Energy Market Company

Regulation Study

A Market Clearing Study of the NEMS

By

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About the Author

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Lu Feiyu joined Energy Market Company, the market operator for the National Electricity Market of Singapore, as a Market Analyst in March 2002. His primary responsibilities are the daily operation of the market and review of its outcome, dissemination of market information and in-house application development. Feiyu is also one of the company's pioneers in conducting local and international training and educational forums about the market clearing engine, specifically its formulations, pricing methodology and system enhancements. He is actively involved in enhancing the market system by identifying gaps between business processes and the market system, suggesting improvements and preparing and performing user acceptance tests. He also contributes to the market rule change process through technical reviews of the proposed changes.

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1.0 Introduction

On 4 June 2005, a price spike ($2,299.95/MWh) was observed in the regulation market in Period 14 (06:30–07:00). A detailed investigation revealed that a high price was set by a generator's regulation offer. The regulation supply suddenly became tight in this period because one of the generating units was disqualified from the pool of regulation providers, which resulted in a loss of 13MW of regulation. As the regulation market demand is constantly set at 100MW, the loss of 13% of the supply was immediately signalled by the rocketing regulation price.

This was not the first time a price spike was observed in the regulation market and neither will it be the last. Among the three products that are traded in the National Electricity Market of Singapore (NEMS), namely energy, reserve[1], and regulation, the regulation market is seen as the most volatile.

Before we find the root cause of such volatility, first we must better understand what regulation is and how it works in the NEMS. This is the primary goal of this paper.

[1] The reserve market comprises three classes – primary reserve, secondary reserve and contingency reserve – according to their respective response time.

2.0 Background

2.1 What is regulation?

Regulation or load-following is a type of ancillary service that is required to cover real-time variations in load from the load forecast. It is sometimes referred to as a frequency-keeping service.

Regulation is a stand-by service, and generators that are dispatched to provide this service are paid for providing this buffer. In addition, they also receive the energy price for any electricity that they produce if they are called upon to provide more energy as a result of an imbalance between demand and supply. However, depending on the prices for energy and regulation, they may lose out if they end up providing less energy.

2.2 How much regulation is required?

The regulation market has a constant requirement of 100MW in each half hour, a requirement that is set by the Power System Operator (PSO). Based on the latest System Operation Manual, published in 2006, the difference between forecasted and actual system demand for every dispatch period of the preceding year will be examined by the PSO by the following January to determine the regulation requirement for the current year. This means that the regulation requirement might change from year to year. Looking forward, EMC and the PSO are contemplating a period-based dynamic regulation requirement model, which might yield more accurate results.

2.3 Who can provide regulation and how much?

Although the requirement for regulation does not seem to be large, the supply is limited and restricted by a number of factors. Generators are the only providers of regulation. Their ability to supply the regulation ranges from 8MW to 22MW, based on the registration data of their equipment. In addition, to qualify for regulation provision, they must operate within the regulation band [RegMin, RegMax]. It is only within this band that the generation can be controlled by the Automatic Generation Control (AGC) system of the PSO, i.e., to be dispatched regulation. Mathematically speaking, three conditions have to be met, before a regulation offer can be included in the dispatch schedule:

$$\begin{cases} \sum_{i=1}^{5} regulationOffer_i > 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1) \\ \sum_{j=1}^{10} energyOffer_j \geq regulationMin \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2) \\ regulationMin \leq InitialMW \leq regulationMax \ldots (3) \end{cases}$$

In other words, the generator must have a valid, i.e., non-zero regulation offer, an energy offer that allows the generation to enter into the regulation band and a satisfactory initial generation level, which is within the regulation band. This last condition is the most tricky as the value of InitialMW is not known to the generator. Due to these strict requirements (to reflect the technical capabilities of the generators) and the dynamic aspect of the power system, the prices of regulation often fluctuate.

2.4 Who bears the cost of regulation?

The cost of regulation in the NEMS is shared by both the consumers and the generators. The consumer is liable for the full amount of energy withdrawal, while the generator bears the regulation cost for up to 10MW of its output.

3.0 Causes of Regulation Price Spikes

As discussed, all three conditions must be met before the regulation offer can be utilised by the MCE. Any failure of the three conditions excludes the regulation offer from the pool, and sometimes this exclusion happens without being noticed by the market players. Following, we will examine the possible exclusion scenarios individually.

3.1 Genco withdraws regulation offer

When a genco withdraws its regulation offer, it obviously tightens the supply pool in the regulation market. Under certain conditions (such as the supply is already tight), a price spike may be inevitable. Although not frequently observed in the NEMS, offer withdrawals have sometimes resulted in rocketing regulation prices.

3.2 Genco reduces energy offer quantity during ramping down

A genco normally brings down its equipment by gradually reducing its energy offer quantity. The reduction in the energy offer quantity, if lower than the RegMin, will result in disqualification of the regulation offer. This is often observed in the transition from peak to off-peak periods when the units are ramping down.

3.3 Unit initial generation level below Reg_Min or above Reg_Max

The third condition in the regulation qualification exercise is the initial generation level (referred to as InitialMW in the MCE). Since the actual initial generation level at the period start is not available at the run kick-off time (which is five minutes before the period start), the best approximation is the network status scan at ten minutes before the period start. If the energy output from the unit is then below its RegMin (which happens more often during low-load periods) or above its RegMax (which happens more often during high-load periods), its regulation offer will be disqualified.

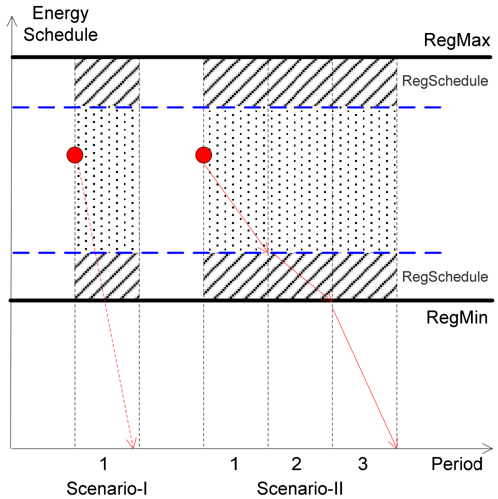
This dynamic aspect poses some uncertainty to the market participant and sometimes results in price spikes. Therefore, the available regulation offers may change drastically from one period to another.

4.0 Impacts of Regulation Constraint

We have discussed how a regulation offer can be disqualified by not meeting one of the three conditions, whether deliberately or not. In this section, we'll look at how a qualified regulation offer can affect the generating unit.

Once the generating unit is qualified for regulation provision, i.e., the three conditions are met, its energy schedule must remain within the band of [RegMin, RegMax]. If its regulation offer is cleared, its energy schedule may have even a smaller band (shaded in the Figure 1 below). This is referred to as the regulation constraint.

Figure 1: Regulation Constraint



If the generating unit is cleared for regulation, it's easier for the generator to understand why the energy schedule cannot go beyond the range of [(RegMin + RegSchedule), (RegMax - RegSchedule)]. However, if the unit has 'no regulation schedule' but its energy schedule is constrained at either RegMin or RegMax, it may be a bit confusing. Most of the time, this is because the unit is still offering regulation that has not cleared for some reason, e.g., it is more expensive than the marginal price. For the MCE, as long as the unit has a valid regulation offer (and fulfils the other two conditions), the regulation constraint is in place. In the case where the unit is cleared zero MW for regulation, though this is perceived as 'no regulation schedule', the unit energy schedule will still be constrained at RegMin.

If the regulation constraint is not handled properly by the market participant, it might impact on the operation of the generating unit and/or market prices, as elaborated below.

4.1 Delayed ramping process

Let's look at the normal ramping-down process of a generator, as represented by Scenario-I in Figure 1. The generator can ramp down completely within a single period, i.e., 30 minutes. However, if the generator is cleared for regulation, its ramping-down process may take three periods, as represented by Scenario-II.

- Period 1: The generator ramps down to (RegMin + RegSchedule).
- Period 2: The generator ramps down to RegMin.
- Period 3: The generator ramps down completely.

Of course, the exact process depends on what strategy the generator uses to ramp down its generating unit. If the generator reduced its energy offer quantity to zero, it would be able to ramp down completely within a single period, because the zero MW energy offer would break the second condition of the regulation constraint checks. However, if the generator increases its energy offer price, it might be stuck at (RegMin + ClearedReg) for more than one period (for example, when the regulation supply is tight), which extends its ramp-down process for even longer than three periods.

If a generator wants to remove the regulation constraint so that it would not suffer from being a price taker, it could try to violate any of the criteria listed above. However, the easiest way would be to withdraw its regulation offer since the generator has no control of its InitialMW, which is a snapshot of the SCADA system, and normally doesn't want to offer less than its RegMin.

4.2 Out of merit order dispatch

When the regulation constraint is binding the generator may become a price taker in the energy market, because the regulation constraint is a hard constraint that cannot be broken (or, to be precise, the cost of breaking such a constraint is too high to be feasible, at 20 * VoLL[2]).

For example, a genco queried EMC about the real-time dispatch in Period 16 on 21 August 2005. The results of this dispatch run (DPR) were as follows:

- USEP = $85.88/MWh
- Primary reserve = $6.10/MWh
- Secondary reserve = $0.02/MWh
- Contingency reserve = $10.63/MWh
- Regulation = $2,749.94/MWh

The genco claimed an over-dispatch of energy for some of its generating units. The generating unit in question received an MNN price and dispatch schedule as below:

MNN Price (MWh)	Dispatch (MW)				
	Energy	Primary Reserve	Secondary Reserve	Contingency Reserve	Regulation
$85.63	190	33	33	33	10

The energy offer (and dispatch) from this generating unit are detailed in the table below:

Energy Offer	Offer Quantity (MW)	Offer Price (MWh)	Cleared Quantity (MW)
Block 1	185	-$14	185
Block 2	95	$86	5

Since the unit was dispatched 190MW, it expected to receive a clearing price no less than its offered price ($86/MWh). However, the MNN price at its injection node was only $85.63/MWh. The genco therefore sought an explanation from EMC.

An investigation revealed that the regulation constraint was the culprit in this case. The particular generating unit had a RegMin of 180MW, while it received a regulation dispatch of 10MW. Since regulation was highly sought after in that period, as indicated by the soaring regulation price ($2,749.94/MWh), all of the regulation offers from the unit (10MW) had been cleared. In order to avail this amount of regulation, the unit's energy was dispatched at [RegMin + Regulation Dispatch], i.e., 190MW [180MW + 10MW]. This turned on its regulation constraint.

Although the offered price at 190MW was $86/MWh, the unit could not set the marginal price because of its regulation constraint. Instead, it became a price taker and accepted a lower marginal price of $85.63/MWh. However, the generating unit was not at a loss, because its gain in the regulation market would have compensated for its loss in the energy market.[3]

[2] VoLL: Value of Lost Load, which is set at $5,000/MWh in NEMS.

[3] A more detailed explanation can be found in the paper originally published by Lu Feiyu in January 2005, *Out Of Merit Order Dispatch*.

5.0 Conclusion

Although the regulation market has a constant demand (100MW), the regulation price fluctuates more than the prices for energy and reserve. Due to the limited regulation capacity of the generators and the dynamic nature of the physical power system, the regulation price might skyrocket from time to time. A good understanding of the design features of the regulation market helps the market participants to make proper decisions in cases where their generating units are bound by the regulation constraint.

Glossary

AGC, Automatic Generation Control
A subsystem in the EMS through which the PSO dispatches the generating units in real time.

DPR, dispatch run
The real-time dispatch as defined in the Market Rules.

EMC, Energy Market Company
The market operator of the NEMS.

EMS, Energy Management System
The system that provides real-time monitoring and control of the power grid, as well as supporting the operation of the NEMS.

Genco, generation company
A company that generates electricity.

MCE, market clearing engine
The software used in the NEMS to discover dispatch schedules and prices.

NEMS, National Electricity Market of Singapore
The Singapore electricity market.

price maker
The generating unit that makes or sets the price; also called the marginal set. In contrast to a price maker, all other generating units are price takers that take the price of the price maker or marginal set.

price taker

The generating unit that takes the price of the marginal set.

PSO, Power System Operator
The system operator of Singapore's power grid.

RegMin
The minimum energy output at which the generating unit can respond to the AGC.

RegMax
The maximum energy output at which the generating unit can respond to the AGC.

SCADA, supervisory control and data acquisition
A core subsystem in the EMS that monitors the status of the grid, provides real-time data to other subsystems and controls the grid components.