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Re-engineering the NEM within the Half Hour

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What if the NEM had been designed from the ground up by control engineers, rather than by economists and financiers with minds focussed on break-ups and sell-offs? Which elements might look the same which different?

These thoughts are prompted by the proposed rule change submitted to the AEMC by Sun Metals[1] to settle the market on a synthesised 5 minute basis rather than the current half hour. This is not a new issue in the NEM but it has never been satisfactorily resolved.

Control of Technical Systems

To James Watt goes the credit of inventing the governor, which made the stream engine practical in the late 18th century. Today's generators operate on that very same principle, albeit with multiple layers of refinement.

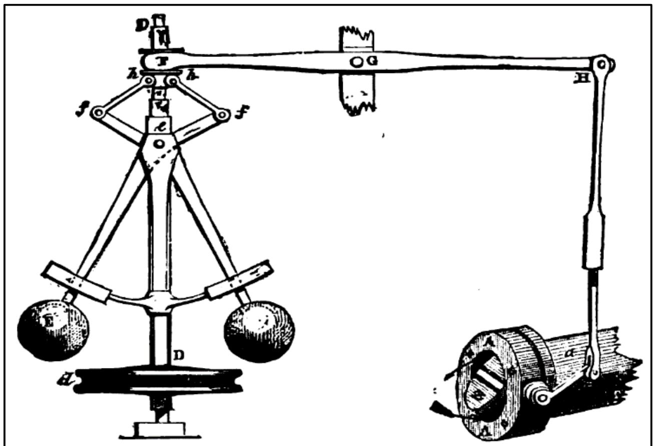

FIG. 4.—*Governor and Throttle-Valve.*

Source: Wikipedia

There are three main elements of such a system. One needs:

- some sort of target or objective, which in this case is maintaining the engine at close to a desired operating speed, otherwise interpreted as balancing demand with supply;
- a means to measure the deviation from ideal; in this case the spinning centrifugal ball mechanism does that job; and
- a feedback of this measurement, in this case through a steam regulating valve, to drive the engine speed back to the desired set point.

We can apply this basic concept to much more complex task such sending a space vehicle to orbit Mars. The stages are:

1. determine a broad strategy, likely to be complex) to get into earth orbit, track to Mars and then go into Mars orbit;
2. implement a feedback system to measure deviations from the broad trajectory, potentially from a range of different sensors;
3. apply some sort of corrective action (e.g. directional thrusters) to steer the vessel back onto course; and
4. re-calculate the broad strategy at regular intervals from the current starting point, before returning to Step 2.

[1] See the AEMC rule change at http://www.aemc.gov.au/Rule-Changes/Five-Minute-Settlement

This process of recalculating strategy projection at intervals coupled with continuous real time control is typical of many control systems. It goes by the name of model predictive control.

Can we relate this cycle of control activity to what happens in the NEM? We certainly can! But let's first review a little history and where we are now.

Brief History of NEM Dispatch and Pricing

The early electricity market reforms in the UK and also state-based efforts in Australia and the US envisaged a daily scheduling and pricing process substantially based on existing scheduling systems. In Australia, after some trials and quite a few errors (happily, only in a so called "paper trial" conducted in the mid 1990s), we finally landed on a proposed design where the dispatch and pricing process would be aligned with the proposed trading interval of half an hour. Participants would manage their own plant themselves, including committing their plant, over longer time intervals. This simplification was a real breakthrough.

However, later work suggested that dispatch and pricing should actually take place at a shorter interval – 5 minutes. Why? To reduce the requirement for out-of-market ancillary services and system operator intervention – also considered a Good Thing.

However, it was not so clear how to reconcile the Good Thing of 5 minute dispatch and pricing (using real time SCADA monitoring and control) with the Good Thing of half hour settlement of spot energy to support contract trading. How was this dilemma finally resolved? Answer - by taking the half hourly trading price as the arithmetic average of the 5 minute dispatch prices. The potential problem with disconnecting pricing from physical dispatch was recognised at the time and has been revisited by AEMO/AEMC several times since, but inertia has prevailed and the problem remains.

Even with 5 minute pricing there is a need for specific services, operating writhing the 5 minutes, to control frequency - the balance between supply and demand. These frequency control ancillary services (FCAS) were originally fully contracted in advance and removed from the market. FCAS were defined in neutral terms as regulation (raise and lower), and contingency services to deal with credible system shocks, defined as raise and lower in timescales of 6, 60 and 300 seconds to 10 minutes. The energy market was assumed to operate outside those timescales.

From 2001 some elements of markets in FCAS were studied and proposed, as well as more dynamic mechanisms to charge for and reward the use and provision of regulation FCAS, known as "Causer Pays"[2]. In the following years these were implemented although not as fully as originally proposed.

The Proposed 5/30 Fix

The change proposed by Sun Metals echoes the solutions proposed in the past, with some modification to make it less costly to implement for loads who do not need or want to be involved. In essence, the proposal is to use 4 second SCADA data or 5 minute revenue metering to synthesise a generation or load weighted price profile, which is then applied to half-hourly metered energy. The proposal and AEMC's Issues Paper identify a range of matters to be considered:

- whether the inefficiencies are large enough to warrant action;
- the impact of the process on contracting
- the accuracy and cost of using SCADA data or 5 minute revenue metering in the settlement process; and
- the management of any additional settlement revenue or deficit.

[2] The general design for FCAS markets, a 5/30 minute fix and the Causer Pays mechanism were proposed in two 1999 IES reports prepared for NEMMCO (now AEMO). The reports and their appendices can be downloaded here.
http://downloads.iesys.com/Insider/Insider%20022/AS%20Stage1%20Appendices%20Final%20-%20IES.pdf
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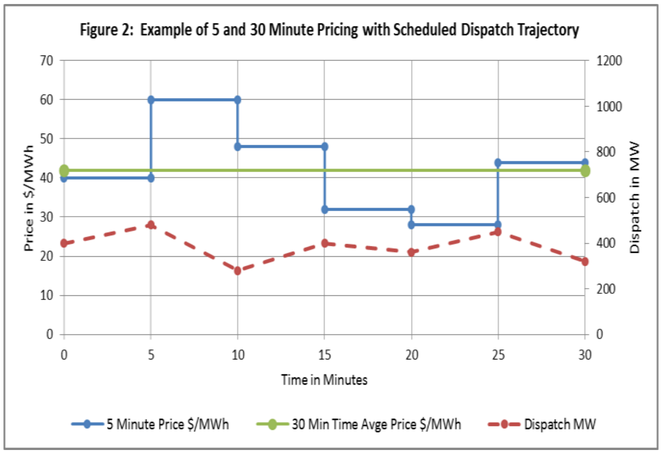
In this article we will not dwell on the current inefficiencies except to note that there is evidence of gaming going on which will likely increase over time as new rapid response technologies such as batteries come to the fore.

So, assuming that a decent fix is worth pursuing, does this slightly revised Sun Metals proposal do the job? An indicative 5 minute dispatch trajectory for a generator, say, 5 minute dispatch pricing and current settlement pricing are illustrated in Figure 2 following.



The figure shows the average price used for all energy generated in the half hour. The 5 minute price will typically vary above and below this average, which breaks the link between dispatch and potentially drives bad behaviour

The Sun Metals proposal, along with proposals of previous years, synthesises a settlement based on the 5 minute dispatch prices. The pricing distortion that arises from averaging is apparently fixed; price and volume are now properly aligned down to the 5 minute level.

However, there is a looming problem here. Even with 5 minute pricing, under the current proposal there would be step price transitions between 5 minute periods, potentially very much larger than those which the current averaging process delivers. Given that these are published in real time as ex ante prices, smart, fast acting technologies could "pile in" to these transitions unconstrained. Such step changes in response might drive up the requirement for FCAS or even, if not tightly controlled, destabilise the system.

This problem must be dealt with. It is surprising that the AEMC Issues Paper does not even mention FCAS and stability as matters to be dealt with in any assessment of this proposal.

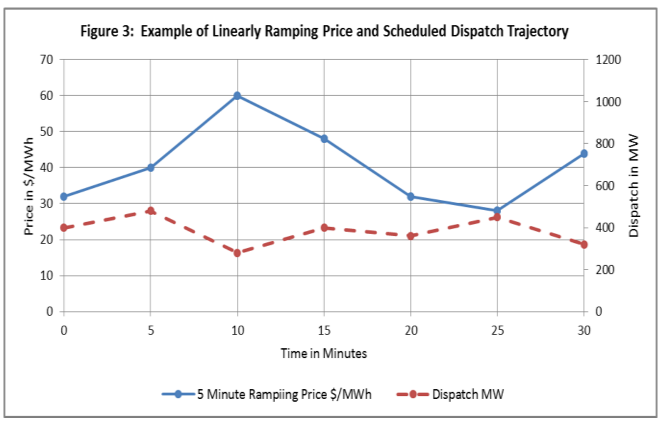
Smoothing the Price Trajectory

As foreshadowed earlier, we can look at the pricing and dispatch task as a control task with a commercial dimension. They key contention of this article is that analysing the task and following through with this perspective yields a simpler and more robust solution.

With a control perspective, we can view 5 minute scheduling and pricing as setting an indicative trajectory for the system both in terms of physical operations and in terms of energy price. A real time controller (FCAS regulation) can then manage the system around this indicative trajectory – more on that control task later.

The scheduled physical trajectory calculated from the dispatch process within each 5 minutes is approximated as a linear ramp as shown in Figure 2. However, the energy price for the whole 5 minutes is currently set at the price from the scheduling and pricing model worked out 5 minutes ahead. A little reflection confirms that his step change is entirely artificial. It seems to be a leftover from a view that the system should be designed operated for the benefit of contract traders rather than smooth operations. In fact, we can achieve both.

The problem is that generation/load offers are entered at discrete prices to model a piecewise linear generator cost curve. These curves are in fact relatively smooth with no artificial step changes in slope, so it makes sense that the energy price should move continuously from one 5 minute boundary to another. As with generation and load 5 minute forecasts, a linear ramping of price (within each region) is a better and shock-free approximation of reality. A linearly ramping set of dispatch trajectories with corresponding linearly ramping prices in are illustrated in Figure 3 below.



The 5 minute dispatch prices are the same as before in this example, except that the price at the start of the period illustrated – the boundary where the previous period ends, is the starting price for the start of the first ramp. The dispatch price at the half hour boundary is shared.

To keep the discussion focused on one issue at a time, let's assume a generator or scheduled load follows its scheduled trajectory precisely; we can relax that assumption later.

How do we work out the settlement amount for the outcome shown in Figure 3? This looks messy, because both price and quantity are continuously moving. Despite appearances, the task is readily done with a little help from high school calculus. That is, given the 7 generation/load target MW values within and at the edge of each half hour, together with the associated dispatch prices (adjusted for MLFs), a simple formula gives you the settlement amount, assuming the trajectory is followed. We won't bore you with the details here[3].

Preserving Spot and Contract Settlements

All the options proposed to fix the 5/30 problem effectively change the average price of energy in the half hour, depending on individual dispatch MW and 5 minute pricing patterns. This individuality might be seen as reducing the liquidity of contract trading. Further, the measurement of energy at less than the half hour requires either 5 minute revenue metering or an approximate approach using SCADA data. Both these issues, if unresolved, could add weight to an argument to do nothing to fix the problem.

However, we can isolate the impact of a 5/30 fix to leave energy spot and contract trading untouched. Again, let's assume initially that a participant follows its scheduled trajectories. For spot settlement in a given half hour we:

- calculate half hourly settlement exactly as we do now, using average dispatch prices[4] and energy quantity as measured by a revenue meter;
- determine an auxiliary payment (positive or negative), being the *difference* between a 5 minute settlement calculation as previously described and a time-average half hourly settlement

If we examine the algebra behind this, we find that the residual term is essentially an adjustment to revenue that accounts for the correlation between price and dispatch volume of the participant over the half hour. For example, a generator whose dispatch tends to track high and low prices would attract a higher average price and extra revenue. The adjustment depends on price and volume *differences* only, some positive and some negative, so any measurement errors are confined to this residual amount[5].

We could regard this price following activity as an additional ancillary service to deal with the 5/30 issue; a Ramping AS, or RAS. It will be participant-specific, so not widely tradeable, although parties with opposite characteristics may well be able to deal with each other to share risk. On the upside, current spot trading and contracting would remain untouched.

To give all this some substance, we have run the half hourly dispatch and price profiles of Figure 3 through our prototype settlement engine and get the following:

Table 1: Settlement Analysis with Energy and RAS Options

Data							
Time in Mins.	0	5	10	15	20	25	30
Price $/MWh	32	40	60	48	32	28	44
Disatch MW	400	480	280	400	360	450	320
Gross Settlement Options							
Sun Metal (5 minute ex ante price)							$8,097
IES (5 minute ramping price)							$7,822
IES Energy and RAS settlement (derived from above)							
Current NEM (time average ex ante price)							$8,155
Ramping AS settlement amount							-$333
Total Settlement (as per IES Gross option)							$7,822

The Sun Metals and IES options using target MW are shown, together with the current NEM time averaged method. The differences are specific to the example, of course. The

[3] For the analytically minded, the settlement amounts of the various options for dealing with the 5 minute problem *can* be expressed in terms of the 7 element vector of MW targets within and at the edge of each half hour, and a corresponding set of dispatch prices.

[4] The current logic is that each 5 minute dispatch target price applies to *all* energy generated/consumed in the previous 5 minutes. If a ramping price model is adopted, the average price used should strictly be slightly modified, although that change makes no difference to settlement based on average prices over a period. It is more an aesthetic issue than a real one.

[5] Later analysis shows that the measurement error only affects energy measured as deviations from target.

three bottom rows show the settlement for the IES proposed approach.

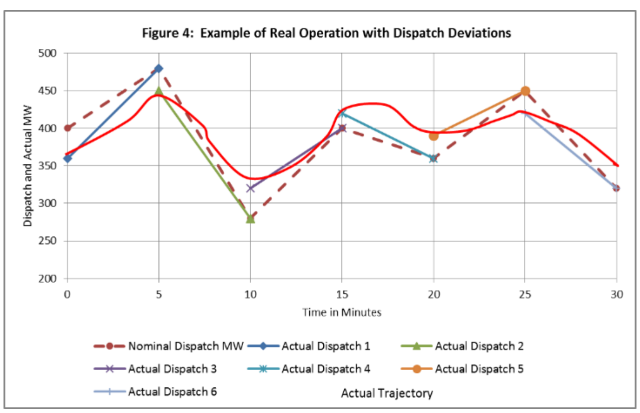
The first of these rows is the current AEMO energy settlement, which would remain unchanged. The second row shows the proposed RAS (based on target MW - Initial MW is an alternative). The final row is the total settlement, which in this case is the IES version of 5 minute pricing and settlement.

Dispatch Compliance and Regulation

There is always some deviation from the forecast and scheduled dispatch trajectory by loads and unscheduled generators, scheduled generators or scheduled loads. Our calculations so far have been based on scheduled megawatts. What error is involved with this assumption, and how can any such error be managed?

An important thing to notice is that dispatch compliance is measured with reference to SCADA data. Even if SCADA data in a particular case has systemic errors such as a constant offset or even a proportional error, error analysis will show that a measurement of deviation from a trajectory based on those measurements is not greatly affected by such errors.

Figure 4 following shows a typical situation for a scheduled unit such as a generator. Let's simplify by setting aside the possibility that it may also be providing regulation FCAS.



The idealised dispatch as discussed so far in this article is shown as the dashed line. However, the generator will never follow the trajectory exactly, as shown in the curved line. So the Initial MW for each 5 minute interval is never the exact MW in the previous schedule, but some deviation from it. However, at the 5 minute boundary AEMO re-sets the generator status to the actual MW as measured by SCADA. The actual dispatch schedule is thus a series of broken ramps as illustrated.

We don't need to delve further into these details to observe the following:

- Nearly all generators operate under AEMO's AGC control. They have little scope to manipulate their trajectories, even if they had the incentive to do so.
- In any case AEMO has a compliance monitoring system in place and can call a participant to account in the event of poor performance in following its schedule.

Another important thing to notice is the proportion of the dispatched energy and settlement amount that may be sensitive to any remaining SCADA metering error.

- The bulk of energy settlement under the current arrangement is unaffected by SCADA error;
- From the figure, it can be seen that the bulk of the proposed settlement adjustment for ramping is reasonably accounted for in the scheduled dispatch pattern. It is only the deviations from the scheduled trajectory that could introduce some settlement error.
- Systematic exploitation by a participant of such deviations for financial advantage appears to be very hard to achieve; certainly much harder than the manipulations possible under the current settlement arrangements.

Our conclusions from this discussion:

- An initial implementation of a Ramping Ancillary Service as described in this article could be based on linearly interpolating scheduled rather than measured values (i.e. using the trajectory shown as dashed in Figure 4), avoiding the need to immediately address metering issues. Scheduled values are already published.
- A useful alternative or refinement of the above could be to use a linear interpolation of the "Initial MW" of a scheduled generator or load, which is also a currently published data item (i.e. using the dotted line trajectories in Figure 4). This trajectory is derived from AEMO's SCADA measurement of where the device is actually operating at the 5 minute boundary. Investigation may show that linear ramping between

those MW levels could be a more robust approximation of actual operation.

- Use of a complete set of SCADA data to refine the settlement process need only apply to deviations from the dispatch schedule. SCADA measurements of such deviations are already used to settle regulation FCAS through the Causer Pays mechanism, so use of SCADA data in this way is nothing new.
- Adjustments to account for deviations from schedule should be regarded as a task for regulation and contingency FCAS. This will be discussed in the next section.

Integrating the 5/30 Fix with FCAS

Keeping participants close to the dispatch schedules is an ongoing AEMO control and monitoring task, but overriding that is keeping the frequency of the system within bounds. These tasks are managed together, normally with Regulation FCAS operating through 4 second SCADA, supplemented with contingency FCAS to deal with larger system disturbances.

The FCAS market operates quire differently to the energy market. When the energy market was under development, there was debate about whether it should be based on energy only, or energy with an additional capacity component. The capacity component would provide, greater assurance of reliable operation, or so it has been argued and continues to be argued by some. The energy only model persists after several reviews because it has worked.

FCAS markets introduced in the early 2000s are integrated with the energy dispatch process and they have also worked well enough so far. However, FCAS suppliers are paid only for capacity; they earn nothing from actually performing, except avoiding a rap over the knuckles from AEMO if performance is judged to be sufficiently bad.

This abrupt change in philosophy from energy only to capacity only when moving into the 5 minutes is curious yet understandable. AEMO is responsible for the frequency stability of the system and it is understandable and arguably necessary to have assured capacity ready for immediate use in that duty, so it makes sense to leave the current arrangements untouched.

Nevertheless, steeper price transitions from a 5/30- minute fix warrants reconsideration of the idea of pricing both FCAS "enablement" (making capacity available for the service) as well as actual usage and provision. In fact, the Causer Pays mechanism for charging for regulation FCAS already provides a pseudo price on FCAS usage.

It would be a straightforward matter to adjust this process to operate in a balanced, two sided manner. This could be introduced as an additional service, without touching existing arrangements. With a charging and usage regime in place, the price of "enablement" or capacity in these markets would likely fall as second by second participation becomes more rewarding and significant.

A Way Forward

If we take a model predictive control perspective, the 5 minute dispatch process would operate as follows.

- The 5 minute scheduling and pricing process provides target MW and prices at a point in time 5 minutes into the future. For a smoothly operating system, both prices and MW trajectories should be assumed to ramp linearly from the current time to the next. This is the "model predictive" component of the control system.
- Real time control then takes over, the current task of regulation and contingency FCAS. The baselines for MW control and pricing of the control are the predicted trajectories of MW and prices over the 5 minutes.
- The 5 minute forecasts produce prices that can be used for settlement of bulk energy as well as a Ramping Ancillary Service. The FCAS regulation process can be configured to deliver 4 second prices to reward and charge for the usage of that service, based on Causer Pays concepts. Enablement services in FCAS would remain as they are.

The issue of metering accuracy needs to be dealt with as is the natural desire of participants to minimise or eliminate changes to existing systems to reduce or avoid implementation costs. This can be done by:

- leaving current energy settlement arrangements untouched;
- defining a separate Ramping Ancillary Service (RAS), settled as the difference between a 5 minute price weighted settlement and a half-hourly time weighted

price settlement, both based on scheduled or Initial MW trajectories; and

- noting that SCADA data need only be used to measure and settle deviations from scheduled trajectories, which is an acceptable use of such data.

The analysis in this article suggests an implementation strategy to fix the 5/30 problem which is less costly and disruptive to implement than the one currently proposed to AEMC for a rule change.

1. Consider implementing a RAS based solely on scheduled prices and ramped dispatch and price trajectories or interpolations based on Initial MW SCADA values. The settlements can be easily calculated by AEMO and can be confirmed by participants with currently published data. No changes to metering are required. While the approach relies on reasonable dispatch conformance by participants, study will likely show it to be a great improvement on the current system, implementable at very low cost and with minimal disruption.
2. Following the above, or simultaneously with it, convert the current Causer Pays software to operate in real time in a two sided manner, using SCADA data. A suitable pricing formula will reflect the logic of the regulation control algorithm. Retain the current Causer Pays logic in parallel for as long as necessary.
3. With regulation real time pricing bedded down, consider adding shorter term components to the FCAS usage pricing algorithm to reward contingency FCAS for performance and to allocate costs more efficiently and fairly to providers and users than at present.
4. Consider how the FCAS pricing algorithm can be built into smart meters to allow non-scheduled participants into the FCAS and 5 minute market without centralised control. Summary values based on in-meter 4 second calculations of energy frequency and time error can be accumulated within the smart meter and 5 minute summaries later read and used for settlement.

Where to Next?

There are details around this implementation approach, which differs in some important detail from the Sun Metals proposal, which require investigation and resolution. A prototype system operating in real time on real NEM outcomes would be a compelling demonstration. It would be a modest development at AEMO with little of any system change requirements imposed on participants.

Based on experience, it may be that many incumbent participants do not see much merit either in attempting to resolve the 5/30 issue or in preparing the system for an eventual proliferation of fast acting technologies such as batteries. But many participants or would be participants, including some who do not even know of their interest yet, can see the benefit of a good fix. The proposal from Sun Metals is evidence of that.

IES is keen to hear from parties who are interested in improving this aspect of NEM operations, or the other aspects that IES has identified in our earlier IES Insider on possible NEM improvements. See contact details below.

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