From Centralised Grid towards the Distributed Grid; the eventual elimination of coal and gas in domestic and light industrial generation

Synopsis

We are trending to see geographical areas able to become renewable energy self-sufficient, to the exclusion of the conventional grid. To better facilitate this, our renewable sources need a unifying standard of frequency so that they may connect to one another without needing reference to the grid. This paper proposes a National Frequency standard that adjacent islands of self sustaining renewable power can readily amalgamate and also seamlessly connect to the grid without power interruption. The realisation that atomic clocks are so superbly accurate and cheap give rise to the idea of using this technology to make a standard for renewables. The paper talks to the means by which this might be achieved.

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1.Background

Large centres of solar and wind power generation supported by energy storage will soon enable multiple property estates domestic and light industrial to exist off-grid. Cumulative numbers of installations, better cell efficiencies trend to ever expanding future. This is a compliance standard for frequency, independent of the grid, but sympathetic to the various contingencies that cause the grid to not hold frequency as readily as renewable sources.

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2. Introducing the Synchronising Pulse (SP)

Atomic clocks are at the heart of the familiar Global Positioning System, the so called GPS. We must be taken back a little at the astonishing accuracy of the atomic clocks that enable the positioning system to be as precise as it is; being able to place a three dimensional position on earth from distant satellites in space.

An atomic clock, CSAC, small in size so that it fits on a circuit board and at a cost of under $2,000 is available from a US manufacturer. Accurate in the extreme, this equipment can be used to create a synchronised pulse over a wide area.

The CSAC's key specs include:

- < 120mW power consumption
- < 17cm^3 volume
- 35g weight
- ±5.0E-11 accuracy at shipment
- <1E^{-11} @1000s Short Term Stability (Allan Deviation)
- <9E^{-10} /mo Aging Rate (Typical)
- -10^oC to +70^oC Operating Temperature
- QUANTUM Chip Scale Atomic Clock Video

The system envisaged transmits a blip every 1 second. That blip represents a national standard of the positive zero crossing of A phase#. --- a National Timing Pulse. Timing and control equipment would be owned and operated by power authorities. The number of clocks is subject to an overall design and this is to be detailed but extreme synchronised accuracy of time is available over a wide distribution network. The equipment could possibly be located in Fibre to the Node

(FTTN) boxes we are seeing in our streets as part of the NBN rollout or further spaced towards the NBN hubs, meaning fewer clocks.

The location of this reference signal is to be agreed but if it is national it could be on the 132 KV system in NSW (I believe this to be the longest line length of any system in Australia)

The pulse standard needs to be national because we must assume renewables will be the ultimate power source and all systems will integrate. Though it might seem deep into the future, one day we will not burn coal or gas to generate electrical power.

Typical Fibre to Node Box being installed.

The Fibre to Node, FTTN, would be connected to every renewable installation, supplying every renewable source with the required system frequency signal. The signal would be terminated at a controller I will call the ‘Pacemaker’

3. The Pacemaker

A Pacemaker on every solar/wind installation would:

1. Receive a time critical pulse from a district transmitter.
2. It would take a precise timing signal on (say) the leading edge of a pulse.
3. It would have an output available to be connected to any existing wind or solar converter.
4. It would drive the inverter at precisely 50 Hz and would be in exact phasing.
5. Single phase solar/wind systems can only deliver energy to the phase to which the converter is connected so the Pacemaker has internal circuitry to derive a correctly timed trigger pulse to suit either A, B, or C phase from the precision timing signal. This is set on installation and would generally never be altered once set.
6. Power to a district may come via a distribution network where Vector Group* of the supplying transformer network may be different to another district. Similar to the phase selection ABC timing, there is facility in the Pacemaker to adjust for non-standard phasing due to Vector Group* differences in the supply network. This is set on installation and would generally never be altered once set.
7. Phase selection and Vector Group* selection are under the sole control of the distribution authority.
8. The distribution authority is the sole controller of the trigger pulse. This means the distribution authority can turn off or turn on a district's solar/wind power contribution to the network. This feature enables the supply authority to facilitate fault protection and safe access to its area networks.
9. The distribution authority has the facility to revert an installation back to Phase Locked Loop control by means of a remotely controlled switch on board the Pacemaker.

(Vector Group* Three phase transformers may be internally connected in a variety of ways so that various angles of phase shift can be introduced for technical reasons. Phase shift affects the position in time that a phase makes its zero crossing. Transformers of different vector group cannot be paralleled so there is standardisation in various areas of distribution.
The Vector Group selector would take into account the sum of all phase angle adjustments that might occur at the various transformer

installations along the way from the reference location of the control pulse to the Pacemaker site.)

Conventionally, inverters usually derive their triggering pulses from the grid. Grid phasing goes to a Phase Locked Loop electronic circuit so that at all times the converter receives an exact trigger pulse from the grid.

For the Pacemaker to operate the Phase Locked Loop system is switched off. The SP received initiates a pure sine wave waveform derived from within the Pacemaker that now drives the inverter at 50 Hz The driver's precision comes from the trigger pulse which updates timing of the 50 Hz waveform every second. Trigger pulse for the converter is received from the district transmitter, which in turn comes from an atomic clock.

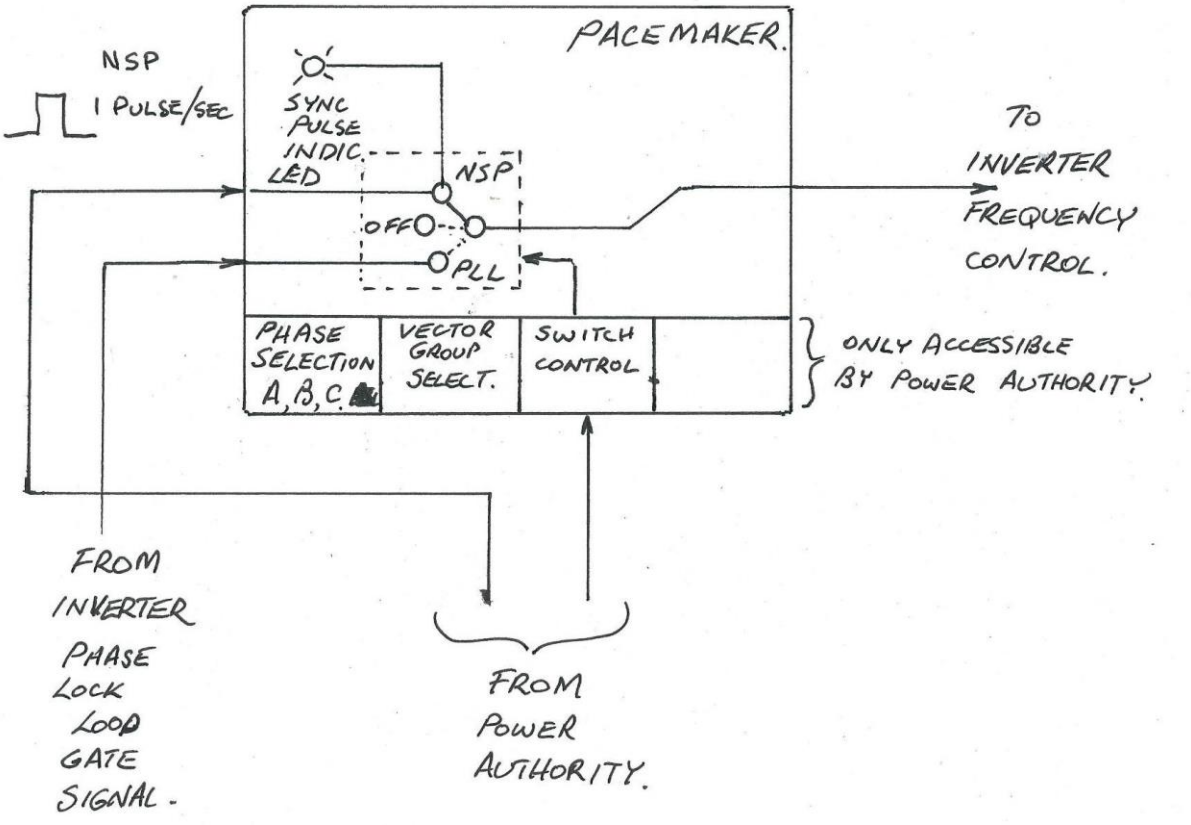

Fig 1 The 'Pacemaker' is installed on all renewable installations. It enables the power authority to free the renewable from the grid

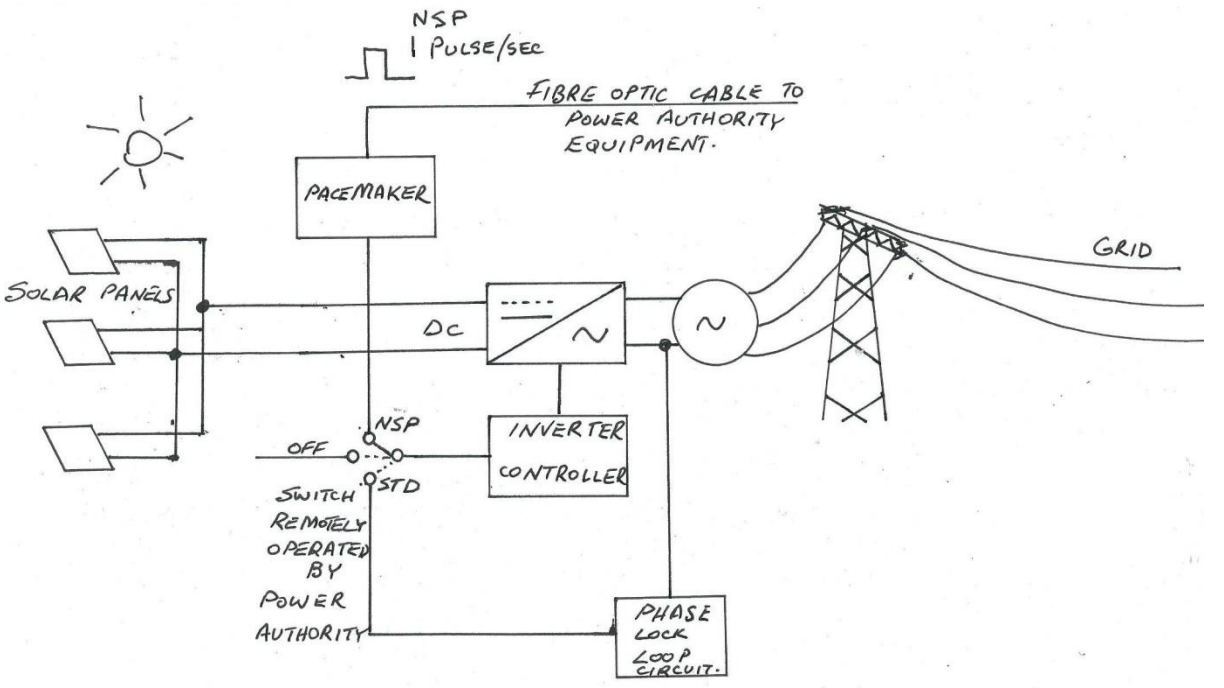

Fig 2. This block diagram shows how the 'Pacemaker' is connected to an existing solar installation for example.

4. What would the Pacemaker enable?

Synchronisation by the SP enables operation of all power generation systems on the basis of no favourites. At present the large, the established hydrocarbon burners need to be the base and renewables join in. If conventional power is unavailable but a large capacity of renewable generation backed by an extensive storage system is, under the SP, power reticulation could commence and later as conventional power became available it could join in to shoulder the supply need. The SP enables a much bolder reliance on renewables because it unshackles it from the fossil burners.

Would that be a good thing?

The more energy renewables are able to tip into the system the easier the coal generation plants have to work. Lots of wind and solar connections make for less coal and gas consumption and this means less CO_2. Less CO_2 is a good thing for the planet.

SP allows the healthy development of renewables to power public reticulation. With battery storage, there will be a strong incentive for people to go off-grid. Essentially, this is antisocial. An established

system of enabling renewable inclusion to the public power supply must be a social aim that SP can facilitate.

5. Role of the Power Authority

States, districts have non-uniform legislation all over Australia. Moving renewables into a more mainstream position will require work and cooperation and legislative change. It will be smooth and easy or bloody minded and difficult but in the end renewables have shown they have an important role in weaning the planet off combustible fuel. Renewables are the future.

Proposed duties of the Power Authority

1. Operate and maintain timer hardware possibly in co-ordination with NBN Co. This means synchronising so that all clocks have identical time.
2. Be involved in the modification of inverter equipment presently in use. This means being abreast of all the various and different types and models in service. This means running an expert advisory service to the solar electric industry. Via an inspection service, check to ensure that when a new system is commissioned or when an existing system is modified for SP, the authority is represented.
3. By means of the Pacemaker selector switch the Power Authority has the ability to remotely switch off any renewable contributor to the grid. With SP selected the inverter will not shut down when the grid is lost. In a fault situation the authority will need to trip inverters. Protection systems need to be developed for this.
4. To synchronise the grid to renewable generation the grid sees a 50 Hz generation source. In a usual technique the the grid is connected to the renewable source when the grid moves to match phase and voltage. After connection Pacemakers are remotely switched to remote by the power authority enabling all phase locked loop synchronisation to take over from the SP. The power authority manages this aspect of the system.
5. If it appears apparent to the power authority the loss of the grid is imminent they have the responsibility to move the distribution system to be synchronised to SP and switch all renewables to SP before they withdraw from supplying. This allows the possibility of renewables continuing to supply without interruption.

Sources:

Microsemi Corporation Corporate Headquarters
One Enterprise Aliso Viejo, CA 92656 USA

Fibre to the node photo:- Somerville Victoria

Ray Osterberg BSc Elec Eng,

Energy Safe Victoria Electrical ISPector 980563 (Retired).

26th April 2017 Rev 1