the marketplace company

Report for

The WESM Project Manager

ISSUE PAPER

ERC Regulatory Filings

Marginal Pricing

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1. INTRODUCTION

M-co retained as Project Manager

M-co has been retained by TRANSCO to assist the WESM Project Manager of the market operations division with the implementation of a wholesale electricity spot market (WESM) for the Philippines. As part of this assignment M-co has been requested to provide input to WESM's response to the Energy Regulatory Commission initial determination on the proposed Price Determination Methodology (PDM).

Purpose

The purpose of this paper is to clarify the definition of marginal pricing and demonstrate numerically how energy prices are calculated in accordance with WESM rules 3.10.2 and 3.10.6

ERC Case No 2003-356

The document used as a basis for this review is:

- ERC Case Number 2003-356 – PDM Submission

Project Deliverables

This report is part of deliverable 11.3 **Activity 11 Additional Optional Services** of Appendix A of the Contract, and covers the following sub-tasks specified under Appendix B: Staffing Schedule:

11.3 Provide Report on PDM

- Advise and Review on PDM

2. Background

Background	ERC have requested WESM to provide various additional information and further filings in support of the original filing of the Price Determination Methodology. This is summarised in the ERC Directives document provided by WESM to M-co. WESM have requested M-co's assistance in preparing some of this material.
Summary	This paper clarifies the definition of marginal pricing and demonstrates numerically how energy prices are calculated as per WESM rules 3.10.2 and 3.10.6
ERC Concerns	There is a need to define marginal pricing as applied in the submission. Specifically, to define whether basis used in the Market Dispatch Optimisation Model (MDOM) is the price of the last increment of energy actually dispatched or the next increment to be dispatched.
ERC Directives	The Market Operator has been requested to submit a paper clarifying the definition of Marginal Pricing as used in the PDM submission to determine whether the Market Operator has indeed adopted the economic principle of marginal pricing or some other form of pricing.
WESM Response	The Market Operator is to make a presentation to ERC on the concepts of marginal pricing. M-co has been requested to provide additional study material and advice in support of this presentation.

3. Analysis

Key Issues

This study covers the following issues:

- Clarification of the definition of shadow price and its economic implications,
- Analysis on the difference in pricing between that based on the next unit and that based on the last unit,
- Clarification of the difference between shadow price (as used by WESM) and the Long Run Avoidable Cost (LRAC) of the Best New Entrant (as proposed by NPC and PSALM in the joint regulatory filing on generation rates of May 2003), and
- Use of numerical examples to demonstrate the calculation of energy price as the shadow price of the nodal energy balance equation.

Definition of marginal pricing

Marginal costs are a critical factor in the economic theory of competitive markets. The assumption of a price-based auction is that competitive pressures will force parties to offer at close to their marginal cost of production. Marginal cost pricing occurs when generators offer to supply electricity based on their marginal cost of production and the marginal generation unit required to meet demand sets the market clearing price which all suppliers receive.

Stoft's Power System Economics (2002) reviews the definition of marginal cost pricing (page 65)

> The *MIT Dictionary of Market Economics* (1992) defines marginal cost as "the extra cost of producing an extra unit of output." Paul Samuelson (1973, 451) defines marginal cost more cautiously as the "cost of producing one extra unit more (or less)." The "or less" is important. The assumption behind this definition is that producing one more unit of output would cost exactly as much as producing one less unit would save. This is true for the continuous marginal-cost curves of textbook economics but not for the discontinuous curves used by power market analysts.

Stoft further defines the following terms (page 67):

- Left-hand marginal cost as the savings from producing one less unit of output
- Right-hand marginal cost as the cost of producing one more unit of output. When this is not possible the right-hand marginal cost equals infinity
- The marginal-cost range as the set of values between and including left-hand marginal cost and right-hand marginal cost.

Stoft then suggests that a competitive producer sets output to a level at which its marginal-cost range contains the market price (page 67).

Shadow price

WESM Rules 3.10.2 and 3.10.6 state that the nodal energy price for each market trading node shall be determined as the shadow price on the energy balance equation for that market trading node.

The shadow price is defined in the WESM Rules as:

> **Shadow Price** *means the marginal net benefit from a unit relaxation of the capacity limitation of a constraint in the market optimization model.*

Put another way, the shadow price for a constraint in the LP problem is the amount of change in the objective function as a result of relaxation of that constraint by 1 unit. Since constraints are often determined by resources, a comparison of the shadow price of each constraint provides valuable insights into the most effective way to apply additional resources in order to achieve the best improvement in the value of the objective function. Therefore, marginal value is not the same as the last unit of the decision variable.

In the case that the constraint is a “less than or equal to” constraint, the calculation is based on increasing the value of that constraint by one unit. Conversely, in the case that the constraint is a “greater than or equal to” constraint, the calculation is based on decreasing the value of that constraint by one unit. In the case that the constraint is an “equal to”, as the nodal energy balance equation constraint in the WESM Rule, the convention is to calculate the cost of supplying the next unit [e.g., as applied in PJM and IMO).

This approach is adopted widely in the power sector. For example Stoft (2002 pages 452-453) defines the shadow price of a constraint as:

> "The reduction in cost that would result from a small relaxation of that constraint. For example, if a 1 kW increase in the flow limit of a power line would reduce the cost of delivered power by 3¢/h by allowing more use of a cheap remote generator, then the shadow price of the line is 3¢/h, or $30/MWh. If a line is not congested, the shadow price is zero because the line constraint is not binding."

Marginal pricing in other jurisdictions

Nodal pricing, also known as locational marginal pricing (LMP) is used in many electricity markets around the world. Applying the shadow pricing principle, the LMP for energy at a node is defined (e.g. by PJM) as:

> "The marginal cost of supplying the next increment of electric demand at a specific location (node) on the electric power network, taking account of generation marginal cost and the physical aspects of the transmission system. "

IMO also adopted the same LMP method, stating that:

> "Each LMP reflects the incremental cost of re-dispatching the system to supply one more megawatt of load at a given location. Thus, LMP provides a precise, market-based method for pricing any re-dispatch required to relieve congestion."

Energy price for WESM

WESM Rules 3.10.2 and 3.10.6 state that the energy price at a market network node is the shadow price on the nodal energy balance equation for that market network node. The energy price thus determined has the following 4 components:

- generation marginal cost
- transmission losses
- congestion
- reserve cost

The congestion component of the energy price is zero where the transmission is free of congestion when serving the extra unit of demand at that market network node. That is the line flow constraint is not binding.

Likewise, the reserve cost component of the energy price is zero where the reserve requirement associated with serving the extra unit of demand at that market network node is the same as that associated with the demand level without adding one extra unit. That is the relevant reserve requirement constraint is not binding.

Where a line flow constraint or a reserve requirement constraint is binding, the least cost generation or least cost reserve cannot be dispatched. As a result, price separation occurs.

4. Clarification between Shadow price and the LRAC

LRAC

The NPC/PSALM joint filing states that the LRAC methodology promotes efficiency in capital cost management while ensuring that the electricity industry remains viable for the longer term. Key points of the proposed regime include:

- The revenue requirements for each region will be based on the LRAC of the Best New Entrant (BNE) reflecting the lowest total cost of an efficient new entrant generating plant in the Philippines.
- This concept diverges from the existing return-on-rate-base arte setting methodology that is based on historical costs and a return on rate base.
- The regional LRAC will be based on a generation plant of 400 MW in Luzon, 100 MW in Mindanao and the larger Visayas regions (Leyte, Cebu, Negros) and 50 MW in Panay and Bohol.
- The regional LRAC will be built up from 19 variable inputs, including exchange rate, capital cost of the most economic new plant, economic life time of the BNE, average generation level as a percentage of capacity, fixed annual running cost of the BNE, variable non-fuel cost of the BNE, proportion of debt to assets, interest rate, tax rate, cash return on equity.

Shadow price vs LRAC

The fundamental differences between the shadow price set out in the WESM Rules and the LRAC proposed by NPC/PSALM are as follows:

	Shadow price in WESM	LRAC by NPC/PSALM
Purpose	Determination of spot prices	Setting regulated tariff
Composition	Short run marginal generation cost of the marginal generation unit that is dispatched in real time, transmission losses, congestion cost, reserve cost	The long term avoidable cost of BNE for a pre-selected plant, and not including congestion cost and reserve cost
Pricing signal and economic interpretation	Short term marginal cost to the entire system in real time, or the incremental cost of re-dispatching the system to supply one more megawatt of load at a given location (Shadow price)	Long run avoidable cost representing the most efficient generation for new entrant, which may or may not be an existing technology
Methodology	Market mechanism, based on bids and offers from WESM participants and applicable grid configuration and PDM	Cost accounting as set out in the joint NPC/PSALM filing.
Overseas experience	Used as settlement price for the spot market (e.g., NZ, Singapore, PJM, etc	Used as the vesting price for the vested quantity in vesting contract arrangements (e.g. Singapore, Korea, Australia)

5. Examples

Assumptions

The numerical examples shown in the following examples are based on the following common assumptions

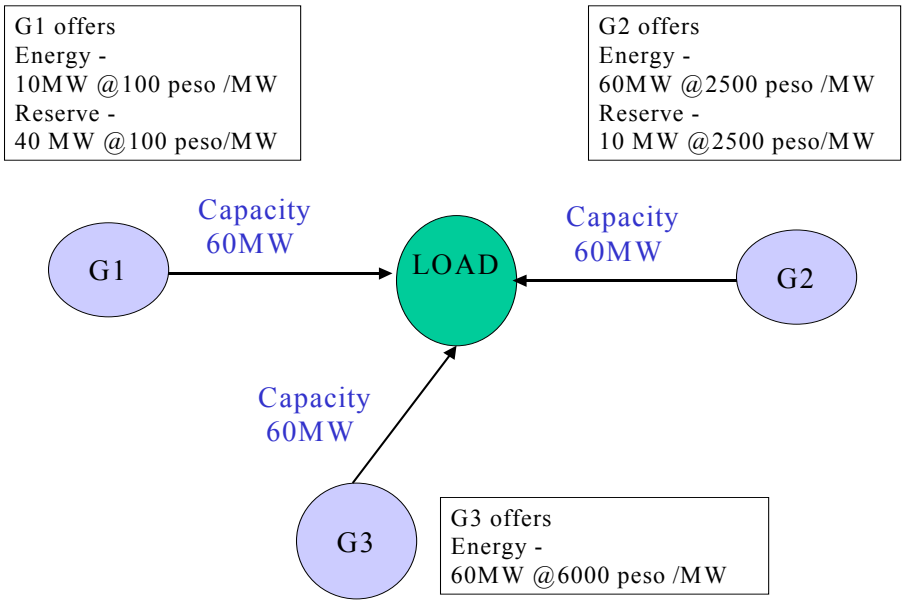
- Lossless transmission
- N-1 security for reserve requirement (largest dispatched generator sets the reserve requirement)
- Load 50 MW
- Three generators, G1, G2 and G3. The table below shows their energy and reserve.
- Transmission capacity 60MW for G1-Load, G2-Load and G3-Load.
- The objective of the dispatch engine – minimizing total cost of delivered energy through co-optimization of energy and reserve

	Energy offer		Reserve offer	
	Quantity (MW)	Price (peso)	Quantity (MW)	Price (peso)
G1	10	100	40	100
G2	60	2500	10	2500
G3	60	6000		

Example 1

The base case is shown in the figure below.

Base case - no transmission congestion



The least cost dispatch schedule for meeting 50MWh load is 105,000 peso, with the following dispatch schedule

- Energy: 10 MWh from G1 at 100 peso/MWh and 40MWh from G2 at 2,500 peso/MWh
- Reserve: 40 MWh from G1 at 100 peso/MWh.

The least cost dispatch schedule for meeting 51 MWh load is 110,000 peso, with the following dispatch schedule.

- Energy: 10 MWh from G1 at 100 peso/MWh and 41MWh from G2 at 2500 peso/MWh
- Reserve: 40 MWh from G1 at 100 peso/MWh and 1 MWh at 2,500 peso/MWh

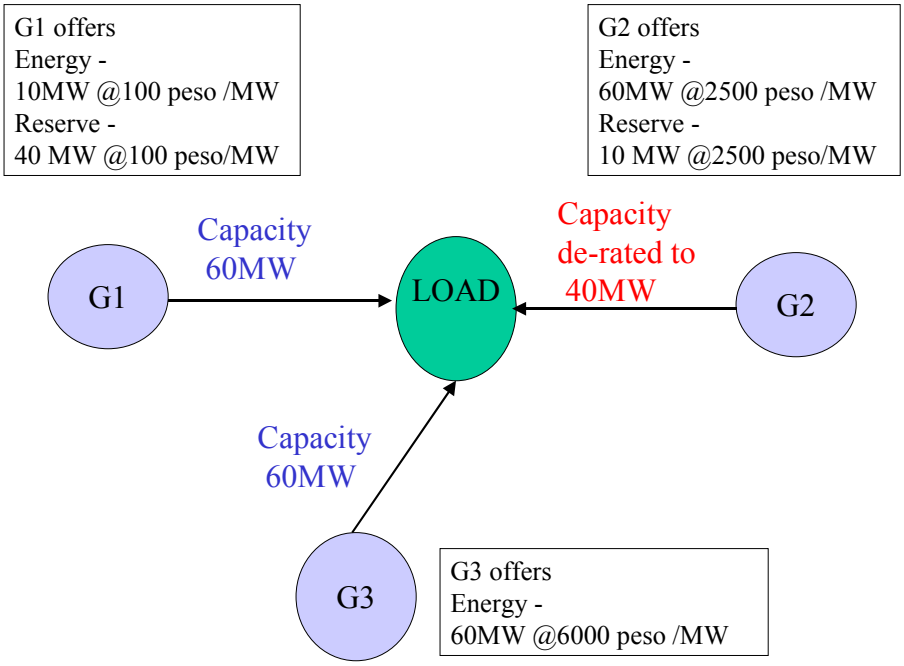
The energy price for the 50 MWh load is 5,000 peso/MWh, calculated as the difference between the total delivered cost for 51 MWh and that for 50 MWh. The price compromises the marginal generation cost of 2,500 peso/MWh and marginal reserve cost of 2,500 peso/MWh.

To demonstrate the effect of demand side response in real tome, it is assumed that the above is the ex ante price based on the ex ante load forecast and that the consumers reduce their load by 1 MWh down to 49 MWh. The ex post energy price is 2,600 peso/MWh, compromising the marginal generation cost of 2,500 peso/MWh and the marginal reserve cost of 100 peso/MWh, and a 2,400peso drop from the ex ante price.

Example 2

Scenario with : transmission congestion

In this example it is further assumed that the transmission capacity for G2-Load is de-rated to 40 MW as shown in the figure below:



The least cost dispatch schedule for meeting the 50MWh load remains at 105,000 pesos, with the following dispatch schedule

- Energy: 10 MWh from G1 at 100 Pesos/MWh and 40MWh from G2 at 2500 Pesos/MWh
- Reserve: 40 MWh from G1 at 100 Pesos/MWh.

However, to meet the 51 MWh load, G3 will be required to generate 1 MW to meet the 51st MW, because the transmission capacity for G2-Load is fully utilised and constrained. The least cost dispatch schedule for meeting 51 MWh load is 111,000 peso, with the following dispatch schedule.

- Energy: 10 MWh from G1 at 100 Pesos/MWh, 40MWh from G2, and 1 MWh from G3 at 6,000 Pesos/MWh
- Reserve: 40 MWh from G1 at 100 Pesos/MWh

The energy price for 50 MWh load is 6,000 peso/MWh, calculated as the difference between the total delivered cost for 51 MWh and that for 50 MWh. The price reflects marginal generation cost of 6,000 peso/MWh.

NB Marginal reserve price is 0 peso/MWh as there is no change in reserve cost for dispatch of 51st MWh.