level from the inverter, where in fact you didn't change a thing. The weaker the radio signal, the more difficult it will be to reduce the interference from the inverter to make the radio signal listenable.

The best thing to do is keep the inverter and all of its wiring as far from the radios as you can. If this simply isn't possible .. see steps 1-8.

I wish you well.

Dan
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