Paladin DRED Control (PDC)

Preamble:

The insight that Demand Response Enabling Device (DRED) control of an Air Conditioner (A/C), although designed originally to allow power companies to reduce the draw of A/C units to prevent grid overload, could also be used in reverse was prescient - given both the reduction in Feed In Tariffs (FIT) and Global Warming (GW) linkage to CO2 production.

The original prototype unit successfully 'throttled' a DRED A/C but suitable hardware and firmware to tie this control correctly to excess PV production was more problematic. The existing Paladin hardware was more than capable of providing the information needed and handling the limited AI (Ant Intelligence) required, but this solution was total overkill, both in complexity and cost.

The minimalist solution was achieved with just a tiny Arduino Nano, some simple support circuitry and some reasonably clever code. Apart from accurately reading both grid in and grid out through a Current Transformer (CT) clipped to the main house grid wire, the major issue was timing. The solution came by using a digital analogue of the Tourbillon (https://en.wikipedia.org/wiki/Tourbillon#External_links) double escapement watch movement from the late 1790's.   With some modification this concept provides an almost perfect answer to the timing conundrum of managing a variable load and an even more variable PV source.

The result is a small, simple and by extension, reliable hardware package and display. The initial concept of using coloured LEDs to indicate status and progress was abandoned in favour of a simple screen to enhance user understanding of the timing and DRED sequences and provide a very useful indication of grid activity when AC control was not needed. A RF433 transmitter / controller compatible with the popular ARLEC remote socket family was added as its action was in total harmony with the AC control, even if that feature was not in use.

User interaction is via a 3 way switch: ON / OFF / AUTO. Power is provided via a 2amp mains lead. A mains connection is required to allow the grid sensing to correct measure current in both directions. Also provided is a TEST/DEMO mode and a TUNING feature for non-standard installations and for installation checks and calibration if needed.

The PDC mains sensing circuit is highly sensitive and responsive, reading the grid CT over 2000 times per second. However small variations in manufacture and component drift can spoil otherwise excellent accuracy. The DRED control algorithm does not need pinpoint accuracy, and delivered units will normally be better than 95% accurate. However with specific tuning to a set installation, this figure can go above 98%, so the Tuning feature is installed for use as required. Both the Tuning and Demo features are undocumented and designed to not be entered by accident.

Web: paladinsolarcontroller.com.au **Email:** sales@paladinsolarcontroller.com.au
Facebook: Paladin Solar Australia Pty Ltd

Fiscal & Environmental Impact:

Given the huge variability of PV installations and climatic conditions, all attempts to specify a particular set of circumstances would be futile. However for the exercise, let's use a dwelling with 20+kWh of excess PV in summer and a 3kW (electrical load) AC unit coupled to the PDC.

For costing we will stipulate 30c/kWh peak in the PM and a FIT of 8c. Using Queensland (the worst example for CO2/kwH) to generate 1kWh generates 746g of CO2.

Fiscal: Using 20kWh of PV would keep a house cool so that in the evening, at peak rates, on a nominal top up would be required to maintain a cool dwelling rather than a prolonged full power cooling effort in the early evening peak. Any equivalence is almost impossible to gauge, but assuming the 20kWh is the same in both scenarios: 20 x 22c = $4.40.

Assuming 240 A/C days per year = 240 x 20 = 4800kWh annually x 22c = $1056

Environmental: Is perhaps more pertinent in today's climate (pun intended).
4800kWh * 746g = 3580kg of CO2. That is a staggering amount, 3.5 tons greenhouse gas. Whatever your views on the reasons for climate change, this is a lot for just one dwelling, just one A/C unit.

Let's take it one step further. If you burn a litre of petrol in an ICE vehicle then that will produce 2.3kg of CO2. So our 3850kg of saved CO2 emissions equates directly to 1556 litres of petrol being used. At average mileage of 5l/100km (for a small car) that is the equivalent of driving 31,000km! More than 2 years motoring. So by implication, using excess PV to run a single AC in the home is the direct equivalent of taking 2 small cars off the road.

Further yet, in terms of carbon credits. What is the value of 3.5 carbon credits per annum? That depends where you look, but it is a lot more than nothing and will only go higher. From a fiscal point of view, this is a pointless exercise, since there is no mechanism for a householder to claim this. However the 'feel good factor' is potentially proportional to your passion.

And lastly: Taking that A/C load off the grid in the early evening peak is a huge win for the grid, and using, rather than exporting that excess PV during the middle of the day is even more pertinent.

The 'Duck Curve' is a real and present danger to the grid and a PDC or similar device can mitigate this in very effectively. Using excess PV in this way is a win-win in so many ways.

Tuning:
Due to variations in components and CT / Wiring etc, there is a possibility that specific grid reading accuracy will be more than desirable for correct operation. As the grid itself is fairly chaotic at times and most end users do not have a method of accurately measuring the Grid anyway, this is likely to be only used at installation or support levels.

Getting there and back again:
Entry into the tuning page must be devious enough to avoid accidental activation as far as possible. Since there is a 5 second delay**, o**n start up anyway, this time can be used to monitor for a specific pattern of switch movements, which if not achieved, allows the program to default to normal operation. Once in the Tuning page, the only way out will be a reset.

Entry:
To start the Tuning page the power must be applied with the switch to the RIGHT. Within the 5 seconds that the start-up page is displayed the switch has to move to the CENTER. This then displays the Tuning page, and if the switch is not returned to CENTER inside 5 seconds the Tuning feature will abort and the program will return to normal ops.

The Tuning Page:
Line 1: "Tune-Restart to Exit"
Line 2: "AAA XXXXX AAA YYYYY" where AAA = IN or OUT and XXXXX = Instant, YYYYY = Averaged
Line 3: "Tuning value XXX.X"
Line 4: "R=Up : L=DN : C=HOLD"

The second line is split: Real Time data on left and 5 second average on Right.
The third line shows Tuning values: (currently 4.0) The first is what you are using now and the second, what you started with.

The bottom line is just stuff you don't need to know about ATM. But basically it is:
Right to Left: Current Mean 0 voltage point - Voltage correction factor - Tuning value

Method:
To successfully navigate to and activate the Tuning page, the switch will be in the CENTER. (See Getting there, above)
With the switch centred, the values for instantaneous and average will update every second. If these are found to different to a KNOWN and ACCURATE mains reading, adjust as follows:

Moving the switch to the RIGHT will increment the Tuning Value Up by 0.1 every second, the Grid reading will go up in concert.

This is not entirely linear and is subject to a few seconds lag. Remember also that unless on a test rig, the grid readings always fluctuate, sometimes considerably. Use the CENTER switch position to allow the readings to stabilise. Down is the reverse process.

When you have completed the tuning process, reset the unit by switching OFF, then ON. Changes to the Tuning value are continuously saved to EEPROM and will restore to the changed value on start up. The only way to change these values is to use the Tuning page.

TRI Colour LED:
LED and connector that mirrors the DRED operation (RED = OFF / GREEN = 50% / BLUE = 75% / OFF = 100% and a RF433 module that mirrors the DRED.

The DIP switches control the compressor size value:

Basic (all OFF) is 1000W
DIP1 adds 500W
DIP2 adds 1000W
DIP3 adds 2000W

So you can select 1000/1500/2000/2500/3000/3500/4000/4500 - which should be enough!!

The RF433 switches on with Max DRED and OFF when the DRED goes OFF.
It mirrors that continuously - only in AUTO or ON/MAX.
If the AC isn't ON or DRED cable not connected then it will work independently and the DIP switch value can be set according to the RF433 switch requirements.