Philippine Electricity Market Corporation

STUDY ON LUZON HYDROELECTRIC POWER PLANTS

by the Technical Committee

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Philippine Electricity Market Corporation

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LIST OF ACRONYMS

ASPA	Ancillary Service Procurement Agreement
ASPP	Ancillary Service Procurement Plan
BS	Black Start
CBK	Caliraya-Botocan-Kalayaan Power Company Ltd.
CR	Contingency Reserve
DOE	Department of Energy
DR	Dispatchable Reserve
ERC	Energy Regulatory Commission
FGHPC	First Gen Hydro Power Corporation
HEPP	Hydroelectric Power Plant
IDR	Irrigation Diversion Requirement
IPP	Independent Power Producers
LHC	Luzon Hydro Corporation
MAG	Market Assessment Group
MARIIS	Magat River Integrated Irrigation System
MOR	Must-Offer Rule
MSC	Market Surveillance Committee
MWSS	Manila Waterworks and Sewerage System
NGCP	National Grid Corporation of the Philippines
NIA	National Irrigation Administration
NPC	National Power Corporation
NWRB	National Water Resources Board
PAGASA-DOST	Philippine Atmospheric, Geophysical and Astronomical Services Administration – Department of Science and Technology
PGC	Philippine Grid Code
PSALM	Power Sector Assets & Liabilities Management
RPS	Reactive Power Support
RR	Regulating Reserve
SNAP	SN Aboitiz Power, Inc.
SO	System Operator
SPDC	Strategic Power Development Corporation
SRPC	San Roque Power Corp.
TP	Trading Participant
TC	Technical Committee
UPRIIS	Upper Pampanga River Integrated Irrigation System
VSNRGC	Vivant Sta. Clara Northern Renewables Generation Corporation
WESM	Wholesale Electricity Spot Market

1. INTRODUCTION

The Technical Committee (TC) is mandated under Clause 1.7.2 of the WESM Rules to (a) monitor technical matters relating to the operation of the spot market; and (b) provide a report to the PEM Board on any matter of a technical nature relating to any WESM member which in the reasonable opinion of the TC, causes (i) the WESM Participant to be unable to comply with the WESM Rules; or (ii) unintended or distortionary effect to the operation of the WESM.

Further, Section 4 of the Technical Committee Market Manual (TCMM) provides that the TC shall conduct technical reviews and studies in relation to (a) power plant technical parameters; and (e) matters of technical nature that led to non-compliance of any WESM participant, and/ or distortionary effects to the WESM operation.

The TC is currently composed of five (5) members, namely, Prof. Jordan Rel C. Orillaza and Engr. William C. Alcantara as Independent Members; Engr. Jaime V. Mendoza, Distribution Management Committee (DMC) Representative; Engr. Joseph Allan C. Baltazar Grid Management Committee (GMC) Representative; and Engr. Santiago A. Dimaliwat IV, Systems Operator (SO) Representative.

This report is prepared by the TC with the assistance of the Market Assessment Group[1] (MAG) of the Philippine Electricity Market Corporation.

1.1. BACKGROUND

The Market Surveillance Committee (MSC) submitted to the Technical Committee (TC) a request for technical study dated 14 December 2011. The request was for the TC to conduct a study that will assist the MSC in assessing the validity of technical reasons cited by trading participants (TP) in explaining the capacity gap of their hydroelectric power plants. Capacity gap refers to the difference between the registered capacity less outage capacity less offered capacity, calculated for each generator.

In the course of the MSC's monitoring of TPs' compliances with the must-offer-rule (MOR), TPs with hydroelectric facilities frequently cited water availability and irrigation diversion requirement (IDR) as reasons for the TP's non-compliance to the MOR.

The request was included in the TC 2012 Work Plan and was undertaken beginning the first quarter. On 10 January 2012, an agreement was made to invite representatives of the National Water Resources Board (NWRB) for a presentation on (a) process of establishing rule curves; (b) procedures and policies in the allocation of water; and (c) configuration of hydroelectric power plants. The invitation was coursed through the Department of Energy (DOE).

Discussion on the Water Level Monitoring Process was held on 15 February 2012 with the National Grid Corporation of the Philippines – System Operator (NGCP-SO), DOE and TC.

On 23 May 2012, an initial meeting between the DOE and NWRB together with the Market Assessment Group (MAG) was conducted to discuss the hydroelectric power plants' water requirements.

[1] The MAG acts as the Technical and Administrative Secretariat of the TC

On various TC meetings during the 2nd, 3rd and 4th quarter of 2012, the TC discussed and identified the data which are deemed useful for the MSC and MAG's monitoring and assessment of water level elevation and reservoir operations of the hydroelectric power plants.

On 25 March 2013, the DOE invited the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) for a joint meeting together with the TC and MAG to seek additional information and procedures on how the latter monitors hourly water elevation.

To gather additional information, the TC invited the TPs with hydroelectric power plants in Luzon and each plant operator for a meeting and presentation as regards the operation of the power plants on 11 & 23 July and 01 August 2013.

Following the meeting with the TPs and plant operators, the TC invited the National Irrigation Administration (NIA) for a meeting on 07 November 2013 to further validate the information received from the presentations of the plant operators and to discuss NIA's protocol/ procedure relevant to the TC study.

1.2. OBJECTIVE

The objective of this report is to present details regarding the operation of Luzon hydroelectric power plants and to highlight the factors that may affect the ability of hydroelectric power plants to generate and offer its maximum available capacity in compliance with the Must-Offer Rule.[2]

It also incorporates the recommendations of the TC in addressing the issue of validating the explanations provided by TPs in their responses to the MSC's inquiry to their alleged failure to offer their maximum available capacity to the energy market.

1.3. SCOPE AND LIMITATION

The study conducted was focused and limited to the hydroelectric power plants that have frequent discrepancies between their maximum available capacity and the actual capacity they offer in the WESM.

Specifically, the Report covers the study conducted by the TC on the twelve (12) hydroelectric power plants in Luzon grid as follows: Angat HEPP, San Roque Multipurpose HEPP, Pantabangan HEPP, Masiway HEPP, Magat HEPP, Binga HEPP, Ambuklao HEPP, Bakun HEPP, HEDCOR mini-hydro, Caliraya HEPP (w/ Botocan HEPP), Kalayaan Pumped Storage Plant and Casecnan HEPP.

[2] Section 3.5.5 of the WESM Rules, as amended, requires all scheduled generation companies to offer their maximum available capacity in the WESM.

Available data were taken from the period covering the billing months beginning 26 December 2011 – 25 July 2013.

1.4. DEFINITION OF TERMS

Maximum Available Capacity - is equal to the registered maximum capacity (Pmax) of the (aggregate) unit less forced unit outages, scheduled unit outages, de-rated capacity due to technical constraints which include plant equipment-related failure and ambient temperature, hydro constraints which pertains to limitation on the water elevation/turbine discharge and MW output of the plant and geothermal constraints which pertain to capacity limitation due to steam quality (chemical composition, condensible and non-condensible gases), steam pressure and temperature variation, well blockage and limitation on steam and brine collection and disposal system.[3]

Registered Capacity - refers to the prevailing Maximum Stable Load or Pmax and the Minimum Stable Load or Pmin of a generating unit or aggregate generating units as registered with the Market Operator or subsequent changes confirmed and implemented by the Market Operator. The Pmax shall be the registered maximum capacity while the Pmin shall be the minimum registered capacity.[4]

2. AN OVERVIEW OF HYDROELECTRIC POWER PLANTS IN LUZON

2.1. Power Plant Profile and Specification[5]

As of 11 October 2013, there are 12 major hydroelectric power plants in Luzon which comprises about 20% of the total registered capacity in Luzon. Table 1 shows the plant profile and specification, including the maximum registered capacity, number of units (including auxiliary if available), plant location, plant operator and its trader, plant type and purpose of each power plant.

[3] WESM Dispatch Protocol Manual, Issue 8.0, 29 August 2013

[4] WESM Manual on Registration, Suspension and De-Registration Criteria and Procedures, Issue 1, 24 January 2012

[5] Data were based on the plant operator's presentations and *WESM Generators Registered Capacities as of 11 October 2013*.

Table 1. Luzon HEPP Profile and Specification

HEPP	Registered Capacity (Pmax)	No. of Units	Location	Trading Participant	Plant Operator	Water Source	Plant Type	Purpose
1. Ambuklao	105 MW	3x35 MW	Bokud, Benguet	SN Aboitiz Power, Inc.	SNAP-Benguet	Agno River	Impounding/ Multipurpose	Flood Control Power Generation
2. Angat	246 MW	4x50 MW (main); 3x6 MW, 1x18 MW, 1x10 MW (auxiliary)	Norzagaray, Bulacan	National Power Corporation	National Power Corporation	Angat River	Impounding/ Multipurpose	Domestic Water Supply Irrigation Flood Control Power Generation
3. Bakun AC	76 MW	1x70 MW	Alilem, Ilocos Sur	Vivant Sta. Clara Northern Renewables Generation Corporation	Luzon Hydro Corporation	Bakun River	Run-of-river	Power Generation
4. Binga	132 MW	4x33 MW	Itogon, Benguet	SN Aboitiz Power, Inc.	SNAP-Benguet	Agno River	Impounding/ Multipurpose	Flood Control Power Generation
5. Caliraya	28 MW	2x14 MW	Lumban, Laguna	Power Sector Assets & Liabilities Management	CBK Power Company Ltd.	Caliraya and Lumot Lake	Impounding/ Pumped Storage	Irrigation Power Generation
6. Casecnan	165 MW	2x82.5 MW	Pantabangan, Nueva Ecija	Power Sector Assets & Liabilities Management	CE Casecnan Water and Energy Co. (CalEnergy)	Casecnan and Taan Reservoir	Run-of-river	Irrigation Power Generation
7. HEDCOR mini-hydro	30 MW	1x30 MW	La Trinidad, Benguet	Power Sector Assets & Liabilities Management	Luzon Hydro Corporation	Various rivers in Benguet	Run-of-river	Power Generation
8. Kalayaan	720 MW	4x180 MW	Kalayaan,	Power Sector	CBK Power	Laguna Lake	Pumped	Power Generation

Pumped Storage			Laguna	Assets & Liabilities Management	Company Ltd.		Storage	(specifically for ancillary service)
9. Magat	380 MW	4x95 MW	Ramon, Isabela	SN Aboitiz Power, Inc.	SNAP-Magat	Magat River	Impounding/ Multipurpose	Irrigation Flood Control Power Generation
10. Masiway	12.4 MW	1x12.4 MW	Pantabangan, Nueva Ecija	First Gen Hydro Power Corp.	First Gen Hydro Power Corp	Masiway Reservoir	Impounding/ Multipurpose	Irrigation Power Generation
11. Pantabangan	120 MW	2x60 MW	Pantabangan, Nueva Ecija	First Gen Hydro Power Corp.	First Gen Hydro Power Corp.	Pantabangan Reservoir	Impounding/ Multipurpose	Irrigation Power Generation
12. San Roque Multipurpose	411 MW	3x137 MW	San Manuel, Pangasinan	Strategic Power Development Corp.	San Roque Power Corp.	Agno River	Impounding/ Multipurpose	Irrigation Flood Control Water Quality Improvement Power Generation

2.2. Power Plant Type

Hydroelectric power plants are designed and built according to the available water, the topography of the watershed and the various functions of the installations. They are mainly classified as (a) impounding, (b) pumped storage or (c) run-of-river. These power plants are built in various capacities and may either be grid-connected or embedded in a distribution system.

2.2.1. Impounding

In general, impounding hydroelectric power plants can store water in its reservoir behind a dam. Reservoir capacities can be small or very large, depending on the characteristics of the site and the economics of dam construction[8].

Impounding hydroelectric power plants in Luzon include Angat HEPP, Pantabangan-Masiway Complex, San Roque Multipurpose HEPP, Magat HEPP, Binga HEPP and Ambuklao HEPP.

PAGASA regularly monitors the status of major reservoirs in Luzon and among these major reservoirs are Angat, Ambuklao, Binga, San Roque, Pantabangan, Magat and Caliraya[9].

Technically, the available electrical power from an impounding hydroelectric power plant can be computed from the potential energy of water from a given height using the following equation[10]:

$$\mathbf{P} = \eta\, \rho\, \mathbf{Q}\, \mathbf{g}\, \mathbf{h}$$

where,

P is electrical power (in watts)
η is the efficiency of the turbine (dimensionless)
ρ is the density of water (approximately 1000 kg/m^3)
Q is the flow rate (in m^3/s)
g is the acceleration due to gravity (approximately 9.81 m/s^2)
h is the effective dam head which is the height difference between the inlet and the outlet (in meters)

With the density of water (ρ) and the acceleration due to gravity (**g**) as constants, and an assumed value for the turbine's efficiency (which can reasonably be between 80% to 95%), an approximate value of electrical power

[8] *Renewable Energy Technologies: Cost Analysis Series*, Volume 1: Power Sector, Issue 3/5, June 2012.
[9] *Status of Monitored Major Reservoirs in Luzon* [Online]. Available: http://kidlat.pagasa.dost.gov.ph/ffb/damwlv.htm
[10] *Hydroelectric Power* [Online]. Available: http://www.mpoweruk.com/hydro_power.htm

in watts can be computed based on the flow rate (**Q** in m^3/s) and the effective dam head (**h** in m).

Ideally, hydroelectric power plants with impounding capacity offer flexibility to a power system. They are able to respond almost instantaneously to changes in the quantity of power in the grid. These power plants can effectively hold inflows in reservoirs rather than generating and could then generate power when needed in the grid.

On the other hand**,** most major dams particularly in Luzon were constructed with the primary purpose of irrigating farmlands and not for generating power. Water supply in the reservoir is largely allocated for domestic supply or irrigation. This will be discussed further in Section 3.1 specifically under multipurpose type of reservoir.

2.2.2. Pumped Storage

In a pumped storage system, water is pumped from a river or lower reservoir into an off-stream storage reservoir at a higher elevation during off-peak demand periods. The water from the storage reservoir is released back to the lower reservoir during peak periods to generate electric power.

Usually, the dam of pumped storage HEPPs generates power during the day when electricity demands and energy values are greatest, and water is pumped back during the night when energy demands and pumping costs are lower.

By incorporating pumped storage capabilities, a hydroelectric power system can often generate the same amount of energy with considerably less storage capacity.

Pumped storage plants are not energy sources but instead are storage devices. These types of plants are able to provide large-scale energy storage and can be a valuable tool for delivering grid stability and flexibility services.

Kalayaan Pumped Storage HEPP is an example to this. It delivers electrical energy and provides ancillary services to the grid. In this case, the Laguna Lake serves as the lower reservoir while the Caliraya Lake serves as the upper reservoir. Water from Caliraya Lake is also utilized by Caliraya HEPP to generate power.

2.2.3. Run-of-River

Run-of-river hydroelectric power plants have no or very little impounding capacity and generation is dependent on the timing and size of river flows. Run-of-river generation uses the natural flow and elevation drop of a river to produce electricity but can be scheduled with proper forecasting.

Due to its being subject to seasonal variation and unpredictable water supply, run-of-river HEPP is considered "unfirm" power sources. Since it has no ability to store large volumes of water, run-of-river plants cannot by itself match the changing consumer demand with its power generation. Run-of-river types thereby generate more power during periods of high river flows and generate less otherwise.

In the Luzon grid, major run-of-river hydroelectric power plants include Bakun, HEDCOR mini hydro and Botocan HEPP. Casecnan HEPP is also considered as run-of-river plant as it has very limited storage capacity. It generates only when water is available. Its reservoir level changes abruptly with sudden increase in river inflow during heavy rain or typhoons[11]. When inflow is higher than the capacity, water has to be spilled.

Run-of-river plants with limited storage capacity can regulate water flows to some extent and shift generation a few hours or more over the day when it is most needed.

Technically, the available electrical power from a run-of-river hydroelectric power plant can be computed from the kinetic energy of water inflow using the following equation[12]:

$$P_{max} = \frac{1}{2} \eta \rho Q v^2$$

where,

P is electrical power (in watts)
η is the efficiency of the turbine (dimensionless)
ρ is the density of water (approximately 1000 kg/m^3)
Q is the flow rate (in m^3/s)
v is the velocity of the water flow (in m/s)

With the density of water (ρ) as constants, and an assumed value for the turbine's efficiency (which can reasonably be between 80% to 95%), an

[11] CE Casecnan Water and Energy Company presentation on Casecnan HEPP, Slide 17
[12] *Hydroelectric Power* [Online]. Available: http://www.mpoweruk.com/hydro_power.htm

approximate value of electrical power in watts can be computed based on the flow rate (**Q** in m^3/s) and the velocity of the water flow (**v** in m/s).

3. REVIEW OF LUZON HYDROELECTRIC POWER PLANT OPERATION PROTOCOL

Hydroelectric power plant operation varies according to the purpose and design of the plant. However there are a number of common protocols that are considered in many of these plants. In the following sections, the hydroelectric power plant operation shall be presented according to the reservoir purpose. Also presented are other operational constraints including the rule curve and the irrigation diversion requirement (IDR). The capability of the TP to offer the registered capacity of the plant it trades in the WESM depends on these factors.

3.1. Reservoir Purpose

Hydroelectric power plants with impounding capacity have multipurpose type of reservoir. Water from such reservoir is allocated for domestic supply, irrigation, flood control, and power generation, in order of priority. Table 2 shows various allocations for HEPPs in Luzon.

Table 2. Primary Purpose of Luzon HEPP Reservoirs[13]

Hydroelectric Power Plant	Purpose
Ambuklao	Flood Control, Power Generation
Angat	Domestic Supply, Irrigation, Flood Control, Power Generation
Binga	Flood Control, Power Generation
Caliraya	Irrigation, Power Generation
Magat	Irrigation, Flood Control, Power Generation
Masiway	Irrigation, Power Generation,
Pantabangan	Irrigation, Power Generation
San Roque	Irrigation, Water Quality Improvement, Flood Control, Power Generation

3.1.1. Domestic Supply

First in the order of priority is the plant reservoir's water allocation for domestic supply. It is comprised of the municipal and industrial uses of water.

[13] Based on various presentations of Plant Operators

The present and future demand for municipal and industrial water is largely influenced by the changing population, projected future development, and the present and anticipated uses of water by the industries.

Water requirements tend to be constant throughout the year except during summer months. For Metro Manila, the domestic needs are determined by the Metropolitan Waterworks and Sewerage System (MWSS). With the privatization of MWSS in 1997, through the Republic Act 8041 also known as “The Water Crisis Act”, the operational responsibilities of MWSS were effectively transferred to two private consortia, the Manila Water Company, Inc. for the East Zone and Maynilad Water Services, Inc. for the West Zone (“MWSS Concessionaires”).[14]

An example of plant reservoir with water allocation for domestic supply is the Angat Dam. Angat Dam is classified as a multipurpose dam and supplies raw water for MWSS Concessionaires. In fact, 98% of Metro Manila's domestic water requirements come from Angat Dam[15] which is equivalent to 46 cubic meters per second (CMS)[16] in terms of flow rate.

3.1.2. Irrigation

Another purpose of multipurpose reservoirs in Luzon is water allocation for irrigation requirement. Water requirements for irrigation depend on the type of irrigation system, the kind of crop, and the irrigation area. In fact, many hydro facilities with impounding capacities were developed with the primary purpose of irrigating farmlands in Luzon such as Pantabangan - Masiway hydro complex, Magat HEPP and San Roque Multipurpose project.

According to the National Irrigation Administration (NIA), the irrigation diversion requirement (IDR) is generally based on the needs of downstream farmlands as determined by the farmers. Essentially, IDR can be defined as the quantity of irrigation water in addition to precipitation required to produce the desired crop yield. IDR will be further discussed in Section 3.3.

Irrigation requirement usually vary seasonally during the dry cropping season and wet cropping season. Multipurpose plants ensure irrigation supply for specific hectares of NIA service area such as for UPRIIS or MARIIS (Upper Pampanga River Integrated Irrigation System; Magat River Integrated Irrigation System). Upon the advice of the field offices of NIA, Magat, Ambuklao, Pantabangan and Masiway reservoirs release water for irrigation purposes.

[14] *MWSS History* [Online]. Available: http://www.mwss.gov.ph/about/our-history/
[15] *Maynilad Virtual Tour* [Online]. Available: http://www.mayniladwater.com.ph/tour/index.html
[16] NPC Presentation on Angat HEPP, Slide 7

Some reservoirs like Binga and Ambuklao that are constructed for power generation and flood control are often requested by NIA to also release water to satisfy the irrigation needs of farmers downstream.

Re-regulation Dam

Some hydro complexes have re-regulation dams. This includes, the Pantabangan-Masiway HEPPs and the Ipo and Bustos dams for Angat HEPP. Re-regulation dam is a dam located downstream from a large hydroelectric power plant used to regulate discharges downstream and are constructed to mitigate the hydrologic impacts of hydroelectric power generation. It is usually built immediately downstream of the hydroelectric power facility, or by using one or more of the lowermost dams in a cascade to re-regulate the flow alterations caused by upstream dams.[17]

In a multi-dam system, re-regulation dam regulates the dramatic peak flows generated by upstream dams through the measured release of water from the dam downstream.[18]

A re-regulating dam can be operated to “undo” the abnormal instabilities caused by hydroelectric power operations on a day-to-day basis, discharging water in a pattern much closer to natural flows. Since regulating dams only reshape daily releases, their capacity is quite small and therefore their cost is usually a small fraction of the cost of the hydroelectric power dam.[19]

In terms of power generation, the available power from the hydroelectric power plant is strongly affected by the capacity and the IDR of the re-regulation dam. To illustrate, Masiway dam serves as the re-regulation dam of Pantabangan. An IDR is assigned to the Pantabangan-Masiway complex based on the requirements of UPRIIS. In this case, electrical power that can be generated by the Pantabangan HEPP will be based on the IDR and the current status of both Pantabangan and Masiway reservoirs. Having a re-regulation dam provides both an opportunity and a constraint in the release of water and consequently the generation of power.

3.1.3. Flood Control

Another purpose of multipurpose reservoirs is Flood Control. Major dams utilized for flood control are San Roque Multipurpose, Magat, Ambuklao, and Binga dams.

[17] Richter, B. D., and G. A. Thomas. 2007. *Restoring Environmental Flows by Modifying Dam Operations*. Ecology and Society 12(1): 12. [Online]. Available: http://www.ecologyandsociety.org/vol12/iss1/art12/
[18] *Water Glossary* [Online]. Available: http://www.westernresourceadvocates.org/water/waterglossary.php
[19] Richter, B. D., and G. A. Thomas.

During typhoon or high water inflow, the operation of the dams is assumed by the dam owner, i.e. either NIA or NPC. Take-over of responsibilities during extraordinary conditions is communicated by the dam owner to the plant operator. According to the Operation Rules[20] of San Roque Multipurpose HEPP, flood operation is under the control of the Flood Forecasting and Warning System of the National Power Corporation (NPC). Government agencies like PAGASA-DOST and local government units (LGU) are also coordinated for flood control. During this period, the plant operator has no control over the use of the dam.

3.1.4. Power Generation

Although power generation presents huge revenue opportunity, it has the lowest priority in terms of water allocation for multipurpose reservoir. In general it is desirable to use as much water for power generation as generator TPs can gain more if it generates more power.

However, generating power to its maximum capacity is not always achievable for hydro power plants as their fuel source varies depending on what was allocated for power generation from the multipurpose reservoir.

<u>Power Generation vis-à-vis Flood Control</u>

For flood-control dams, water level is controlled if there is an impending large inflow during storms. For multipurpose dams, power generation is the least priority and additional water can only be utilized for power generation if the water level is above the rule curve. Rule Curves is discussed further in Section 3.2.

<u>Power Generation vis-à-vis Irrigation and Seasonal Water Requirements</u>

It is noted that the major dams in Luzon were constructed for irrigation purposes and water utilization for power generation would come last. In most cases, whatever is the irrigation or water supply requirement, this will then constitute the releases for hydroelectric power. Thus, even if there is enough water in the reservoir to generate power, hydroelectric power plants are constrained to generate only what is allocated for irrigation based on the policy agreed upon by concerned parties, i.e. plant operator, NIA or NPC, and NWRB.

Historically, energy demands in the Luzon grid are highest in summer while the water level in the dams may be at its lowest. Further, water releases for irrigation are more during the summer. High water level during the wet season should be stored to supplement the low inflow of the dry season.

[20] Based on *San Roque Operation Guidelines*

Figure 1 shows a sample HEPP monthly average water discharge and water inflow for the period 2002 – 2005[21]

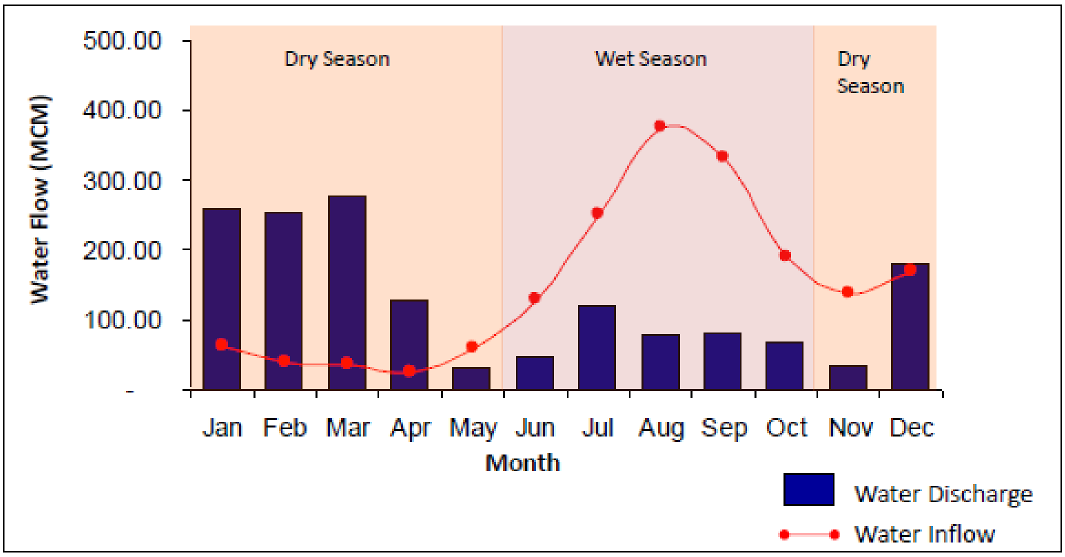

Figure 1

As shown in Figure 1, during the wet season when water inflow is high, the releases for irrigation are decreased to preserve the water supply for the upcoming dry season. Similar case applies to other major hydro power plant dams with irrigation as its primary purpose.

Also worth noting is the optimization of hydroelectric power plants during wet season to accommodate the annual preventive maintenance of thermal power plants.

Power Generation with Pumped Storage

Power generation with pumped storage can be more flexible since water available can be planned using the pumping function of the plant. At any time, the amount of electrical power available is based on the amount of water in the upper reservoir. Due to the plant's inherent flexibility, it is highly utilized for ancillary services. Ancillary services are discussed further in the succeeding section.

3.1.4.1. Ancillary Services

Most hydroelectric power plants are able to provide ancillary services. In fact, some TPs with hydroelectric power plants have contracted capacities for

[21] Based on presentation of Plant Operator(s)

ancillary service. The capacity contracted for ancillary service is also often cited by TPs as reasons for their failure to offer their registered capacity in the WESM energy market.

Ancillary Services are support services such as Frequency Regulating[23] and Contingency Reserves[24], Reactive Power support[25], and Black Start Capability[26] which are necessary to support the transmission capacity and Energy that are essential in maintaining Power Quality (in terms of system frequency and voltage profiles) and the Reliability and Security of the Grid[27].

Hydroelectric power plants with existing Ancillary Service Procurement Agreement (ASPA), allocate some of the available capacity for Ancillary Services. This further widens the Capacity Gap which is the difference between the registered capacity less outage capacity less offered capacity, calculated for each generator resource node per trading interval.

In the absence of a reserve market, ancillary service is decided day ahead thus TPs should be able to apportion their capacity offers for energy in the WESM. The capacity contracted for ancillary service can be validated further through the ASPA which is publicly available in the ERC website.

Table 3 shows the list of ancillary service providers with existing ASPA for TPs with hydroelectric power plants in Luzon.

Table 3. Ancillary Services Providers (Luzon)[28]

Participant Name	Generation Facility/ WESM Resource Name	Pmax[29] (MW)	Pmin[30] (MW)	RR	CR	DR	RPS	BS
NPC-PSALM	3CALIRY_G01	28	5					
NPC-PSALM	1HEDCOR_G01	30	0					
NPC-PSALM	3BOTOCA_G01	20.8	0.8					
NPC-PSALM	1CASECN_G01	165	50					
NPC-PSALM	3KAL_G01	180	90	yes	yes	yes	yes	yes
	3KAL_G02	180	30	yes	yes	yes	yes	yes

[23] Frequency Regulating Reserve refers to a Generating Unit that assists in Frequency Control by providing automatic Primary and/or Secondary Frequency response.
[24] Contingency Reserve is Generating capacity from Qualified Generating Units allocated to cover loss of a synchronized generating unit or the power import from a single-circuit interconnection, whichever is larger.
[25] Reactive Power Support is the injection or absorption of reactive power from Generators to maintain Transmission System voltages within ranges prescribed in the Code.
[26] Black Start Capability is the ability of a generating unit to go from a shutdown condition to an operating condition and start delivering power to the Grid without offsite power.
[27] *Philippine Grid Code*, Amendment No.1, 2007, pp. 4.
[28] *Ancillary Services Providers Generator Unit Data based on Accreditation Certificate as of 09 September 2013*
[29] Based on *WESM Generators Registered Capacities as of 11 October 2013*
[30] Based on *WESM Generators Registered Capacities as of 11 October 2013*

	3KAL_G03	180	90	yes	yes	yes	yes	yes
	3KAL_G04	180	90	yes	yes	yes	yes	yes
SNAP-Magat	1MAGAT_G01	380	0	yes	yes	yes		Yes
SNAP-Benget	1BINGA_G01	132	0		yes	yes		
	1AMBUK_G01	105	0	yes	yes	yes	yes	yes
First Gen Hydro Power Corp.	1PNTBNG_G01	120	30		yes	yes	yes	yes
	1MASIWA_G01	12.40	0.10					
NPC	1ANGAT_A	46	0.5					
	1ANGAT_M	200	5					
Strategic Power Development Corp.	1SROQUE_G01	411	45	yes	yes	yes		

3.2. Rule Curve

The operation of the reservoir follows a certain procedure so that all water users would be able to get its equitable share based on the agreed policy such as the quantity allocated and timing of usage for each user and who has the priority at each point of time. Water allocation is usually dictated by a rule curve. The Rule Curve together with operation protocol is unique for each hydroelectric power plant and is agreed upon by the dam owner (NIA or NPC), plant operators, and NWRB, among others.

One of the main purposes of the rule curve is to ensure safe operation of the dam. Rule curves are derived from historical data of river flows and water demands and show the minimum water level requirement in the reservoir at a specific time to meet the particular needs for which the reservoir is designed. Moreover, rule curves shall be followed except during periods of extreme drought and when public interest requires. For multipurpose reservoirs, water allocation is more complex as there are many water users that need the water from the reservoir. As general guidelines, conditions of water flow and allocation of water in the reservoir are to be taken into consideration in power generation (Table 4).

Table 4. Guidelines in Water Allocation
During normal flows, the reservoir will be retained and kept at the rule curve level
During floods, the water level will be above the rule thus when extreme floods occur, the reservoir is drawn down below the rule curve before the flood reaches the dam.
During prevailing low flow conditions, the reservoir is drawn down below the rule curve to discharge the design dependable flow to satisfy the downstream needs.
During drought periods, the reservoir may be completely emptied.

Based on the rule curve, operation rules for water allocation is in general dependent on the reservoir water flow conditions.

A typical rule curve from one of the HEPP is shown in Figure 2.

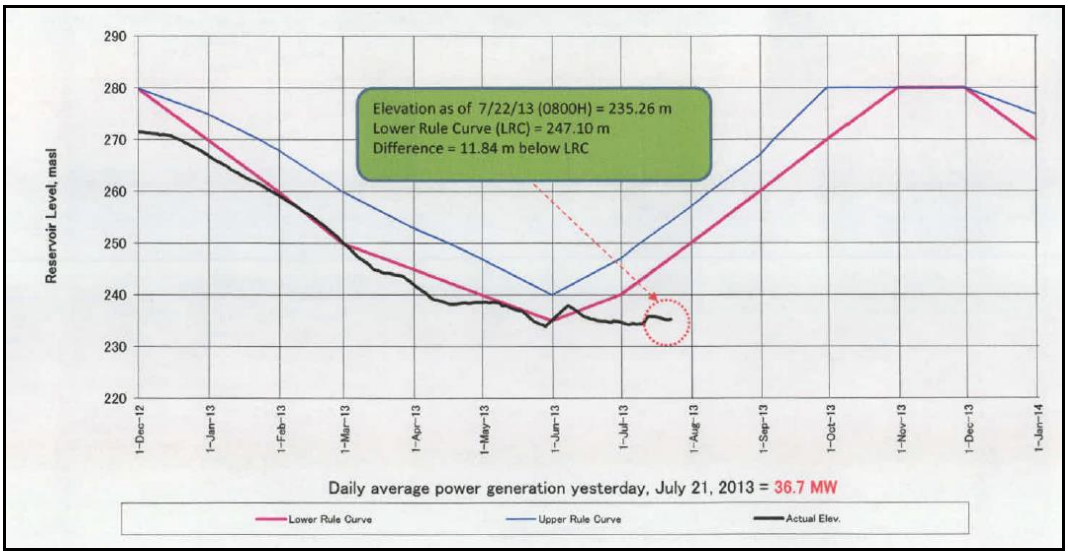

Figure 2[31]

As shown in Figure 2, during the period beginning the year 2013, the actual elevation is in fact below the lower rule curve. Releases for power generation are limited during this period.

As long as water elevation is above the upper rule curve, water releases should be allowed to satisfy all requirements for water supply and/or irrigation, contracted capacity, river flow maintenance as well as additional release for power generation provided that the resulting reservoir level will not fall below the upper rule curve or would not affect the operation plan.

Between the upper and the lower rule curves, all demands for water supply and irrigation are satisfied. When the water elevation is at this point, generation of electricity is limited to the released water for water supply and/or irrigation. Water releases for power generation is allowed provided such operation is coordinated with the concerned party. Plant operators will be advised by NIA personnel when additional release for power generation is allowable.

When the water level is below the rule curve, this means that there is only enough water for domestic and/or irrigation. For Angat, the remaining water in the reservoir is reserved for domestic water supply only in case of Angat and domestic supply

[31] Based on presentation of Plant Operator(s); actual elevation shown as of 22 July 2013

only. In cases of multipurpose reservoir with irrigation as priority such as Magat, Pantabangan, Masiway and San Roque, water in the reservoirs will be released for irrigation only. Generation of electricity is limited to these releases.

Close coordination and monitoring on the releases shall be done by the NPC or NIA with the concerned agencies involved in the operation and management of reservoir particularly the users of water from the reservoir and trader of the electricity generated from the power plant.

During off-irrigation period, there is an allowable minimum release for power generation.

3.3. Irrigation Diversion Requirement

Irrigation Diversion Requirement (IDR) can be defined as the quantity of irrigation water in addition to precipitation required to produce the desired crop yield.

This quantity of water must be decided for uses such as irrigation scheduling for a specific field and seasonal water needs for planning, management, and development of irrigation projects. The volume and timing of precipitation strongly influence irrigation water requirements.

IDR is expressed in water flow rate in cubic meters per second (CMS) or volume of water in million cubic meters (MCM). The IDR is notified by the NIA to the plant operators.

The volume of water required for irrigation (IDR) is determined based on the demands and agricultural needs for irrigation of farmers. If the amount of water needed by farm lands is minimal, then the hydroelectric power plant would have less water to utilize for power generation.

For hydroelectric power plants with dams used for irrigation, power generation depends on the IDR. Volume of water releases from the reservoir remains as initially notified until further advised by NIA. NIA inspectors closely coordinate with the irrigation release schedules with the plant operator.

To explain the water source and local flow of power plant dams and reservoir and NIA's Operation Rule Curve (ORC) for irrigation and power generation, NIA presented the Pantabangan-Masiway cascading hydro complex as an example.

Philippine Electricity Market Corporation

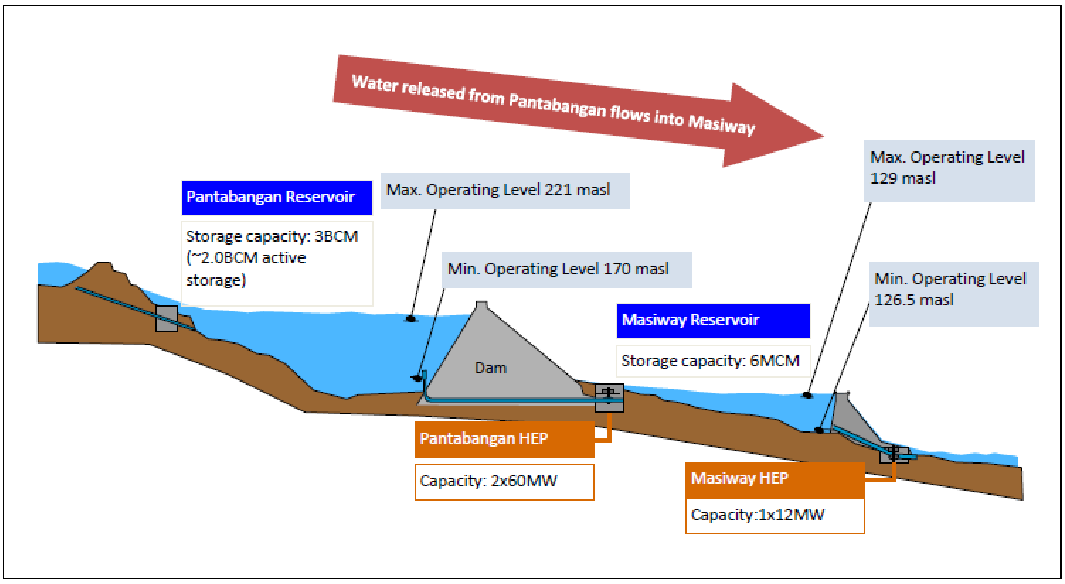

Figure 3[32]

NIA explained that water coming from the Pantabangan dam flows into the Masiway re-regulation dam and that at this stage the water released by the Pantabangan dam may already be utilized for power generation. Water after being used by the hydroelectric power plant is then passed on to the Masiway re-regulation dam. When Masiway hydroelectric power plant cannot accommodate the required IDR, the spillway will be utilized.

In such case, the release of water from Pantabangan dam is limited by the capacity of Masiway re-regulation dam. TPs cite the rule curve and IDR as basis for their water allocation for power generation as indicated in the Summary of Explanations of Trading Hours with Capacity Gaps ("Appendix A").

A number of impounding hydro power plants have their own (downstream) re-regulating dam. The capacity and the water level of the regulating dam both affect the amount of power that can be produced by the upstream plant. In fact, the IDR is typically assigned to the regulating dam, instead of the main dam.

Based on the presentation and information previously provided by the NIA, it was shown that NIA determines the IDR and that this should be followed by the power plants in determining their power generation. The same protocol is basically followed by other hydro plants with water supply coming from dams that are utilized for irrigation.

[32] FGHPC Presentation on Pantabangan-Masiway HEPP

Basing on the information provided by NIA, it is worth noting that (1) NIA has the control over the dam, including the water releases, for irrigation; and (2) IDR depends on the capacity of the re-regulation dam (for hydro complex with re-regulation dam).

3.4. Other Operational Constraints

Power generation of hydroelectric power plants is also constrained by PAGASA forecasts especially during periods of minimum rainfall or in cases when the country experiences *El Niño* affecting the inflow in the reservoirs resulting to low water elevation.

In such cases, the SO will strictly limit the dispatch of some hydroelectric power plants to its contracted capacity depending on the advice of the dam owner. Unless weather disturbances will hit the area of the reservoir and cause changes that would result to the increase of water elevation, the strict implementation of dispatch as instructed by the SO will still be followed.

NIA repairs and maintenance also affect the power generation of hydroelectric power plants. Energy offers of some trading participants are limited to its contracted capacity during peak hours due to restoration activities implemented by the NIA. Instructions for zero release will be observed during off-peak hours to enable NIA to conduct repair and maintenance.

Request for additional releases of hydroelectric power plants for power generation are also limited to prevent possible downstream flooding. Hydroelectric power plants are also constrained by their contractual obligations with Independent Power Producers. Some hydroelectric power plants have contractual obligations to generate at maximum when water is available.

4. DATA LIMITATION

In the process of reviewing the acceptability of explanations of TPs with hydroelectric power plants, the TC gathered information from the plant operators, NIA and MAG-Market Monitoring Unit (MMU). Appendix A shows the Summary of Explanations of Trading Hours with Capacity Gaps covering the period 26 December 2011 – 25 December 2013.

In its letter to the TPs dated 24 October 2013 the TC requested the rule curves duly validated by the NWRB for each power plant as TC's reference. (Shown in "Appendix B" are the duly validated rule curves provided by SNAP, FGHPC, NPC and SPDC).

A sample data on Pantabangan – Masiway HEPPs were gathered for the period 26 December 2012 to 25 July 2013 based from the explanations provided by the TPs to the inquiry of the MSC in relation to the compliances with the MOR of Luzon Generators as reported by the MAG-MMU. Data included the reservoir elevation and NIA IDR for all intervals with possible non-compliance to the MOR.

5. REVIEW OF RELEVANT RULES AND PROVISIONS

Based on the explanations of the TPs, their inability to submit their maximum availability capacity in the WESM is due to the constraints and limitations of the hydroelectric power plants resulting from either their contracted capacity for ancillary and/ or water supply.

Moreover, presentations provided by the plant operators showed that other than having variable water supply, operators of hydroelectric power plants are constrained with the operation of the reservoir in consideration of the prioritization of water allocated for domestic use, irrigation, flood control, water quality improvement, among others.

To guide the TC in its study, the TC reviewed the provisions of the WESM Rules and WESM Dispatch Protocol pertaining to the submission of offers. The TC also reviewed the Philippine Water Codes/ Acts & IRRs (P.D. No. 1067), NWRB/ NIA Protocol, ASPP and other relevant documents pertaining to operations and other protocols of hydroelectric power plants.

5.1. WESM Rules

All Generator Trading Participants are required to comply with the submission of offers in accordance with Section 3.5.5 and Appendix A1.1 of the WESM Rules, as amended:

- Section 3.5.5 Generation Offers and Data (WESM Rules)

  3.5.5.1 Each Scheduled Generation Company including Generation Companies with bilateral contracts shall submit a standing generation offer for each of its scheduled generating units for each trading interval in each trading day of the week in accordance with the timetable.

  3.5.5.2 Each generation offer shall include the information specified in Appendix A1.1:

- Appendix A1.1 Generation Offer (as amended by DOE DC No. 2006-01-0001 dated 10 January 2006):

  x x x

  (c) May include up to ten (10) energy offer blocks per (aggregate) unit. The maximum combined capacity of generation and reserve offers must not be less than the maximum available capacity of the generator.

Further, Maximum Available Capacity is defined under the Dispatch Protocol as equal to the registered maximum capacity (Pmax) of the (aggregate) unit less forced unit outages, scheduled unit outages, de-rated capacity due to technical constraints which include plant equipment-related failure and ambient temperature, hydro constraints which pertains to limitation on the water elevation/turbine discharge and MW output of the plant and geothermal constraints which pertain to capacity limitation due to steam quality (chemical composition, condensable and non-condensible gases), steam pressure and temperature variation, well blockage and limitation on steam and brine collection and disposal system.

5.2. Philippine Water Codes/Acts & IRRs

The Presidential Decree (PD) 1067 establishes the laws governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources.

Chapter 1, Article 3(d) states that *"the utilization, exploitation, development, conservation and protection of water resources shall be subject to the control and regulation for the government through the National Water Resources Council ('Council')".*

Further, water may be appropriated for the following purposes: (a) Domestic; (b) Municipal; (c) Irrigation; (d) Power Generation; (e) Fisheries; (f) Livestock Raising; (g) Industrial; (h) Recreational; and (i) Other purposes (Chapter 3, Article 10).

Chapter 3, Article 12, states that *"waters appropriated for particular purpose may be applied for another purpose only upon prior approval of the Council and on condition that the new use does not unduly prejudice the rights of other permittees, or require and increase in the volume of water".*

Also, Article 22 states that *"between two or more appropriators of water from the same sources of supply, priority in time of appropriation shall give the better right, except that in times of emergency the use of water for domestic and municipal purposes shall have a better right over all other uses…".*

Per Article 62 of Chapter 5, *"…all reservoir operations shall be subject to rules and regulations issued by the Council or any proper government agency".*

The Water Code further discloses that, *"the conservation of fish and wildlife shall receive proper consideration and shall be coordinated with other features of water resources development programs to ensure that fish and wildlife values receive equal attention with other project purposes"* (Chapter 6, Article 73).

Chapter 6, Article 73 applies to run-of-river plants in particular as all hydro plants or any entity diverting water from any river for whatever purpose is required to observe a compensation flow. The NWRB would allow that entity to divert only a certain amount which is the compensation flow to make sure that the river will not dry out completely for the aquatic life downstream or upriver.

Aside from the required compensation flow, most run-of-river plants have no issue as regards the water allocation for power generation vis-à-vis for irrigation. Thus, other than its fuel variability constraint, water supply for run-of-river types has no competing uses and is generally available for power generation.

Rule 2, Section 42 of PD 1067 Implement Rules and Regulations identifies that owners and persons in control of a reservoir shall submit to the Board the proposed reservoir operation rule curve together with all pertinent data for approval which shall be followed except during periods of extreme drought and when public interest so requires, wherein the Board may change the operation during the period after due notice and hearing.

Furthermore anyone who operates a reservoir shall submit to the Board his plan for handling maximum discharges with a view to avoiding damage to life and property (Rule 2, Section 42).

5.3. NWRB/ NIA Protocol

All water reservoir utilizing rule curves duly approved by the NWRB should strictly follow the protocol contained in the Board resolution.

The operation and management of reservoirs is governed by the Reservoir Operation Rules. Operation rules vary for each reservoir except for the general rules on the flood operation, upper and lower rule curve. Revision and review of rule curves differ for each reservoir, essentially, rule curves for Angat are reviewed every five (5) years while that of San Roque is reviewed every two (2) years.

Operation and maintenance of ‘non-power’ components of most hydroelectric power plant reservoirs are undertaken by the NIA based on the plant operator and NIA O&M Agreement. The plant is required to release water in accordance with NIA’s IDR and policy agreed upon by concerned parties. In other cases, the plant operator pays for the requested water used to generate power.

5.4. Ancillary Service Procurement Agreement (ASPA)[33]

Available ASPAs for hydroelectric power plants were also reviewed to confirm the contracted capacities of the hydroelectric power plants for specific ancillary service.

The PGC defines ancillary services as support services essential in sustaining the transmission capability & energy that are crucial in preserving the power quality, reliability & security of the grid. The primary function of ancillary service is to uphold the load generation stability of the system.

The System Operator being the transmission provider may use reasonable actions in procuring and entering into Ancillary Services Procurement Agreement (ASPA) with capable generation companies to deliver adequate ancillary services to the grid.

Succeeding entries below are excerpts contained in ASPAs of sample hydroelectric power plants.

ASPA for San Roque Multipurpose Hydroelectric Power Plant (04 March 2013)

The SRPC Plant has a capacity of 411 MW and has been certified by NGCP to be capable of providing Regulating, Contingency and Dispatchable Reserves as mandated under Section 6.10.1 of the Philippine Grid Code. It was further certified that the standard Ancillary Services technical requirements of the System Operator were met and complied with during the actual testing of the said plant.

The firm contracted capacity is 160 MW which shall be made available at all times for NGCP's instruction and dispatch except upon the existence of any of the circumstances specified in the ASPA.[34]

ASPA for Pantabangan Hydroelectric Power Plant (06 June 2011)

NGCP and FGHPC alleged that the Ancillary Services covered by the ASPA like Contingency Reserve, Dispatchable Reserve, Reactive Power Support and Black Start Capacity, are essential in maintaining the power quality, reliability and security of the Luzon Grid.

The Pantabangan Hydroelectric power Plant is certified by NGCP to be capable of providing the said Ancillary Services as mandated by the Philippine Grid Code (PGC) under Section 6.10.1 of the Test Requirements. Further, the standard Ancillary

[33] In compliance to the OATS Rules (Module D7), TransCo developed & filed to the ERC on December 2004 the Ancillary Service Procurement Plan which outlines the processes that the system operator must undergo in order to implement the procurement of the Ancillary Service.
[34] ERC Case No.2013-009 RC, pp. 8

Services technical requirements of the System Operator were met and complied with during the actual testing of the said plant.[35]

ASPA for Ambuklao Hydroelectric Power Plant (03 June 2013)

The Ambuklao HEPP has a capacity of 104.55 MW. It is certified by NGCP as capable of providing Regulating Reserve, Contingency Reserve, Dispatchable Reserve, Reactive Power Support Service and black Start Capability as provided under the PGC, particularly, Section 7.10.1 of the Test Requirements.

The firm contracted capacity is 35 MW for Regulating Reserve and 60 MW Contingency Reserve (off-peak only) and shall be made available at all times for NGCP's instruction and dispatch except upon the existence of any of the circumstances specified in the said ASPA.[36]

ASPA for Magat Hydroelectric Power Plant (03 June 2013)

The Magat HEPP has a capacity of 360 MW. It is certified by NGCP as capable of providing Regulating Reserve, Contingency Reserve, Dispatchable Reserve, Reactive Power Support Service and Black Start Capability as provided under the PGC, particularly, Section 7.10.1 of the Test Requirements.

The firm contracted capacity is 95 MW for Regulating Reserve and 60 MW Contingency Reserve (off-peak only) and shall be made available at all times for NGCP's instruction and dispatch except upon the existence of any of the circumstances specified in the said ASPA.[37]

6. OTHER DISCUSSIONS

Utilization Rate

Some impounding hydroelectric power plants provide a Utilization Rate (Urate) value in m^3/kWHr. This relates the volume of water (in m^3) in the dam needed to produce a kWHr of electrical energy. However, since the evaluation is concerned with capacity gaps (in MW), this quantity is not directly valuable, unless the Trading Participant provides the available energy from a given dam volume while explicitly providing the hourly planned dispatch.

This concept also highlights the relationship between available electrical energy and available electrical power (or available capacity). For an impounding hydroelectric power

[35] ERC Case No. 2011-062 RC, pp. 4
[36] ERC Case No. 2013-054 RC, pp. 5,11
[37] ERC Case No. 2013-053 RC, pp. 5,11

plant, water is typically considered as *fuel* for these power plants. As such, it is common to quantify the volume of water needed for every kWHr of electrical power produced. Suppose a power plant has a daily water volume allocation in million cubic meters (MCM = 1×10^6 m^3). For a known utilization rate, this volume of water translates to an amount of electrical energy that can be produced throughout the day. The plant operator has the option to either (Case A) use the entire water volume during the first hour, producing a large amount of electrical power (in MW) for a single hour or (Case B) equally distribute this volume to be used throughout the 24-hour period, producing much smaller electrical power (in MW) but available throughout the next 24-hour period. These are shown as Cases A and B in Figure 4.

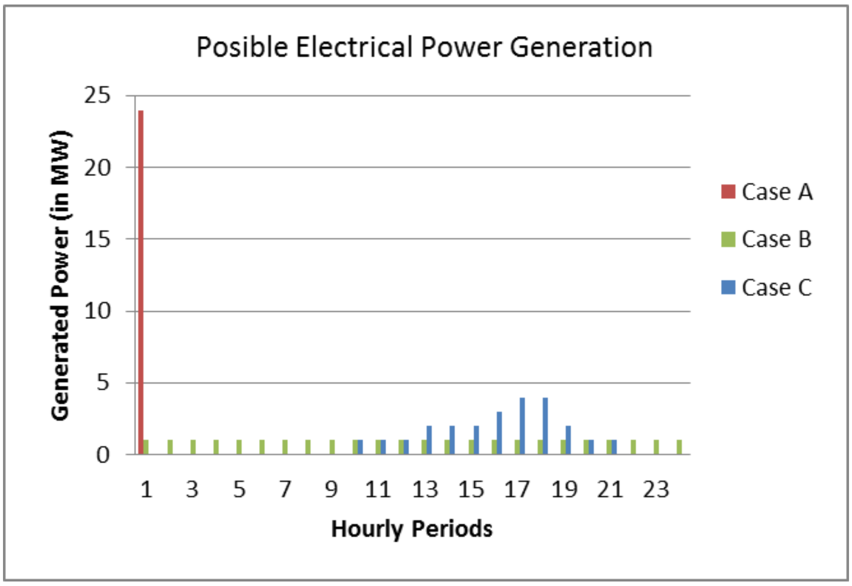

Figure 4

Similarly in Section 2.2., it was presented that the available electrical power (in W or MW) is a function of the flow rate (or water release) in m^3/s. At any point in time, a large water release will produce a correspondingly large electrical power.

For Trading Participants with hydroelectric power plant with a specified volume of water allocation, the offered capacity for the next 24 hours shall be decided appropriately.

For multipurpose water reservoir, the power plant is given a flow rate (in m^3/s) allocation as well. At this rate, Case A (in Figure 4) may not be allowed, hence a more suitable schedule for power generation could be similar to Case C. Note that for all three cases, the same total energy has been generated throughout the 24-hour period (which is equivalent to 24 units of energy)

7. SUMMARY AND RECOMMENDATIONS

The operation of different types of hydroelectric power plants is affected by a number of protocols and constraints.

Major hydroelectric complexes are served with multipurpose reservoir. Hence other functions with higher priority than electrical power generation have to be served first. A Rule Curve is established for most of these reservoirs. They are derived from historical data of river flows and water demands and show the minimum water level requirement in the reservoir at a specific time to meet the particular needs for which the reservoir is designed. For multipurpose reservoirs with irrigation functions, an IDR allocating daily water volume and flow rates are also specified. In addition, some hydropower plants have re-regulation dams that both provide opportunities and constraints in the generation of electrical power. Likewise, most of these power plants are capable of providing ancillary services. All these information has to be taken into account to determine the amount of electrical power that can be offered to the WESM energy market.

Pumped storage hydroelectric power plants operate between two water reservoirs. Although the amount of available electrical power depends upon the water available at the upper reservoir, the operator can practically control this water level using the plant's pumping function. In the case of Kalayaan HEPP, the only pumped storage plant in the Luzon Grid, the allocation for ancillary services largely determines the amount of electrical power that can be offered to the WESM energy market.

For run-of-river hydroelectric power plants, the available electrical power depends upon the inflow. With suitable forecasting tools and techniques, this inflow can be predicted hours or even days ahead. The same information on inflow can determine the amount of electrical power that can be offered to the WESM energy market.

The TC understands the complexity of the operation of the different hydroelectric power plants. There are a number of factors that may affect the TP's capability to offer capacity of their respective hydroelectric power plant. However, the information currently provided by the TPs in explaining the capacity gap is deemed insufficient for the MSC to soundly judge the validity of the offered maximum available capacity.

8. RECOMMENDATIONS

In assessing the explanations cited by TPs regarding any capacity gap, it is recommended that the MSC should firstly take into consideration the hydroelectric power plant type.

For impounding HEPPS, the following data needs to be submitted as part of the explanation for any capacity gap

- Turbine efficiency (**η**);
- Flow rate IDR (**Q** in m^3/s or CMS); and
- Effective Dam height (**h** in m)

In addition, for HEPPs with re-regulating dams, flow rate IDR and effective dam height of the re-regulating dam should also be provided.

For a pumped storage HEPP (i.e. Kalayaan HEPP), its pumping capability allows it to control its effective dam height and flow rate. Hence the above data are not necessary.

Even though both Bakun HEPP and Casecnan HEPP are considered run-of-river plants, they both operate at a specified head. The available power is mostly due to the potential energy of water instead of kinetic energy only. Hence, it is recommended that these plants submit the same data requirements as for an impounding power plant.

For strictly run-of-river HEPPs the following data needs to be submitted as part of the explanation for any capacity gap

- Turbine efficiency (**η**);
- Flow rate IDR (**Q** in m^3/s or CMS); and
- Velocity of water flow (**v** in m/s)

It has been noted that many hydroelectric power plants are capable to provide one or more ancilliary services. For plants with ASPA, part of the available capacity is allocated for this. Hence, it is recommended that the amount (in MW) of their planned or contracted ancillary service be included in the explanation.

After a suitable period of time, when sufficient amount of data has been gathered, these can be used to estimate the maximum available capacity through statistical modelling such as but not limited to multiple regression. It is expected that the maximum available capacity can be predicted by a model.

A regressed expression may be something like:

$$\textbf{Maximum Available Capacity} = k_1(H1 * IDR) + k_2(H2) + k_3(AS) + k_4$$

where,

H1 is the effective head of the main dam (in m)
H2 is the effective head of the regulating dam (in m)
IDR is the Irrigation Diversion Requirement (in m^3/s)
AS is the Ancillary Service provision (in MW)
k_i are the regression coefficients where some of which could be negative numbers.

In the conduct of this study, there was an attempt to perform regression analysis between the offered capacity and the submitted elevation and flow rate IDR (as submitted by the TPs with capacity gaps.) However, there was not enough data available yet to draw any significant finding.

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Summary of Explanations for Trading Hours with Capacity Gap
26 December 2011 - 25 December 2013

Node Name	Registered Capacity (MW)	Explanations	Offered Capacity (MW)	Ratio (Offer over Reg. Cap less Outage)	Capacity Gap (MW)
1ANGAT_A	46	AU1 AUTOTRIPPED - MAINTAIN WATER ELEVATION AT IPO DAM	33	71.74	13
1ANGAT_A	46	AU1 ONLINE @ 1110H - MAINTAIN WATER ELEVATION AT IPO DAM	38	82.61	8
1ANGAT_A	46	CPF REQUESTED FOR 5 CMS DECREASE IN WATER RELEASES	33	71.74	13
1ANGAT_A	46	CPF REQUESTED FOR ADDITIONAL 5 CMS DECREASE IN WATER RELEASES	29	63.04	17
1ANGAT_A	46	CPF REQUESTED FOR IPO TARGET ELEV AT 100 OT 100.20M	34	73.91	12
1ANGAT_A	46	CPF REQUESTED FOR MINIMUM LOAD	5.5	11.96	40.5
1ANGAT_A	46	CPF REQUESTED INCREASED OF WATER RELEASES	35	76.09	11
1ANGAT_A	46	CPF REQUESTED REDUCED WATER RELEASES	29	63.04	17
1ANGAT_A	46	CPF REQUESTED TO DECREASE WATER RELEASES OF 4 CMS	30, 32	75, 65.22	10, 16
1ANGAT_A	46	MAINTAIN IPO DAM ELEV @ 100.00 TO 100.20 MASL	9 - 35	19.57 - 82.5	7 - 37
1ANGAT_A	46	MAINTAIN WATER ELEVATION AT IPO DAM	37, 38	80.43, 82.61	8, 9
1ANGAT_A	46	MANILA WATER (CPF) REQUEST FOR 7 CMS REDUCTION OF WATER RELEASE	28	60.87	18
1ANGAT_A	46	MWSS REQUESTED FOR REDUCED WATER ALLOCATION DUE TO HIGH WATER ELEV AT IPO DAM	31	67.39	15
1ANGAT_A	46	MWSS WATER ALLOCATION @ 46.00 CMS	9 - 38	32.14 - 82.61	5 - 25
1ANGAT_A	46	MWSS WATER ALLOCATION @ 46.00 CMS.AUX# 1 2 & 3 ON M.O.	23	57.5	17
1ANGAT_A	46	MWSS WATER ALLOCATION @ 46.00 CMS.AUX#1 ON M.O.	33	82.5	7
1ANGAT_M	200	MU#1 ON DS MU#2 & 4 ON MO NIA IDR @ 32.00 CMS	24, 33, 40, 45, 60	45, 48, 66, 80, 90	5, 10, 17, 26, 40, 55
1ANGAT_M	200	MU#1 ON DS MU#2 & 4 ON MO NIA IDR @ 32.00 CMS	0	0	50
1ANGAT_M	200	MU#1 ON DS MU#2 & MU#4 ON MO NIA IDR @ 36.00CMS	40	80	10
1ANGAT_M	200	MU#1 ON DS MU#2 ON MO NIA IDR @ 32.00 CMS. MU4 UNDER TESTING	55, 60	55, 60	40, 45
1ANGAT_M	200	MU1 ON DS & MU2 ON MO NIA IDR AT 30 CMS	10, 25, 30, 35	10, 25, 30, 35	65, 70, 75, 90
1ANGAT_M	200	MU1 ON DS & MU2 ON MO NIA IDR AT 30 CMS	0	0	100
1ANGAT_M	200	MU1 ON DS MU2 4 ON MO NIA IDR 32CMS	30	60	20
1ANGAT_M	200	MU1 ON DS MU2 3 4 ON MO NIA IDR 32CMS	10	20	40
1ANGAT_M	200	MWSS WATER ALLOCATION @46 CMS	35	35	65
1ANGAT_M	200	NIA IDR @18.90 CMS	20, 21	40, 42	29, 30
1ANGAT_M	200	NIA IDR @ 22.60 CMS	25, 35	23.33, 25	25, 75, 115
1ANGAT_M	200	NIA IDR @ 28.11 CMS	25, 32	25, 32	68, 75
1ANGAT_M	200	NIA IDR @ 46.51 CMS	10, 50, 54	10, 50, 54	46, 50, 90
1ANGAT_M	200	NIA IDR @ 48.88 CMS	57	57	43
1ANGAT_M	200	NIA IDR @ 16.00 CMS	15, 25	30, 50	25, 35
1ANGAT_M	200	NIA IDR @ 16.95 CMS	15, 25	30, 50	25, 35
1ANGAT_M	200	NIA IDR @ 20.59 CMS	15, 22	10, 14.67	128, 135
1ANGAT_M	200	NIA IDR @ 32.00 CMS. MU#1 ON DS & MU#2 ON MO	46	46	4, 54
1ANGAT_M	200	NIA IDR @ 32.00 CMS. MU#1 ON DS & MU#2 ON MO	0	0	50
1ANGAT_M	200	NIA IDR @ 36.00 CMS MU#1 ON DS MU#2 ON MO	34, 40	34, 40	60, 66
1ANGAT_M	200	NIA IDR @ 36.00 CMS MU#1 ON DS MU#2 ON MO MU#3 ON PO	15, 33, 39, 40, 50	15, 33, 39, 40, 50	50, 60, 61, 67, 85
1ANGAT_M	200	NIA IDR @ 36.00 CMS MU#1 ON DS MU#2 ON MO MU#3 ON PO	0	0	100
1ANGAT_M	200	NIA IDR @ 36.00 CMS MU#1 ON DS MU#2 ON MO MU#3 ON RS	33, 34	33, 34	66, 67
1ANGAT_M	200	NIA IDR @ 36.00 CMS MU#1 ON DS MU#2 ON MO MU#3 ON RS	0	0	100
1ANGAT_M	200	NIA IDR @ 36.00 CMS. MU#1 ON DS & MU#2 ON MO	35, 36	35, 36	64, 65
1ANGAT_M	200	NIA IDR @ 36.00 CMS. MU#1 ON DS & MU#2 ON MO	0	0	100
1ANGAT_M	200	NIA IDR @ 42.73CMS MU#1 ON DS MU#2 ON MO MU#3 ON PO	39	39	61
1ANGAT_M	200	NIA IDR AT 16.65 CMS MU1 ON DS MU2 ON MO	15, 25	15, 25	25, 35, 75, 85
1ANGAT_M	200	NIA IDR AT 29.34 CMS MU1 ON DS MU 2 ON MO MU3 ON PO	20, 40, 45	20, 40, 45	55, 60, 80
1ANGAT_M	200	NIA IDR AT 29.34 CMS MU1 ON DS MU2 ON MO	15, 20, 40, 55, 60	15, 20, 40, 55, 60	40, 45, 60, 80, 85
1ANGAT_M	200	NIA WATER ALLOCATION @ 22.60 CMS	25	16.67	75, 125

Summary of Explanations for Trading Hours with Capacity Gap
26 December 2011 - 25 December 2013

Node Name	Registered Capacity (MW)	Explanations	Offered Capacity (MW)	Ratio (Offer over Reg. Cap less Outage)	Capacity Gap (MW)
1ANGAT_M	200	NIA WATER ALLOCATION @ 30.24 CMS	33	22	117
1ANGAT_M	200	NIA WATER ALLOCATION @ 33.61 CMS	28, 37, 42	18.67, 24.67, 28	108, 113, 122
1ANGAT_M	200	NIA WATER ALLOCATION @ 42.44 CMS	47	31.33	103
1ANGAT_M	200	NIA WATER ALLOCATION @ 48.53 CMS	57	57	43
1ANGAT_M	200	NIA WATER ALLOCATION AT 25.60 CMS	28	18.67	122
1BAKUN_G01	76	BASED ON WATER ELEVATION	6, 7	7.89, 9.21	69, 70
1BAKUN_G01	76	BASED ON WATER LEVEL	5.8 - 74	7.63 - 97.37	2 - 70.2
1BAKUN_G01	76	DISPATCHABLE LOAD BASED ON WATER CAPABILITY (LIMITATION IN THE 5.0MW INCREMENTAL)	5.8	7.63	70.2
1BINGA_G01	132	Provision of AS	5 - 66	5.43 - 75	9.5 - 87
1CASECN_G01	165	Based on water availability	55 - 160	33.33 - 96.97	5 - 110
1CASECN_G01	165	Based on water availability	0	0	82.5, 165
1CASECN_G01	165	BASED ON WATER AVAILABILITY; PLANT NOMINATION	60, 65, 70	36.36, 39.39, 42.42	95, 100, 105
1HEDCOR_G01	30	Based on water availability	5 - 28	16.67 - 93.33	2 - 25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY - PLANT NOMINATION = 2.5MW	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY PLANT NOMINATION = 3.7MW	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY = 1 - 5 MW	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY AND PLANT NOMINATION = 2. - 6 MW	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY PLANT NOMINATION	5 - 15	16.67 - 50	15 - 25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY PLANT NOMINATION = 3.5 - 6 MW	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY;	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY; PLANT NOM	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY; PLANT NOMINAT ION IS AT 3MW DUE TO REPAIRS BEING MADE BY NGCP	5	16.67	25
1HEDCOR_G01	30	BASED ON WATER AVAILABILITY; PLANT NOMINATION = 1.0 - 5 MW	5	16.67	25
1HEDCOR_G01	30	NOMINATION AT 4.7 MW	5	16.67	25
1HEDCOR_G01	30	NOMINATION IS EQUAL TO 4.9	5	16.67	25
1HEDCOR_G01	30	PLANT NOM @ 4.2MW	5	16.67	25
1HEDCOR_G01	30	PLANT NOMINATION = 3.6 - 7 MW	5	16.67	25
1MAGAT_G01	380	Provision of AS	5 - 360	1.32 - 94.74	20 - 375
1MASIWA_G01	12	LOW IRRIGATION DIVERSION	5.1 - 10	42.5 - 83.33	2 - 6.9
1MASIWA_G01	12	LOW IRRIGATION DIVERSION	0	0	12
1MASIWA_G01	12	LOW IRRIGATION DIVERSION REQUIREMENT	5.1 - 10	42.5 - 83.33	2 - 6.9
1MASIWA_G01	12	LOW IRRIGATION DIVERSION REQUIREMENT	0	0	12
1PNTBNG_G01	120	LOW IRRIGATION DIVERSION	33, 55	27.5, 91.67	5, 27, 87
1PNTBNG_G01	120	LOW IRRIGATION DIVERSION REQUIREMENT	33 - 118	27.5 - 98.33	2 - 87
1PNTBNG_G01	120	LOW IRRIGATION DIVERSION REQUIREMENT	0	0	120
1SROQUE_G01	411	Limited capability due to low water elevation	258, 390, 399	94.16, 94.89, 97.08	12, 16, 21
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 3.60m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 3.73m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 3.77m below lower rule curve	100, 110	24.33, 26.76	301, 311
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 3.94 m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.22m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.41m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.57m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.60m below lower rule curve	95	23.11	316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.64m below lower rule curve	95	34.67	179

Summary of Explanations for Trading Hours with Capacity Gap
26 December 2011 - 25 December 2013

Node Name	Registered Capacity (MW)	Explanations	Offered Capacity (MW)	Ratio (Offer over Reg. Cap less Outage)	Capacity Gap (MW)
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.66m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.68m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.69m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.73 m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.74m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.83m below lower rule curve	95	34.67	179, 316
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.85 m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.87m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation already at 4.91m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.13 m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.13m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.32m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.59m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.73m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.79m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 0.97m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.21m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.34 m below lower rule curve	115	27.98	296
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.59 m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.69 m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.74m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.80m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 1.92m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.13m below lower rule curve	115	41.97	159
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.30m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.51m below lower rule curve	95, 120, 150, 180	34.67, 43.8, 54.74, 65.69	94, 124, 154, 179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.65m below lower rule curve	95, 115	34.67, 41.97	159, 179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.79m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.80 m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 2.88m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 3.10m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 3.45m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability due to reservoir elevation at 3.51m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Limited capability to increase water level in preparation for Irrigation Diversion Requirements (IDR)	120	29.2	291

Summary of Explanations for Trading Hours with Capacity Gap
26 December 2011 - 25 December 2013

Node Name	Registered Capacity (MW)	Explanations	Offered Capacity (MW)	Ratio (Offer over Reg. Cap less Outage)	Capacity Gap (MW)
1SROQUE_G01	411	Limited capability to increase water level in preparation for start of cropping season Irrigation Diversion Requirements (IDR)	100	24.33	311
1SROQUE_G01	411	Limited due to low water elevation	399, 402	97.08, 97.81	9, 12
1SROQUE_G01	411	LIMITED TO 115MW TO INCREASE WATER LEVEL IN PREPARATION FOR THE START OF CROPPING SEASON IRRIGATION DIVERSION REQUIREMENTS (IDR)	115	27.98	296
1SROQUE_G01	411	Limited to 390 MW due to low reservoir water level	390	94.89	21
1SROQUE_G01	411	Limited to 405MW due to low reservoir water level	405	98.54	6
1SROQUE_G01	411	Limited to 95MW to increase water level in preparation for the start of cropping season Irrigation Diversion Requirements (IDR)	95	23.11	316
1SROQUE_G01	411	Limited to increase water level in preparation for start of cropping season Irrigation Diversion Requirements (IDR)	100	24.33	311
1SROQUE_G01	411	NIA Brush Dam repair	95	23.11	316
1SROQUE_G01	411	NIA Brush Dam Repair and water level below lower rule curve	95	23.11	316
1SROQUE_G01	411	Offer limited to 95MW to increase water level for Irrigation Diversion Requirements (IDR)	95	23.11	316
1SROQUE_G01	411	Reduced capability due to water level below lower rule curve	50, 55, 60, 95	12.17, 13.38, 14.6, 23.11	316, 351, 356, 361
1SROQUE_G01	411	Reservoir level at 4.26m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Reservoir level at 4.42m below lower rule curve	95	34.67	179
1SROQUE_G01	411	Reservoir water level already at 4.55m below lower rule curve	95	34.67	179
1SROQUE_G01	411	SRPC declared capability at 402 MW due to low reservoir water elevation	402	97.81	9
3CALIRY_G01	28	BASED ON PLANT NOMINATION	14	50	14
3CALIRY_G01	28	BASED ON PLANT NOMINATION; 1 UNIT ON OPERATION	14	50	14
3CALIRY_G01	28	Based on water availability	14, 18.5	50, 66.07	9.5, 14
3CALIRY_G01	28	BASED ON WATER ELEVATION	14	50	14
3CALIRY_G01	28	Low water level	14	50	14
3CALIRY_G01	28	ONLY 1 UNIT WILL GENERATE TO INCREASE WATER ELEVATION IN CALIRAYA RESERVOIR AND AID KPSPP U3 IN ITS INTERNAL NCC TEST	14	50	14
3CALIRY_G01	28	ONLY 1 UNIT WILL GENERATE TO INCREASE WATER ELEVATION IN CALIRAYA RESERVOIR AND AID KPSPP U4 IN ITS INTERNAL NCC TEST	14	50	14
3KAL_G01	180	Energy offer is up to 95 MW and the rest is offered as Ancillary Service	95	52.78	85
3KAL_G02	180	Cancelled offer to conserve water at Caliraya Lake		0	180
3KAL_G02	180	Energy offer is up to 95 MW and the rest is offered to Ancillary Services	95 - 99	52.78 - 55	81, 82, 83, 84, 85
3KAL_G02	180	Cancelled offer to conserve water at Caliraya Lake		0	180
3KAL_G03	180	Energy offer is up to 95 MW and the rest is offered to Ancillary Services	95	52.78	85
3KAL_G04	180	Cancelled offer to conserve water in the Caliraya Lake		0	180
3KAL_G04	180	ENERGY OFFER IS UP TO 95 MW AND THE REST IS OFFERED TO ANCILLARY SERVICES	95 - 99	52.78 - 59.44	73 - 85

First Gen
Hydro Power

Doc. No.: **MO-VP13-04**

4 November 2013

MR. CHRYSANTHUS S. HERUELA
VP-Market Assessment Group
Philippine Electricity Market Corporation
9/F Robinsons Equitable Tower
ADB Avenue, Ortigas Center

Thru: **DR. JORDAN REL C. ORILLAZA**
Acting Chairperson for the Technical Committee

Subject: **RULE CURVE OF MASIWAY HEPP AND PANTABANGAN HEPP**

DEAR MR. HERUELA,

Kindly find below the Daily Operating Rule Curve Data validated by the National Water Resources Board (NWRB) and currently utilized by the National Irrigation Administration (NIA) at the Pantabangan HEPP. There is, however, no Rule Curve established for the Masiway HEPP.

Thank you and best regards.

Very truly yours,

DENNIS P. GONZALES
Vice President

PHILIPPINE ELECTRICITY MARKET CORP.
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UPRIIS OPERATION RULE CURVE DATA (ORIG)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	211.15	208.51	203.37	199.65	199.35	199.16	200.65	204.51	207.39	210.23	211.83	212.14
2	211.09	208.36	203.20	199.60	199.34	199.17	200.75	204.63	207.49	210.31	211.86	212.12
3	211.04	208.20	203.02	199.56	199.34	199.18	200.86	204.74	207.58	210.38	211.89	212.11
4	210.99	208.04	202.85	199.52	199.33	199.19	200.97	204.84	207.68	210.46	211.92	212.09
5	210.93	207.88	202.68	199.48	199.33	199.21	201.08	204.95	207.78	210.53	211.94	212.07
6	210.87	207.71	202.52	199.45	199.32	199.23	201.20	205.05	207.87	210.60	211.97	212.05
7	210.82	207.54	202.36	199.43	199.31	199.25	201.31	205.15	207.97	210.66	211.99	212.03
8	210.76	207.36	202.20	199.40	199.30	199.27	201.44	205.25	208.07	210.73	212.01	212.00
9	210.70	207.18	202.04	199.38	199.29	199.30	201.56	205.34	208.17	210.79	212.04	211.98
10	210.64	207.00	201.89	199.37	199.28	199.33	201.68	205.44	208.27	210.85	212.06	211.95
11	210.58	206.81	201.75	199.35	199.27	199.36	201.81	205.53	208.37	210.91	212.07	211.92
12	210.51	206.62	201.60	199.34	199.26	199.40	201.94	205.63	208.47	210.97	212.09	211.89
13	210.44	206.43	201.47	199.33	199.25	199.43	202.07	205.72	208.57	211.03	212.11	211.86
14	210.37	206.24	201.33	199.32	199.24	199.47	202.20	205.81	208.67	211.09	212.12	211.83
15	210.30	206.05	201.20	199.32	199.23	199.51	202.33	205.90	208.77	211.14	212.14	211.80
16	210.23	205.85	201.07	199.32	199.21	199.56	202.47	205.98	208.87	211.19	212.15	211.78
17	210.15	205.66	200.95	199.32	199.20	199.61	202.60	206.07	208.97	211.24	212.16	211.73
18	210.07	205.46	200.83	199.32	199.19	199.66	202.74	206.16	209.07	211.29	212.17	211.70
19	209.98	205.27	200.72	199.32	199.18	199.71	202.87	206.25	209.16	211.34	212.18	211.66
20	209.90	205.07	200.61	199.32	199.17	199.77	203.00	206.33	209.26	211.38	212.18	211.63
21	209.81	204.88	200.50	199.33	199.17	199.83	203.14	206.42	209.35	211.43	212.19	211.59
22	209.71	204.68	200.40	199.33	199.16	199.90	203.27	206.50	209.45	211.47	212.19	211.55
23	209.61	204.49	200.30	199.33	199.15	199.97	203.40	206.59	209.54	211.51	212.19	211.52
24	209.51	204.30	200.21	199.34	199.15	200.04	203.53	206.68	209.63	211.55	212.19	211.48
25	209.40	204.11	200.12	199.34	199.14	200.11	203.66	206.76	209.72	211.59	212.18	211.44
26	209.29	203.92	200.04	199.35	199.14	200.19	203.79	206.85	209.81	211.63	212.18	211.40
27	209.17	203.73	199.96	199.35	199.14	200.28	203.92	206.94	209.90	211.67	212.18	211.36
28	209.05	203.55	199.89	199.35	199.14	200.36	204.04	207.03	209.99	211.70	212.17	211.32
29	208.92	203.46	199.82	199.35	199.14	200.46	204.16	207.12	210.07	211.74	212.16	211.28
30	208.79		199.76	199.35	199.14	200.55	204.28	207.21	210.15	211.78	212.15	211.24
31	208.65		199.70		199.15		204.40	207.30		211.80		211.19
	208.65	203.46	199.70	199.35	199.15	200.55	204.40	207.30	210.15	211.80	212.15	211.19

Republic of the Philippines

NATIONAL WATER RESOURCES BOARD

BOARD RESOLUTION NO. 003-1209

Approval of the New Angat Reservoir Operation Rules

WHEREAS, the operation and management of the Angat Reservoir as multipurpose dam for municipal, irrigation, power and flood control uses, is governed by the Angat Reservoir Operation Rules:

WHEREAS, the existing operation rules curves for Angat Reservoir agreed upon by MWSS, NIA, NPC and NWRB was approved by the Board last December 14, 1998 and its operation criteria was modified last February 19, 2004 thru Resolution No. 004-2004 with criterion No. 2 amended pursuant to Resolution No. 004-0406 dated April 28, 2006 for effective utilization and allocation of water in the dam;

WHEREAS, ~~due to the~~ increasing demand ~~from the Angat~~ reservoir, occurrence of extreme climatic event and the contribution of Umiray water into the Angat reservoir, the said operation rules has to be revised:

WHEREAS, the NWRB staff in consultation with the members of the Technical Working Group (MWSS, NIA, NPC, PAGASA and NWRB as chair) developed a new Angat Reservoir Operation Rules for the optimum benefits from the reservoir:

NOW THEREFORE, BE IT RESOLVED, AS IT IS HEREBY RESOLVED, to adopt the Operation Rules for Angat Reservoir, as follows:

OPERATION RULES FOR ANGAT RESERVOIR

1. The reservoir is divided into three zones, as follows:
   a) *Flood Control Zone* - is the reservoir storage above the normal-high-water levels (NHWL) which is set at Elev. 212 M (Dec. 1 - April 30) during non-flood season and Elev. 210 M during flood season (May 1 - October 31).
   b) *Operating zone* - is the reservoir storage bounded by the NHWL and the minimum water supply level which is set at Elev. 180M.
   c) *Drought Zone* - is the reservoir storage from Elev.180 and below.

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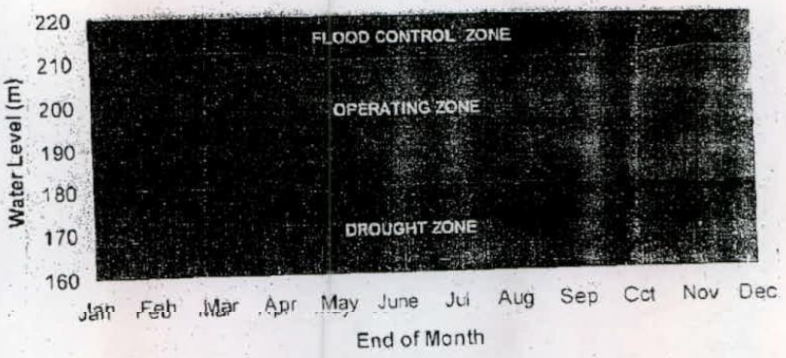
Oct 30 2013 3:15PM HP LASERJET FAX p.3

Board Resolution No. OG3-1209

ANGAT RESERVOIR



2. The reservoir operational plans shall be prepared by the TWG and approved by the NWRB for more efficient management of the reservoir and for stable water supply. The reservoir operational plan intervals are the following:
   a) Annual Operational Plan - Annual plan at the start of the cropping operation in November)
   b) Seasonal Operational Plan - Seasonal plan to consider the seasonal cropping operations of NIA-AMRIS.
   c) Monthly Operational Plan - Monthly plan to incorporate changes in hydrological and climatic conditions.
   d) 10-day Operational Plan or as needed - To incorporate changes in flow duration, and request by the users and concerning agencies.
3. All water releases from the reservoir, in principle, shall be made by turbine discharges and must be recommended by the TWG and approved by the NWRB; except when the water level is above the NHWL.
4. When water level is above the NHWL, the reservoir operations shall be in accordance with the flood operation rule. The TWG shall review the flood operation plan of the Flood Forecasting and Warning System for Dam Operations (FFWSDO) before the operations commence. Monitoring report shall be submitted to the NWRB Board.
5. When there is sufficient available water supply from the reservoir as determined by the NWRB, all of the water requirements of municipal and irrigation uses shall be satisfied. However, during periods when there is deficit in the available water supply, the water releases for municipal and irrigation uses shall be reduced in accordance with the Philippine Water Code.
6. The water level of the reservoir at any given time shall not be allowed to fall in the drought zone or below Elev 180 M; except during critical water shortages

where the water releases shall be made on the following order of priority: i) Municipal use ii) Irrigation use iii) River maintenance.

7. Requests for additional water releases for power generation or for the maintenance of the minimum elevation of Bustos Dam and Ipo Dam shall be subject to the approval of NWRB.

8. When the water level is within the operating zone and there is incoming weather disturbance, pre-release shall be allowed provided that the flood operation shall not adversely affect the requirements of the water supply and its recovery to its full capacity. The Operator/FFWSDO shall submit to NWRB for approval the flood operation plan indicating the volume of water to be released and its release time.

9. NWRB approval is not required for water releases during emergency reservoir operation. Provided that the water releases as determined by the Operator shall not adversely affect the requirements of water supply in normal operation and the recovery of the reservoir to its full capacity. The operational procedures of such emergency shall be reviewed by the TWG for appropriate water level reduction. The emergency reservoir operations are defined as follows:

   a) *Black start* – In time of system black out, the plant may be dispatched for immediate restoration of power to the Luzon Grid.

   b) *Major earthquake* – After major earthquake, when safety of the dam is at stake, the reservoir water must be lowered at a safe reservoir level as determined by the Operator.

   c) *Abnormal seepage* – When abnormal seepage trend is observed that might compromise the safety of the dam, reservoir water level must be lowered as determined by Operator to relieve the dam/dyke from high hydraulic pressure.

10. The TWG shall review the Angat Reservoir operation rules every 5 years or whenever necessary to incorporate the long-term changes in hydrological conditions and to improve the operation with advanced technology and state-of-the art system. Any revision made on the operation rules is subject for NWRB approval.

This resolution supercedes NWRB Resolution No. 02-1298, 004-0204 and 004-0406.

IN WITNESS WHEREOF, we have hereunto set our hand this December 10, 2009 in Quezon City:

Sec. Jose L. Atienza Jr., DENR (Chair)
rep. Usec. Demetrio L. Ignacio, Jr.

Acting Dir. Gen. Augusto B. Santos, NEDA (Vice-Chair)
rep. ADG Rubén S. Reinoso, Jr.

Oct 30 2013 3:16PM HP LASERJET FAX p.5

Board Resolution No. 023-2209

Members:

Sec. Margarito T. Teves, DOF
rep. Dir. Soledad Emilia J. Cruz

Sec. Agnes VST Devanadera, DOJ
rep. Atty. Ruben F. Fondevilla

Sec. Francisco T. Duque III, DOH
rep. Engr. Joselito M. Riego De Dios

Dir. Guillermo Q. Tabios III, NHRC-UP

Dep. Exec. Dir. Nathaniel C. Santos, NWRB

RESOLUTION NO. 255-2, SERIES 1985
April 8, 1985 - 255th Council Meeting
MAGAT OPERATION RULE CURVE

The Executive Director submitted for Council consideration the proposed rule curve and operation criteria for the Magat Reservoir in order to optimize benefits from the project and to safeguard against shortages of water supply for power generation and irrigation purposes.

The proposed operation rule curve would service the total MPMP service area of 102,000 has. during both the wet and dry seasons as well as provide for average power generation of 120.5 MW (continuous) or 1,058 GWH annually.

The Council adopted the following resolution:

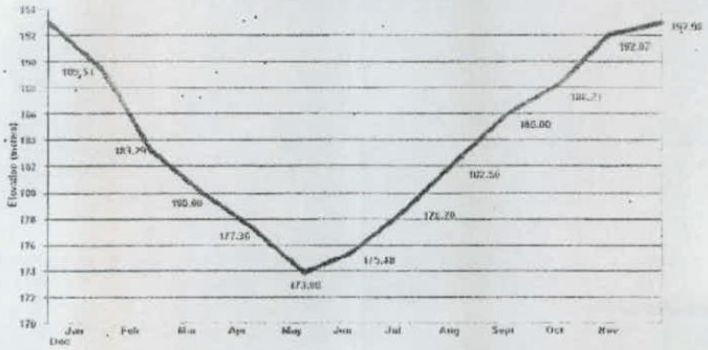
RESOLVED, AS IT IS HEREBY RESOLVED, to adopt the operation rule curve of the Magat Reservoir in order to optimize the power and energy generation capability of the Magat Power Plant.

RESOLVED FURTHER, that the following criteria be observed in conjunction with the rule curve:

a) The water surface elevations of the reservoir at any given time should not be allowed to go below the rule curve.

b) As long as the water surface elevation is above the rule curve, additional water releases for power generation should be allowed in addition to release requirements for irrigation, provided, that the resulting reservoir level will not fall below the rule curve.

Magat Reservoir Rule Curve

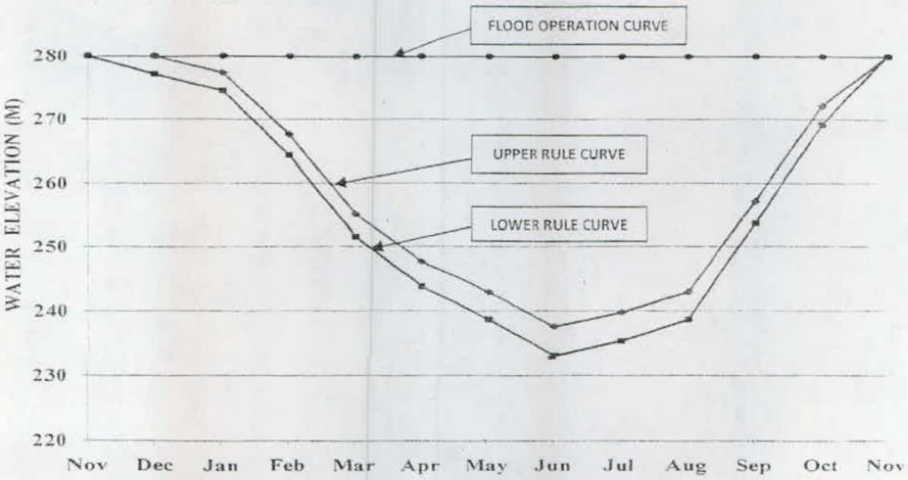


Certified by:

ARCHIE EDSEL C. ASUNCION
Board Secretary

SAN ROQUE RESERVOIR OPERATION RULE (2013)

The operation of the San Roque Reservoir shall be governed with the reservoir operation guidelines in conjunction with the operation rule curves as shown:



Month	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Flood Rule Curve (M)	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0
Upper Rule Curve (M) (Start of the Month Elev)	280.0	280.0	277.3	267.6	255.1	247.7	242.9	237.5	239.8	242.8	257.2	272.0
Lower Rule Curve (M) (Start of the Month Elev)	280.0	277.1	274.5	264.4	251.5	243.7	238.7	233.0	235.3	238.7	253.6	269.1
Design Inflow (CMS)	67.8	41.9	25.0	21.6	18.9	18.7	23.6	41.7	89.8	132.7	117.4	94.1
Irrigation Requirement. (CMS)	58	44	58	66	35	5	0	25	70	73	45	35
Proposed Water Supply Requirement (CMS)	8	8	8	8	8	8	8	8	8	8	8	8
River Maintenance (CMS)	2	2	2	2	2	2	2	2	2	2	2	2
Power Contracted Capacity (MW)	115	115	115	115	115	115	115	115	115	115	115	115