Role of contribution factors in the transmission queue model – 18 August 2022

Purpose of paper

In its submission to the transmission access reform consultation paper, the Clean Energy Investor Group (CEIG) has affirmed and clarified its Transmission Queue Model (TQM).[1] CEIG explained its preference for this model over alternative model options, including a version of the TQM modified by the Energy Security Board (ESB).

ESB took an action to prepare this paper to settle the question of whether TQM, in the form proposed by the CEIG, results in inefficient dispatch outcomes.

The TQM contains both investment and operational elements; the former describes how queue numbers are assigned to generators and the latter explains how these numbers are used in dispatch. This paper only reviews the operational aspect of the TWG and does not consider the merits of the model in investment timeframes. The impact of the model in investment timeframes is arguably more important, as this is the timeframe that the TQM is designed for.

This paper examines these issues as follows:

1. Overview of the TQM
2. How will the TQM affect dispatch?
3. How will the TQM affect bidding?
4. How will the TQM affect RRP?
5. Implementing TQM in dispatch
6. Conclusions

Context

The ESB has been considering access reforms in which the allocation of access is separated from physical dispatch, with differences settled at LMP. With generators paid LMP at the margin, they have a stronger incentive to bid close to cost, compared to the current market where constrained off generators will bid at the market price floor (MPF) to maximise dispatch. Cost-reflective bidding results in more efficient dispatch.

Both the congestion management model (CMM) and congestion relief market model (CRM) have this core attribute. In contrast, the TQM doesn't separate access from dispatch but rather changes the dispatch algorithm itself, to incorporate and reflect queue numbers. For that reason, there is no equivalent prima facie expectation that it will improve dispatch efficiency. This is what this paper examines.

1. Overview of the TQM

Today, the dispatch algorithm finds the cheapest feasible dispatch, based on bid prices, marginal loss factors (MLF) and contribution factors (CF). In principle, the preference to dispatch one generator over another depends upon two factors: their relative CF in binding constraints, and their relative bid prices (adjusted for MLF). Where constrained generators all bid at the MPF, bid price is no longer a factor and so dispatch differentiates solely on the basis of CF(s). In a simple scenario, with a single binding constraint, generators will be dispatched in order of ascending CF.

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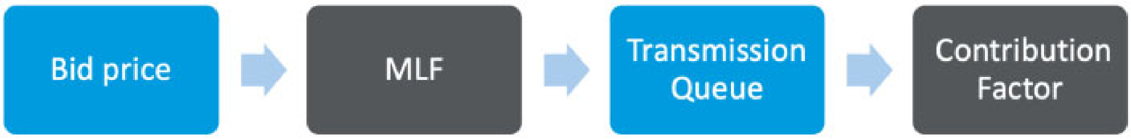
[1] CEIG, https://www.energy.gov.au/sites/default/files/2022-06/CEIG%20Response%20to%20transmission%20access%20reform%20consultation%20paper%20May%202022.pdf, 10 June 2022

The TQM would change the dispatch order via the dispatch algorithm. The TQM assigns a queue number to each generator with "0" representing the front of the queue and the highest number the back. In the original TQM, the queue number only came into effect to "tie-break" between two generators with identical loss-adjusted bids and contribution factors.[3] However, the latest CEIG submission has clarified that queue number will *always* take priority: eg generator with queue number zero will *always* be preferenced over a generator with identical bid but higher queue number, irrespective of CFs. Under the TQM, the dispatch algorithm would favour generators with lower queue numbers, even if this led to a more expensive dispatch.

Figure 1 Proposed placement of the queue in the NEMDE dispatch algorithm



The figure above shows that the NEMDE should first determine the bid-stack by assessing all MLF weighted bids to determine the least cost generation mix to meet demand in a given five-minute interval.

Next, where there are binding constraints within the NEM that NEMDE must resolve, NEMDE should curtail generators in descending order of the queue. This means that NEMDE would seek to resolve binding constraints by curtailing generators with a high queue number and then proceed down the generators in the queue until the constraint is resolved. If NEMDE cannot resolve the binding constraint using queue order, then NEMDE should resolve the constraint using contribution factors as it currently does. Thus, if NEMDE reaches generators with queue number 0 without resolving the constraint then it should resolve the constraint using contribution factors as it does now.

Source: CEIG, CEIG response to the TAR consultation paper released May 2022, 10 June 2022, p.8

2. How will the TQM affect dispatch?

Figure 2 illustrates a scenario where three generators have differing CFs. There is a fourth generator located at the RRN which provides the balance of the load.

The simplified scenario is similar to the reference scenario provided to the TWG operational subgroup (21 July 2022), except that the three generators behind the constraint all have a short run marginal cost (SRMC) of $0/MWh. This is designed to control the variables and isolate the impact of the TQM on dispatch.

[3] Castalia Ltd, on behalf of the CEIG, https://ceig.org.au/wp-content/uploads/2022/02/2022-02-23-Report-on-Transmission-Access-Reform.pdf, February 2024, p.24

Figure 2 Reference scenario

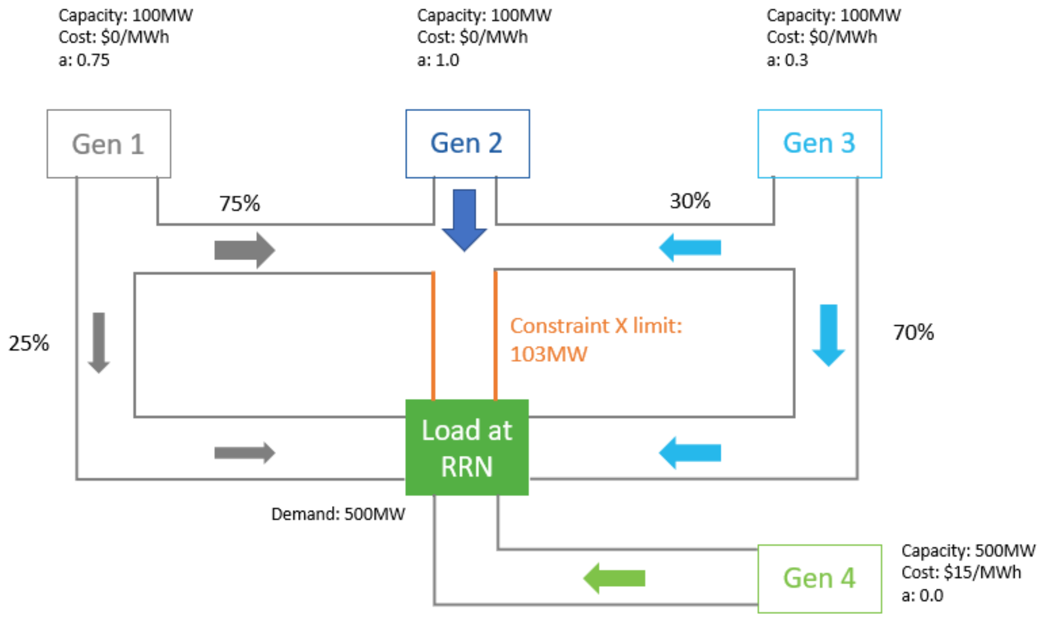


Figure 1 illustrates the impact of the CFs on dispatch outcomes. For example:

- Gen 3 has the lowest CF of 0.3. For every 1 MW flowing through the constraint, 2.33 MW is dispatched around the constraint.
- Gen 2 has the highest CF of 1.0. For every 1 MW flowing through the constraint, 0 MW is dispatched around the constraint.

Every MW dispatched by Gen 1 – 3 displaces the higher cost marginal generator being Gen 4. Hence, maximising dispatch based on a combination of bid price **and** CF leads to a lower cost outcome.

Given that the constrained generators all have equivalent costs, the dispatch outcomes are identical for an efficient dispatch (bidding at cost) or a winner takes all dispatch (bidding at MPF). These outcomes are summarised in Table 1 below.[5]

Table 1 Dispatch Costs

	Unit	Efficient dispatch	WTA dispatch
Gen 1	MW	97	97
Gen 2	MW	0	0
Gen 3	MW	100	100
Gen 4	MW	303	303
Dispatch Cost	*$*	*4,540*	*4,540*

Generator 4 is not constrained and is not directly affected by the access models. But the dispatch has an implied priority order for generators. In the efficient dispatch, the order is "312" ie Gen 3 is dispatched first, Gen 1 next and Gen 2 last, with each generator dispatched up to full output in sequence, until the constraint binds.

[5] The analysis used to derive these results is described in more detail in the CMM paper presented to the operational sub-group on 21 July 2022. Note the efficient dispatch and WTA dispatch differs from the CMM paper because the costs of Gen 1, 2 and 3 have been modified to $0/MWh.

The TQM would return an identical dispatch if queue positions happened to be assigned in order of this priority: ie Gen 3 at the front of the queue, Gen 1 in the middle, Gen 2 at the back.

Table 2 calculates dispatch for the six possible queueing permutations.

Table 2 Dispatch costs under different queue permutations

Generator	***Unit***	***Queue Order***						
		123	***132***	***213***	***231***	***312*** ⁺	***321***	***average***
Gen 1	MW	100	100	4	0	97	0	*50*
Gen 2	MW	28	0	100	100	0	73	*50*
Gen 3	MW	0	93	0	10	100	100	*51*
Gen 4	MW	372	307	396	390	303	327	*349*
Cost	*$*	*5580*	*4600*	*5940*	*5850*	*4540*	*4905*	*5236*

(⁺) WTA dispatch, which is also efficient dispatch in this example

Since this paper does not consider the process for assigning queue positions, for the purposes of exposition it is assumed that the queuing order is "random": ie each of the six permutations is equally likely.

The expected dispatch cost is the average of the six dispatches. *For this example*, the expected dispatch cost is higher than the status quo. Every permutation has a dispatch cost higher than the efficient/WTA dispatch.

However, we should not draw general conclusions from this. For example, if the cost of Gen 1 and Gen 3 increased to $5/MWh and $10/MWh respectively, the expected cost would be *lower* than the WTA dispatch, as would be 3 out of the 6 permutations. This sensitivity of outcomes to inputs shows that the question of whether the TQM worsens dispatch efficiency compared with the status quo is not straightforward to answer.

3. How will the TQM affect bidding?

The TQM designers proposed that the model would improve operational efficiency by reducing disorderly bidding. If Gens 1 to 3 each have a different queue number, their bidding is irrelevant so long as their bid is below Gen 4, which sets the RRP. Dispatch is no longer optimising against bids so bidding cost-reflectively does not mean efficient dispatch.

However, in general, some generators behind a constraint are likely to have common queue numbers and dispatch will then choose on the basis of relative bid prices and CFs, as it does today. In these circumstances, bidding at the MPF (for in-merit constrained generators) will be the best and safest bidding strategy, whether at the front or back of the queue. So there is unlikely to be any change in bidding and, even if there were, it would be unlikely to impact dispatch efficiency.

4. How will the TQM affect RRP?

In the example, there is a single, large generator at the RRN which is always at the margin. This has the effect of "locking" RRP at its bid ($15) irrespective of the dispatch of generators behind the constraint. This is for the sake of simplicity. If we want to examine RRP impacts, we need to include multiple generators with different bid prices at the RRP: eg

- Gen 4A: offering 350MW @ $15
- Gen 4B: offering 30MW @ $100
- Gen 4C: offering 100MW @ $1000

If these three generators replace Gen 4 in our example, RRP will vary depending upon the queue order. This is summarised in

Table 3 below. Note that the total output of these three generators is the same as the output of Gen 4 in Table 2. RRP is set by the offer price of the marginal generator at the RRN: ie the one that is partly loaded.

Table 3 Dispatch and RRP with multiple RRN generators

RRN Generation Mix			**RRN Generation Dispatch**					
Gen	**Capacity**	**Cost**	**123**	**132**	**213**	**231**	**312** +	**321**
Gen 4A	350	$15	350	307	350	350	303	327
Gen 4B	30	$100	22	0	30	30	0	0
Gen 4C	100	$1000	0	0	16	10	0	0
Total	*480*		*372*	*307*	*396*	*390*	*303*	*327*
RRP			*$100*	*$15*	*$1000*	*$1000*	*$15*	*$15*

(+) WTA dispatch (also efficient dispatch in this example)

It is seen that the WTA – among others – gives the lowest RRP outcome. This will generally be the case where there is a single constraint in a single region and several generators are unconstrained. The ordering under WTA – by ascending order of contribution factor – is the way to maximise the aggregate of the constrained generators, thus minimising the aggregate output of the unconstrained generators and so RRP.

The CEIG submission recognises the potential impact on RRP and proposes that:

> "NEMDE should only curtail generators in order of the queue to the point where it would require changing the marginal generator. If using the queue to resolve a constraint would result in increasing the cost of the RRP, then we propose that NEMDE revert to the use of contribution factors to resolve a binding constraint."

Looking at table 3 it is seen that this provision would be triggered under three out of the six queue permutations: 123, 213 and 231. In general, the more different the queue ordering is from the WTA dispatch order, the more likely that RRP will be impacted and the CEIG provision triggered.

5. Implementing TQM in dispatch

The CEIG submission describes a method for implementing the TQM dispatch as follows:

> "NEMDE should first determine the bid-stack by assessing all MLF weighted bids to determine the least cost generation mix to meet demand in a given five-minute interval. Next, where there are binding constraints within the NEM that NEMDE must resolve, NEMDE should curtail generators in descending order of the queue."

One can see how this could work in our simple example. The "least cost generation mix" would involve dispatching Gens 1-3 at their full output, with Gen 4 contributing the remainder. Since this would violate the constraint, generators would then be curtailed in reverse queue order: eg under a 123 permutation, Gen 3 would be fully curtailed and then Gen 2 partially curtailed, with Gen 4 dispatch increasing to offset the curtailed generation. This gives the dispatch shown in table 2, above.

However, it is not clear that this approach can be generalised to a situation of multiple binding constraints and regions. For example, in the 123 dispatch above, Gen 2 might plausibly contribute to a *second* binding constraint in which no queue position 3 generators participate. If Gen 2 has to be curtailed anyway to manage this second constraint it might then be unnecessary to also curtail Gen 3 in the original constraint.

The ESB is considering instead using the reverse approach: dispatching generators at the front of the queue first, and then progressively adding lower priority generators to the dispatch until the constraint is binding. In the two-constraint example above, this would mean:

- Firstly dispatching Gen 1 to full output, which can be done with no constraint violations;
- Next dispatching Gen 2 until the second constraint binds
- Then dispatching Gen 3 until the original constraint binds

Under this approach, each dispatch is a complete, feasible dispatch, calculated using the dispatch algorithm. If there are N queue positions, then N runs of the dispatch algorithm will be required to calculate the TQM dispatch. If the CRM is added, one further run of the dispatch algorithm will be needed to clear this market.

This approach does not address or resolve the CEIG's proposal to unwind the TQM prioritisation if it leads to higher RRP than the status quo. In principle, another, WTA dispatch could be run and the RRPs compared, with WTA dispatch selected if it gives rise to lower RRPs. However, this approach would not identify possibly hybrid dispatches, which follow the TQM prioritisation to some extent whilst still avoiding RRP increases. Finding such hybrid dispatches would appear to be difficult.

6. Conclusions

The relative cost of the TQM dispatch compared to status quo (WTA) is unclear. If the queue positions are essentially "random" in the operational timescale, TQM dispatch could be cheaper or dearer than the status quo, depending upon how efficient, or inefficient, the status quo is.

An objective of the ESB's access reform is to improve dispatch efficiency; bringing it closer to an idealised optimal efficiency by encouraging generators to bid cost-reflectively even when constrained. The TQM will not achieve this unless, by fortunate coincidence, the queue order happens to align with efficient dispatch.

On the other hand, the CMM and CRM *are* expected to improve dispatch efficiency, through an LMP secondary market re-allocating access to those generators that value it most. So a fourth option, a TQM-CRM model which integrates the TQM with the CRM, could similarly lead to improved dispatch efficiency.

The TQM dispatch could, in some cases, give rise to higher RRPs than the status quo dispatch, other things being equal. If the CEIG's proposed approach is adopted, of reverting to WTA dispatch in these situations, this might reduce the value and certainty that is provided to generators at the front of the queue.

The CEIG's proposed approach, of dispatching all generators and then curtailing generators at the back of the queue to remove constraint violations, seems unlikely to be workable in the general situation of multiple regions and binding constraints. But an alternative approach of dispatching generators at the front of the queue first seems to be feasible, although it would require multiple runs of the dispatch algorithm.