Philippine Electricity
Market Corporation

INCREASING PENETRATION OF VRE RESOURCES AND THE RESERVE MARKET

by the Technical Committee

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LIST OF ACRONYMS

A/S	Ancillary Services
ASPP	Ancillary Services Procurement Plan
CREZ	Competitive Renewable Energy Zones
DOE	Department of Energy
ERC	Energy Regulatory Commission
ESS	Energy Storage Systems
FIT	Feed-in Tariff
NGCP	National Grid Power Corporation of the Philippines
PEMC	Philippine Electricity Market Corporation
RE	Renewable Energy
VRE	Variable Renewable Energy
WESM	Wholesale Electricity Spot Market

1. INTRODUCTION

The last four years saw the increasing contribution of Variable Renewable Energy (VRE) resources[1] in the power generation mix of the Philippines. The increase was largely attributed to the entry of wind and solar farms, following the issuance of policies by the government in the previous years, specifically the adoption of the Feed-in Tariff (FIT) Rules[2] in 2010, the approval of the FIT rates[3] in 2012, and the issuance of guidelines in awarding certificates for FIT eligibility[4] in 2013 to encourage the entry of VRE resources. Electricity generation from VRE resources is further expected to grow, considering the increase in the installation targets for FIT-eligible solar and wind farms in 2015.[5]

On the standpoint of the country's electricity market, the increasing penetration level of VRE Resources promotes lower market prices due to the fact that the respective nominations from these resources are prioritized in the Merit Order Table.[6]

In 2016, the Technical Committee took the initiative to undertake a study regarding the penetration of VRE resources in the power system and to further understand its effect on the reserve requirement. Early in the study, the TC realized the need to consolidate in a single document

[1] **Variable Renewable Energy Generating Facility**. A facility consisting of one or more Generating Units, where electric Energy is produced from a source that is renewable, cannot be stored by the facility owner or operator and has inherent intermittency that is beyond the control of the facility owner or operator. For avoidance of doubt, it refers to Wind Farms, Photovoltaic Generation System, and Run-of-River Hydroelectric Generating Plant.
Ref: Philippine Grid Code 2016 Edition.

[2] ERC Resolution No. 16, Series of 2010.

[3] ERC Resolution No. 10, Series of 2012.

[4] DOE Circular DC2013-05-0009.

[5] DOE Circular DC 2015-07-0014.

[6] Section 2 of Republic Act No. 9513 *Renewable Energy Act of 2008*

the changes in reserve categories and the procedures from the present Central Scheduling of Reserves and the eventual implementation of a reserve market.

1.1. Objective and Scope of the Study

This study aims to present the growth of VRE resources, specifically for wind and solar farms, in the Philippines and the challenges it poses on system and market operations.

This study also aims to discuss the opportunities that the Reserve Market can offer to address foreseen problems that the increasing penetration level of VRE resources in the Philippines.

1.2. General Outline

The next chapter discusses the historical growth of VRE resources in the Philippines along with the review of relevant policies and issuances promulgated by the Department of Energy (DOE) and Energy Regulatory Commission (ERC). An outlook on the projected growth of VRE resources based on the committed and indicative projects initiated by the private sector, which were subsequently reviewed and approved by the DOE, is also presented.

Furthermore, the challenges that the increasing penetration level of VRE resources poses in the power system of the country and the respective recommendations are presented in Chapter 3.

Chapter 4 details the current state of reserve provision in the WESM, a review of various VRE Integration Studies, and the opportunity that the Reserve Market introduces to the electric power industry.

2. VRE RESOURCES IN THE PHILIPPINES

Prior to 2005, the share of VRE resources in the energy generation of the country is practically zero. The implementation of FIT rates along with the continuous support from the government through formulation of policies and guidelines in relation to Renewable Energy (RE) development led to the increase in the number of VRE resources that are integrated to the power system.

With a total of 281 Department of Energy (DOE)-awarded solar and wind projects as of 2017, it can be expected that the penetration level of VRE resources will continue to increase in the following years[7].

2.1. Review of Relevant Policies and Issuances

Acknowledging that there is a need to meet the growing power demand and to address the effects of climate change and increasing fossil fuel prices, the Philippine government enacted the Republic Act 9153 or the Renewable Energy Act of 2008 (RE Act) which aims to promote the development, utilization, and commercialization of RE resources.

As mandated by the RE Act, the DOE, being the policy-making body of the energy industry, issued a number of department orders and circulars to continuously encourage investments in RE resources and support its development. The rules and regulations regarding the implementation of RE Act was promulgated through the Department Circular No. 2009-05-0008.

On the regulatory side of the industry, the Energy Regulatory Commission (ERC), was ordered under Section 7 of the RE Act to

[7] NREB Summary of Renewable Energy Projects as of 31 December 2017.

formulate and promulgate the FIT Rules for VRE resources. With this, the ERC issued Resolution No. 16 Series of 2010 providing the FIT Rules which guaranteed eligible RE developers with fixed rates for a period of 20 years.

In line with the implementation of FIT Rules, the DOE endorsed the installation targets for FIT-eligible RE resources – initially 200 MW for wind and 50 MW for solar – to the ERC which resulted to the issuance of Resolution No. 10 Series of 2012 approving the FIT Rates for different types of RE resources. Further revisions to the installation targets and FIT Rates were issued in 2015 to further encourage RE development in the country. Table 1 shows the approved installation targets in 2011 and approved FIT Rates in 2012 (FIT1) along with revised installation targets and approved FIT Rates in 2015 (FIT2) for solar[8] and wind[9] farms.

Table 1 VRE Resource Installation Target and FIT Rate

VRE Resource	Initial FIT Installation Target (MW)	FIT1 Rate (PHP/kWh)	Amended FIT Installation Target (MW)	FIT2 Rate (PHP/kWh)
Wind	200	8.53	400	7.40
Solar	50	9.68	500	8.69

In accordance with Section 20 of the RE Act, the framework for the implementation of Must Dispatch and Priority Dispatch of the RE resources in the Wholesale Electricity Spot Market (WESM) was promulgated by the DOE through the Department Circular No. 2015-03-0001. Section 4 of the circular defines Must Dispatch and Priority Dispatch as follows:

[8] ERC Resolution No. 06, Series of 2015.

[9] ERC Resolution No. 15, Series of 2015.

"Must Dispatch is facilitated in the WESM by qualified and registered intermittent RE-based plants, whether or not under FIT system, such as wind, solar, run-of-river hydro, or ocean energy, according to the preference in the dispatch schedule whenever generation is available. The enjoyment of Must Dispatch by intermittent RE-based plants is based on the difficulty to precisely predict the availability of RE resource thereby making the energy generated variable and irregular and the availability of resource inherently uncontrollable pursuant to Section 20 of the RE Act."

"Priority Dispatch means giving preference to biomass plants, under the FIT system, in the dispatch schedule pursuant to Section 7 of RE Act."

Following the mandate of the DOE, the Philippine Electricity Market Corporation (PEMC) initiated the necessary rules change proposals to reflect the implementation of preferential dispatch, FIT payment and collection, and non-expiry of standing submissions in the WESM Rules and relevant Market Manuals. The proposal was completed in 2016 and was thereafter approved by the Rules Change Committee and the Philippine Electricity Market (PEM) Board for endorsement to the DOE. The DOE promulgated the rules changes through the Department Circulars No. 2016-01-0002 and 2017-03-0002.

Moreover, the rules and guidelines governing the establishment of Renewable Portfolio Standards (RPS) for on-grid areas was promulgated in 2017.[10] With the RPS, energy industry participants are mandated to source or produce a specified portion of their electricity from eligible RE

[10] DOE Circular DC2017-12-0015.

resources. This promulgation aids to meet the target 35% share of RE resources in the energy generation mix of the country by 2030.

2.2. Growth of VRE Resources

With the laws, issuances, and policies discussed in the previous section on the development of VRE resources in the country, the historical and projected growth of wind and solar farms presented in this section shall serve as evidence for the effectiveness of the initiatives made by the government in committing its objective to source clean and low-cost electricity for the Philippines.

Back in September 2000, the National Renewable Energy Laboratory (NREL) published a wind resource analysis and mapping study in the Philippines which presented that various areas are ideal for wind power installation. These areas include Bangui and Burgos towns in Ilocos Norte. This led to the construction of the 25-MW Bangui Wind Farm Phase I which was then commissioned in 2005 marking the start of integration of wind farms to the country’s power system as shown in Figure 1.

With the approval of the FIT Rates in 2012, there was a notable increase in the number of VRE resources in 2014. This increase can be largely attributed to the start of the commercial operation of wind and solar farms under FIT: 22-MW San Carlos Solar Farm (SaCaSol), 150-MW Burgos Wind Farm, and 81-MW Caparispisan Wind Farm.

As the cost of solar PV panels decreases, the increase in the number of solar farms in the country became evident. The commissioning of the 50-MW Tarlac Solar Farm, 63.3-MW Calatagan Solar Farm, and 132.5-MW Cadiz Solar Power Plant in 2016 resulted to the 742-MW increase in the installed capacity of solar farms.

By 2017, the installed capacity of wind farms is at 427 MW where 393.90 MW are FIT-eligible. The installed capacity of solar farms, on the other hand, is at 885 MW where 526.95 MW are FIT-eligible. Thus, the revised installation targets, for FIT-eligible solar and wind farms from Table 1 were already met. Capacities which were not approved to be FIT-eligible are traded in the WESM.

Given the installed capacities of wind and solar farms and the recorded non-coincidental peak demand of 13,789 MW in 2017[12], the percentage of penetration of wind and solar are 3.10% and 6.42%, respectively[11].

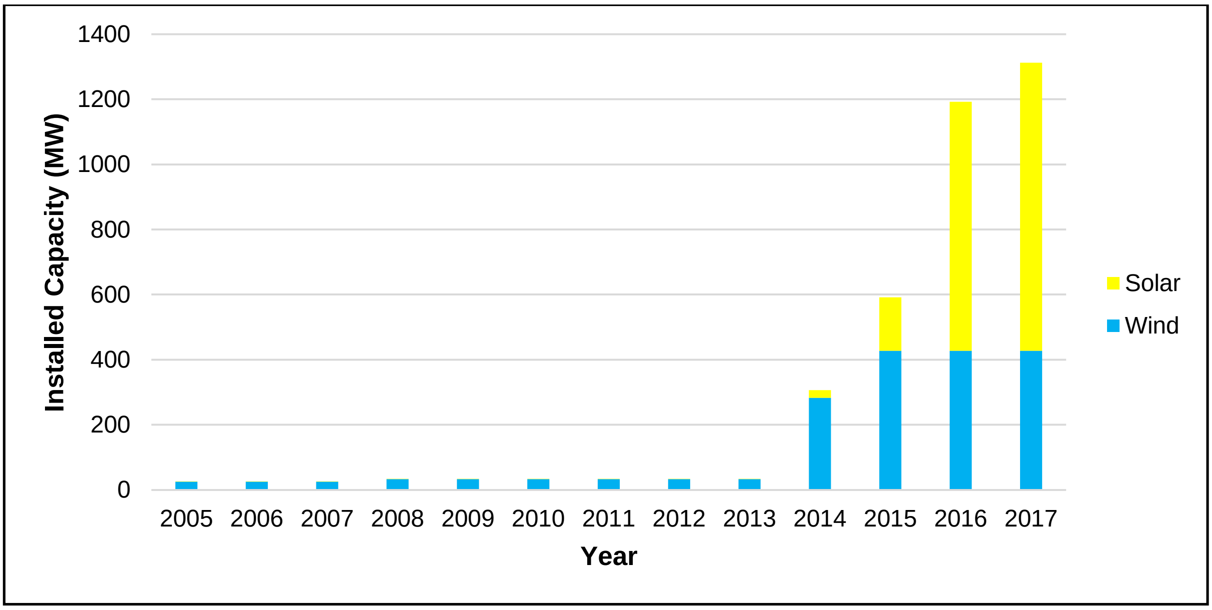

Figure 1 Historical Installed Capacities of VRE Resources[12]

To look into the share of VRE resources in the supply of electricity, Figure 2 shows the 2017 WESM Power Generation Mix for Luzon and Visayas grids.[13] Based on the data, the primary source of electricity in

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[11] The penetration levels were calculated as: $Penetration(\%) = \frac{VRE\ Installed\ Capacity}{System\ Peak\ Demand} X100$

[12] DOE Philippine Power Statistic as of 31 December 2017.

[13] "Other REs" include geothermal and hydropower power plants.

Luzon is coal which covers 49% of the total electricity supply. On the other hand, for Visayas grid, RE resources dominate the electricity supply at 53%. For both grids, VRE resources have minimal contribution (i.e. 2% for Luzon and 7% for Visayas).

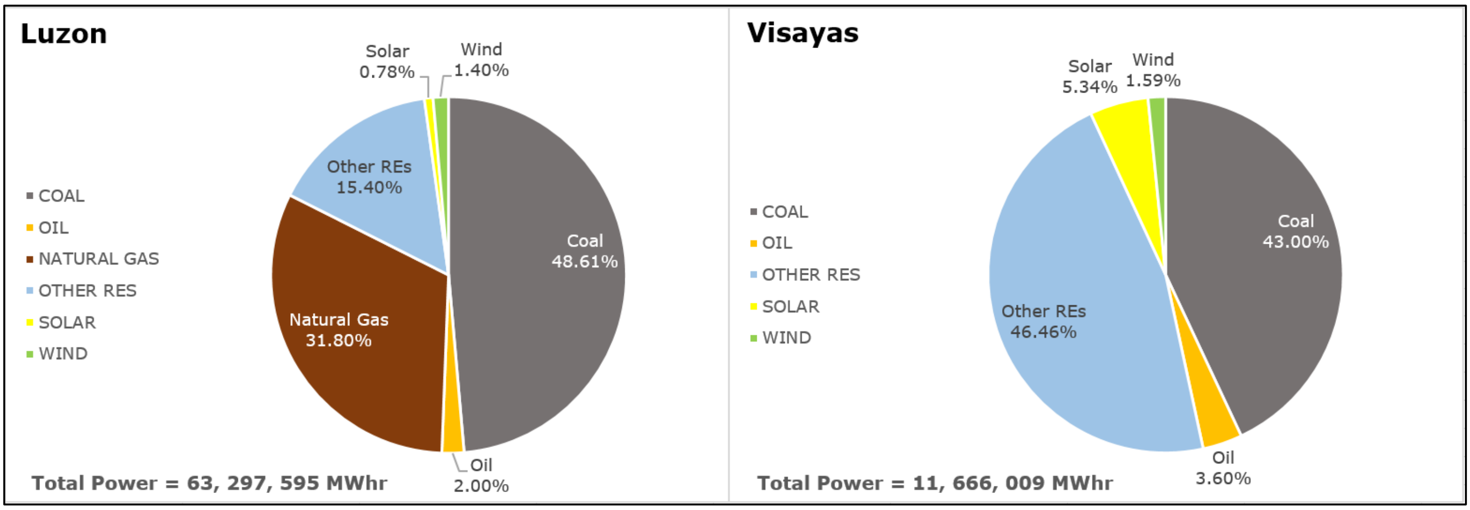

Figure 2 Power Generation Mix in 2017[14]

From the historical growth of VRE resources in the power system, it can be expected that there will be further increase in their installed capacities. The projection on further growth of VRE resources until 2022 is shown in Figure 3. This assumes that all the initiated projects by the private sector, whether committed or indicative, as of December 2017 will be completed based on their published target completion date. With this, it can be expected that by 2022, the installed capacities of solar and wind will be 2612.06 MW and 2625.4 MW, respectively.

[14] WESM accumulated Metered Quantity per resource from January to December 2017.

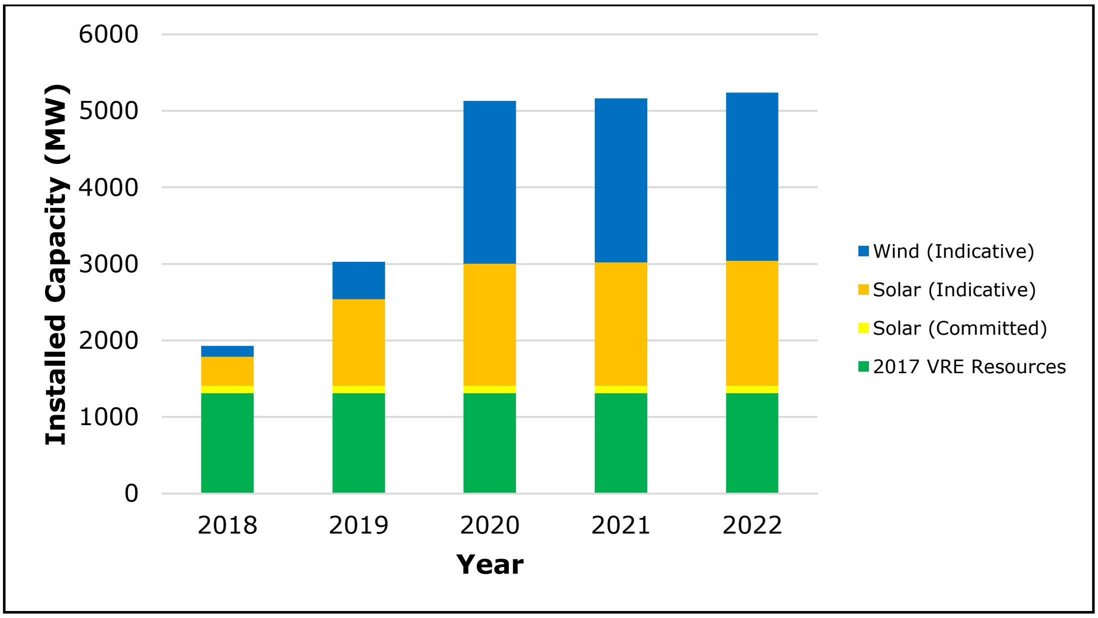

Figure 3 Projected Growth of VRE Resources[15]

The growth in the peak demand of the country together with the penetration level of VRE resources is shown in Table 2. From the table, significant increase of 9.72% in the penetration level of wind farms can be expected starting 2020 which is largely attributed to the indicative wind projects in Visayas region amounting to 1075 MW of installed capacity.

[15] DOE data on private sector initiated power projects as of December 2017.

Table 2 Projected Peak Demand and Penetration Level of VRE Resources

Year	Projected Peak Demand (MW)[16]	Projected Penetration Level of VRE Resources (%)
2018	14575	9.32% (solar) 3.70% (wind)
2019	15422	13.69% (solar) 5.95% (wind)
2020	16323	15.77% (solar) 15.67% (wind)
2021	17221	15.06% (solar) 14.93% (wind)
2022	18173	14.37% (solar) 14.45% (wind)

There is an evident growth in the installation of solar and wind farms in the country. With this, system supply variability can be expected to increase as well. Maintaining system stability and reliability will become a challenge in the future thus sufficient reserves must be secured along with proper system network planning.

[16] DOE Power Development Plan 2016-2040.

3. CHALLENGES AND RECOMMENDATIONS

The energy sector is facing various challenges in relation to variability, uncertainty, and concentration of VRE resources. This is highly attributed to the increasing penetration level of VRE resources in the Philippines as presented in Chapter 2 of this study. This chapter discusses and presents actual data on these and provides respective recommendations.

3.1. Variability of VRE Resources

VRE resources, as the name implies are variable in nature. Variability refers to the changes in the generation output of a VRE resource. Unlike generation from a conventional thermal power plant such as coal-fired which may be controlled at will by regulating the amount of steam driving the turbine, wind speed and solar irradiance cannot be controlled to a desired level. Increasing contribution from VRE resources introduces challenges to system reliability and frequency stability. Since its power output is variable, any sudden reduction or increase in the power supplied to the system can cause the system frequency to deviate from its nominal level.

3.1.1. Illustrative Examples of Variability of Wind Resources

To illustrate the variability of wind farms, Figure 4 shows the five-minute snapshot of the generation metered quantity of wind farms in Ilocos Region on 20 October 2017, a day when Luzon grid was declared to be on red alert.

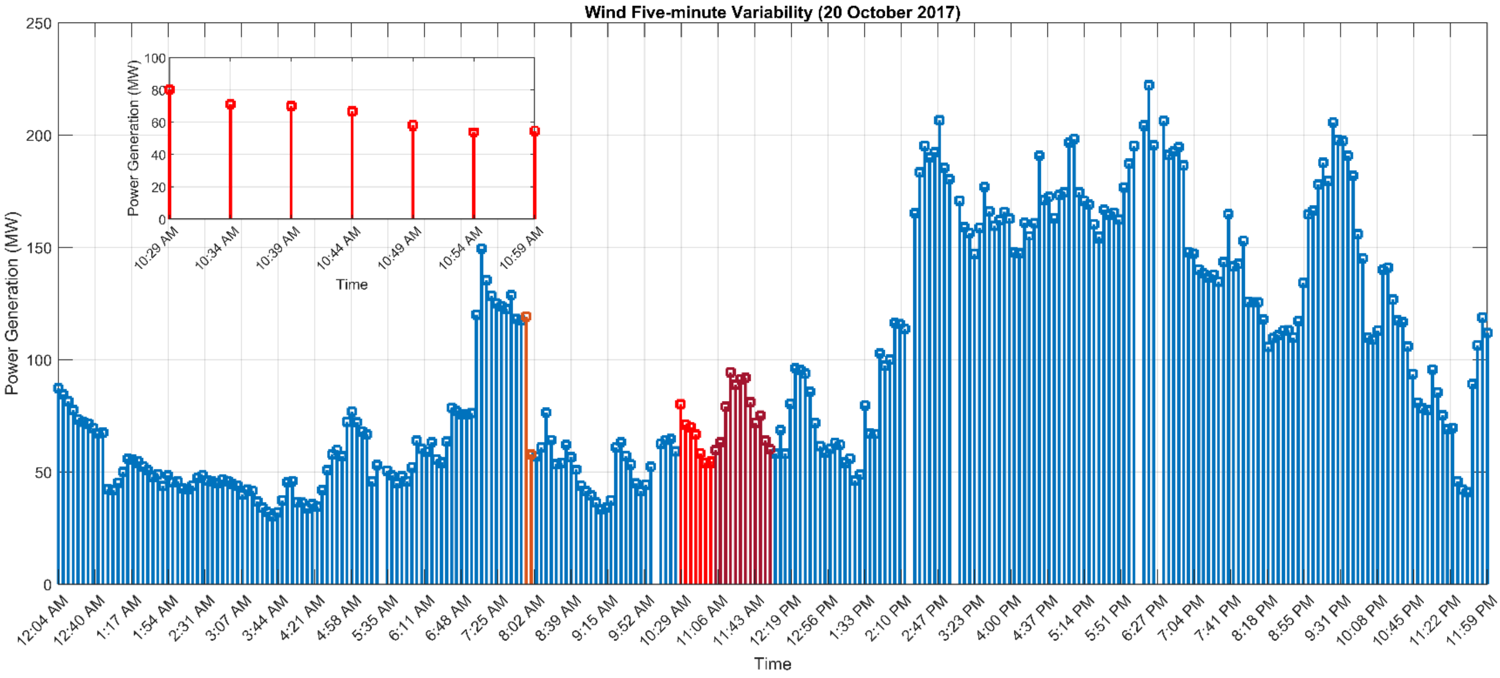

Figure 4 Five-minute Snapshot of Wind Farms Generation in Ilocos Region

At 9:04 AM, the Pagbilao-Tayabas Transmission Line 1 tripped causing the Pagbilao Coal Fired Power Plant Units 1 and 2 to be isolated. From 10:29 AM to 10:59 AM (red region), the power generation coming from wind farms dropped from 80.2 MW to 54.61 MW causing a total drop of 25.59 MW to the electricity supply of Luzon grid in a span of 30 minutes which further exacerbated the condition of the grid. The System Operator then declared the grid to be on red alert from 11:00 AM to 12:00 PM (maroon region).

During the same day, it can likewise be observed in the figure that from 7:54 PM to 7:59 PM (orange region) there is a drop of 61.46 MW in the generation of wind farms in a span of five minutes. This clearly illustrates that integration of wind farms to a system can cause considerably large variations to the power supply in a short span of time.

The five-minute variations shown in Figure 4 led to the variations in the hourly generation of wind farms as shown in Figure 5. On the 14th hour, the generation of wind farms dropped by 26.3 MW, 6.28 MW, 3.87 MW, and 3.17 MW for Wind Farms 1, 2, 3, and 4, respectively. These changes caused a total decrease of 39.62 MW. On the 15th hour, however, there was an increase of 80.94 MW to the system's electricity supply caused by the increase in generation of the referred wind farms by 45.34 MW, 24.12 MW, 4.94 MW, and 6.54 MW, respectively.

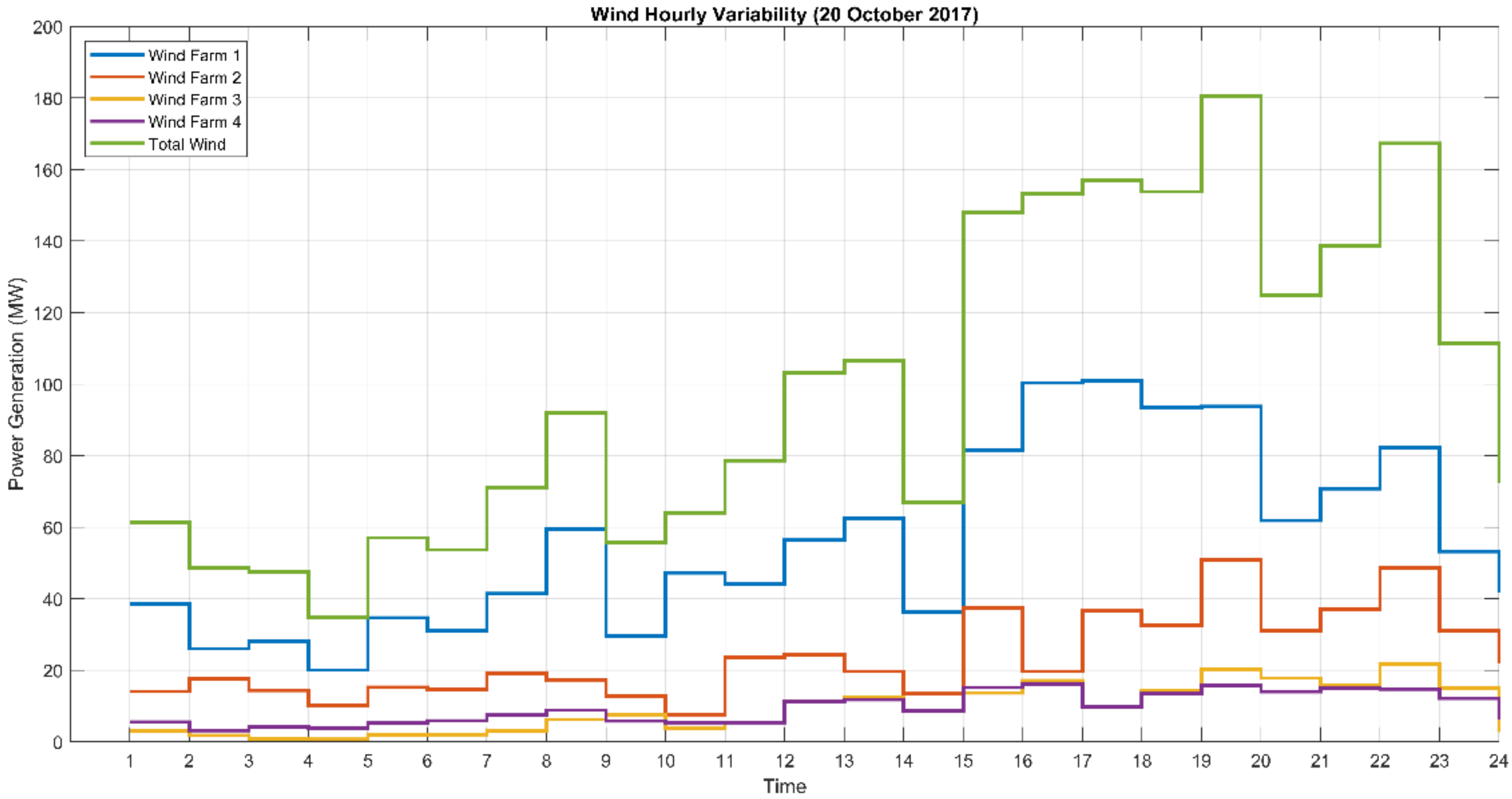

Figure 5 Hourly Generation of Wind Farms in Ilocos Region

3.1.2. Illustrative Examples of Variability of Solar Resources

Solar farms introduce variability in supply during daytime. Figure 6 shows the five-minute snapshot generation metered quantity of solar farms in Negros Island on 07 August 2017. On this day, Automatic Load Dropping was activated twice in Visayas grid due to reduction in the power output of solar farms in Negros Island and to the absence of HVDC control to regulate system frequency following the Leyte earthquake.

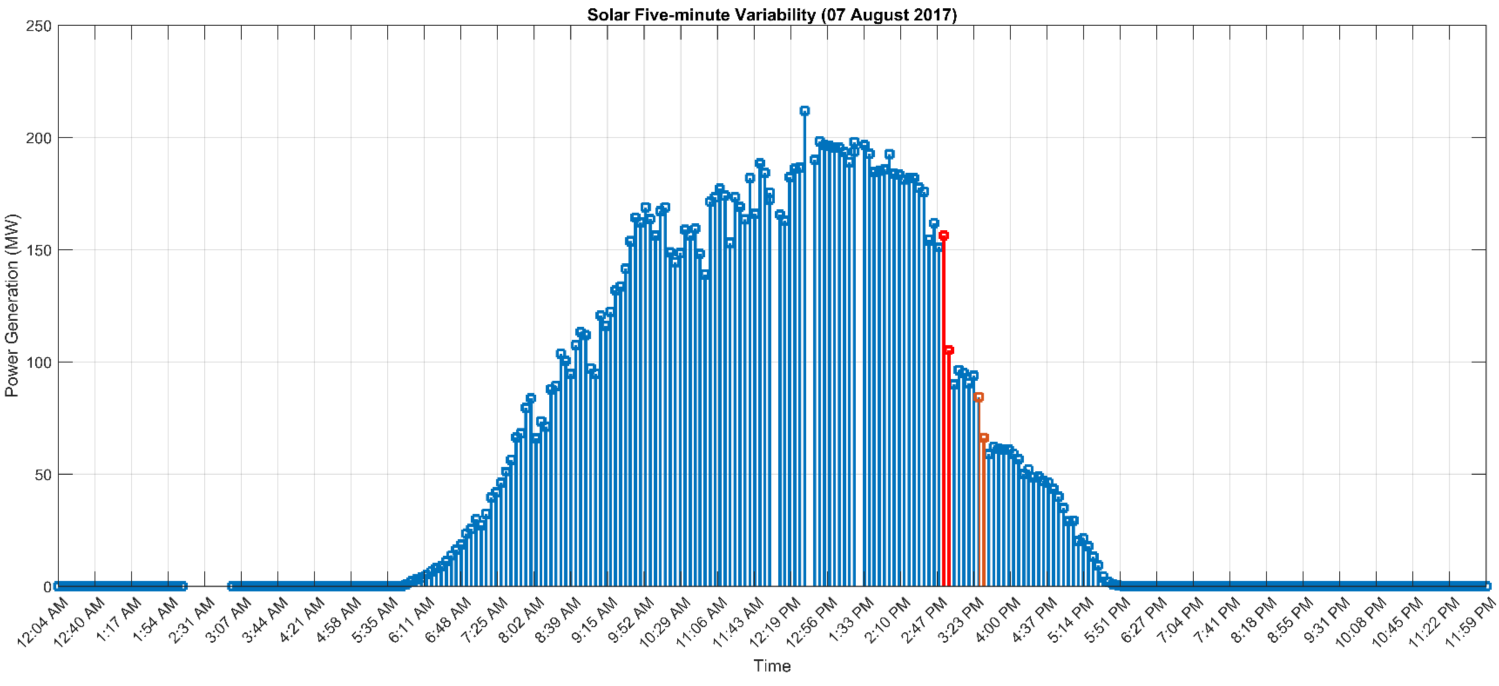

Figure 6 Five-minute Snapshot of Solar Farms Generation in Negros Island

Based on Figure 6, from 2:54 PM to 2:59 PM (red region), there is a drop of 51.16 MW in the electricity generation of solar farms in Negros Island in a span of five minutes. Due to this, the System Operator activated 1st Level Automatic Load Dropping at 2:57 PM in order to restore the system frequency to its nominal value. Another considerable drop of 18.22 MW occurred again between 3:29 PM and 3:34 PM (orange region) which likewise resulted again to the activation of 1st Level Automatic Load Dropping at 3:31 PM. These events illustrate that simple natural events such as change in solar irradiance due to the passage of group of clouds can significantly affect the power system if the penetration level of the VRE resource is considerably high and there is not enough replacement power to regulate the frequency.

Figure 7 shows the hourly variation in the generation metered quantity of each solar farms in Negros Island on 20 June 2017. Between the 10th and 12th hour, it can be observed that there is a significant drop of 44.85 MW, 9.11 MW, and 18.96 MW in the power generation of Solar Farms 1, 2, and 3, respectively. This caused a total of 72.92 MW drop in the gross power generation in the island during the said interval. On the other hand, the power generation of the other five (5) solar farms varied within 1 MW to 4 MW.

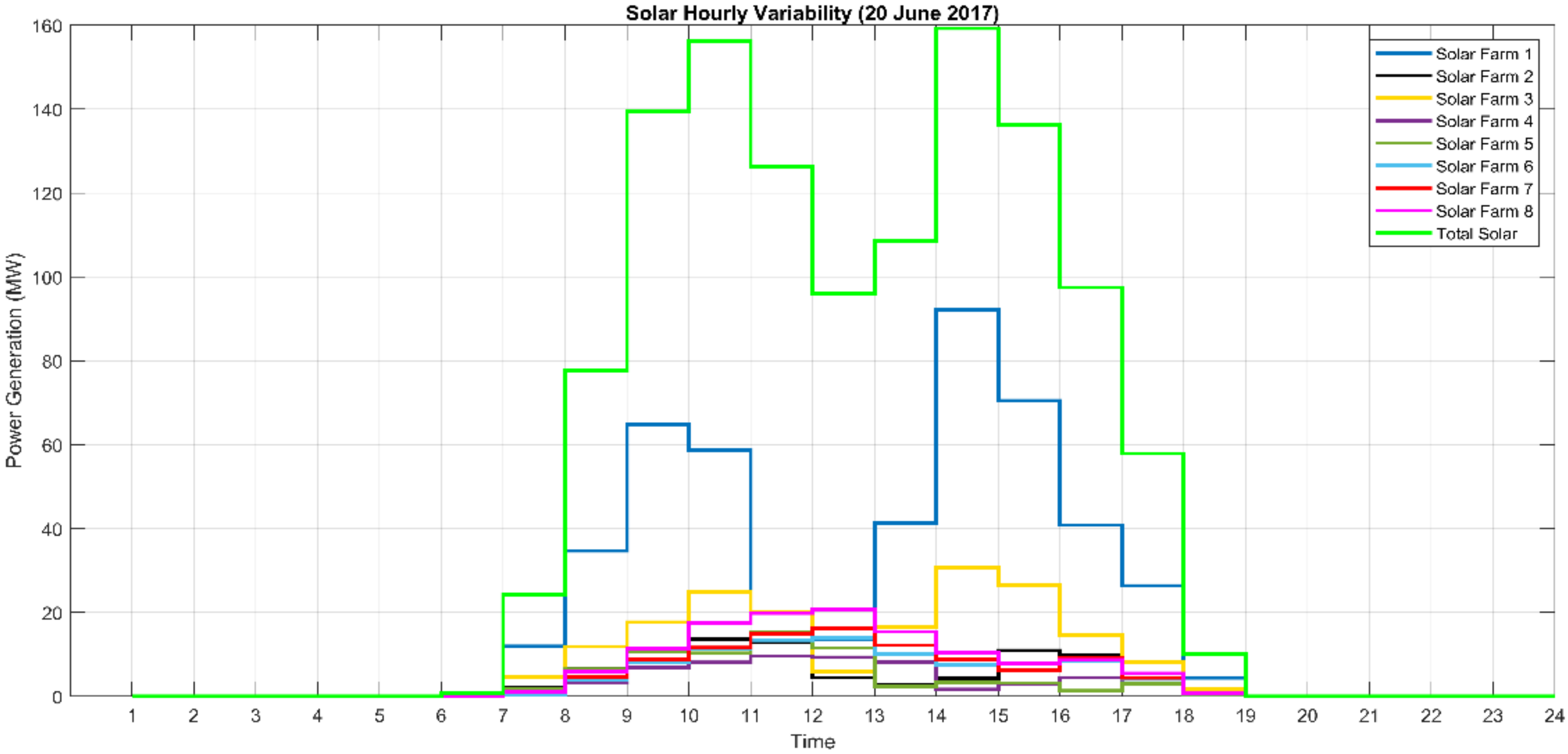

Figure 7 Hourly Generation of Solar Farms in Negros Island

In between the 12th and 15th trading hour, the power generation of Solar Farms 1, 2, and 3 significantly increased by 56.70 MW, 6.43 MW, and 20.61 MW, respectively while the power generation of Solar Farms 4, 5, 6, 7, and 8 dropped by 6.27 MW, 8.39 MW, 5.90 MW, 10.038 MW, and 12.83 MW, respectively.

At this point, it is of importance to note that the similar behaviours across Solar Farms 1 to 3 were observed because of their proximity with each other. The same is true for solar farms 5 to 8. This challenge will be further discussed in Section 3.3 of this study.

Having shown in Sections 3.1.1 and 3.1.2 that wind and solar farms can significantly change the power supply to the system, it is recommended to utilize support technologies such as Energy Storage Systems (ESS) and Synthetic Inertia to address the variability of VRE resources.

3.1.3. Role of Energy Storage Systems

ESS such as grid-connected batteries are expected to address the supply variability introduced by VREs. Among many studies that are publicly available, a study by International Renewable Energy Agency (IRENA) highlights the energy smoothing and short-term electricity balancing contributed by Battery Energy Storage System (BESS).[5]

In the said study, the applications of ESS are expected to provide effective results in the following cases:

- **Variable Renewable Energy Smoothing and Energy Time Shift**

  In the grid level, the utilization of ESS integrated with solar and wind farms has been proven to have good effects in the system security and reliability, mostly in smoothing the energy outputs and its economic effects in the energy markets. With an integrated ESS, the output of a solar farm can be smoothened as shown in Figure 8.

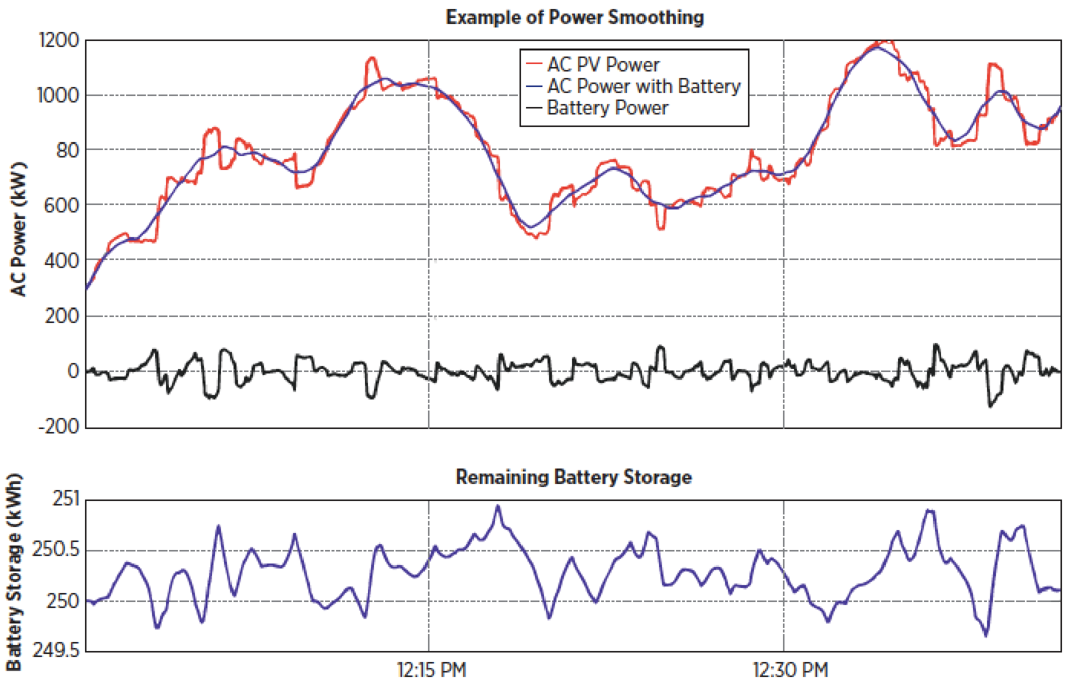

Figure 8 BESS Energy Smoothing[5]

Aside from energy smoothing, ESS can store the power generated by VRE farms to be used later or during the peak hours. This technique is defined as energy time shift. One of the existing Battery Energy Storage (BESS) in Italy uses energy time shift methods to make electricity supply from renewable energy sources more predictable – a unique contribution from ESS.

- **Fast, Short-term Electricity Balancing in Ancillary Markets**

ESS are likewise utilized as A/S Providers in other jurisdictions. One of the advantages of these systems is that they provide bidirectional regulation. Figure 9 illustrates that ESS (left) can fully utilize its MW rating on upward or downward regulation compared to a conventional generator (right) having the same rating.

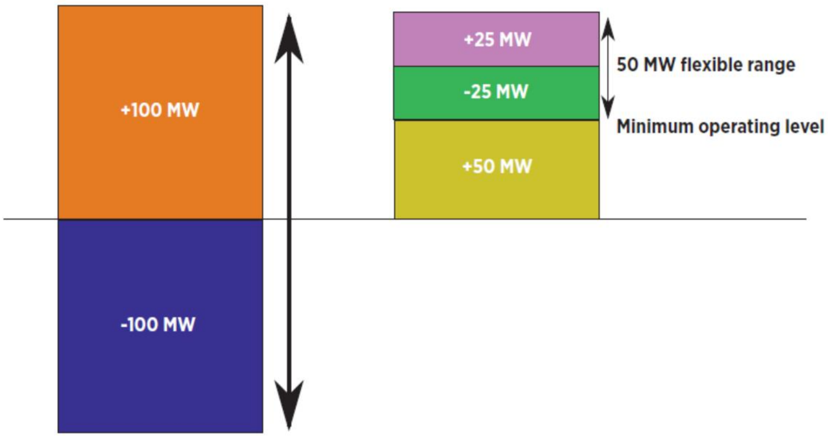

Figure 9 ESS Operating Level VS Conventional Generator[5]

In the categorization of A/S Providers, the response time of each provider is highly considered. In North America, primary control providers are required to respond within 10-60 seconds, while secondary control providers are set to respond within a period not over 10 minutes. On the other hand, tertiary control providers are required to respond during the period over 10 minutes up to several hours to address imbalances and threats to the security of the grid. With the required response time for various categorizations for A/S Providers, ESS may be categorized in any of the categorizations due to its instantaneous response time and controllable supply of energy.

With the characteristics of an ESS presented above, VRE plant operators may opt to integrate the same in their facilities to store excess generated power and utilize it as replacement power in compliance with Section 3 of the DOE Department Circular No. 2015-07-0014 which mandates the RE developer to procure replacement power for any insufficiency it may cause in the supply.

On the other hand, ESS may also be integrated to the grid as stand-alone facility providing services for both energy and reserve markets. In the ERC Resolution No. 9 Series of 2015, the commission already approved the participation of BESS in providing A/S to the power system. Likewise, the Technical Committee’s initiative to introduce changes in the rules regarding the participation of BESS in the WESM has already been approved by the Rules Change Committee (RCC) through its RCC Resolution No. 2018-04 and by the PEM Board through its PEM Board Resolution No. 2018-27. Also, the DOE has also commenced the drafting of the department circular regarding the framework on participation of BESS in the WESM.

3.1.4. Synthetic Inertia

Other than ESS, another emerging technology that may be utilized to address variability of VRE resources in the country’s power system is Synthetic Inertia. The total power system inertia, defined as the measure of the system’s resistance to generation and demand imbalance, determines the initial Rate of Change of Frequency (ROCOF) of the system.[17] Synchronous and induction generators provide inertia to the system by accelerating or decelerating. For example, a frequency dip due to sudden decrease in the generation of VRE resources causes the synchronous and induction generators to decelerate, but the momentum of their spinning turbines resists deceleration and thus providing inertia to the system. This results to the slowing down of the ROCOF which can give time for the operator to restore the system frequency to its nominal value.

[17] Kundur, P. (1994). *Power System Stability and Control.* McGraw-Hill.

As discussed by Anaya-Lara (2014)[1], in the case of modern Wind Turbine Generators (WTG), they do not provide inertia inherently due to the fact that their rotational speed is isolated from the system frequency through the use of power converters. With controller design modification, WTGs will be able to provide inertia to the system, referred to as Synthetic Inertia.

In order to enable WTGs to provide synthetic inertia, the demanded torque from the turbine during normal operation, T_{ref}, is increased by the inertial torque, $T_{inertia}$. This approach is referred to as the Torque Control Approach (TCA). A block diagram for the TCA is shown in Figure 10 where $\frac{df}{dt}$ is the ROCOF and H is the inertial constant.

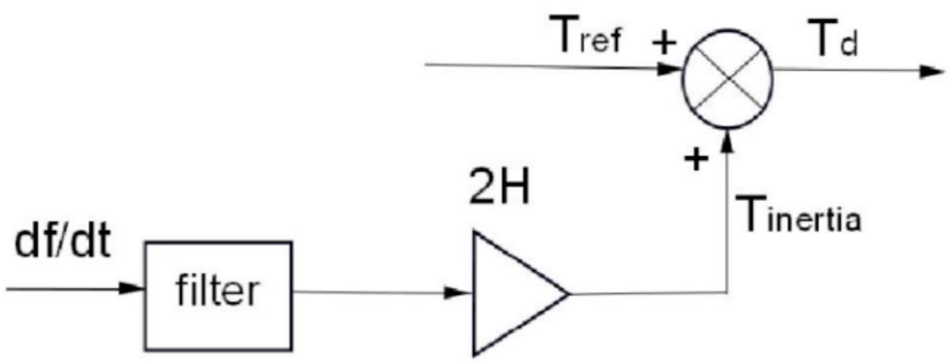

Figure 10 Torque Control Approach Block Diagram[1]

Due to the increase in the demanded torque, the mechanical rotation of the wind turbine will decrease, but its momentum will resist the deceleration which in turn will slow down the ROCOF. Thus, harnessing the inertia from the moving part of the WTG.

The decrease in the speed of rotation of the WTG, may result to revenue loss for the operator. Also, it is still unclear whether synthetic inertia can affect the lifespan of wind turbines. However, in Canada, Hydro-Québec TransÉnergieis already mandates synthetic inertia from wind farms[1].

3.2. Uncertainty of VRE Resources

Aside from variable generation from wind and solar farms, another factor that must be considered in their integration to the system is their uncertainty which refers to the deviation of their actual generation from the forecasted value. With increasing penetration level of VRE resources in the country, the amount of forecast error also increases. For the System Operator, any deviation from the supply-demand balance will require utilization and provision of sufficient amount of reserves.

3.2.1. Illustrative Example of Uncertainty of Solar and Wind Farms

Intermittent renewable energy source-based generators such as wind, solar, run-of-river hydro, or ocean energy are categorized in the WESM as Must Dispatch Generating Units[18] under Generation Companies. Pursuant to the WESM Rules Clause 2.3.1.5, the forecasted quantity of must-dispatch generating units shall be prioritized in the WESM Merit Order Table.[19] This means that the nominations made by the VRE resources for their projected outputs

[18] **WESM Rules Glossary** *"Must Dispatch Generating Unit. A Generating Unit or Generating System so designated by the Market Operator under Clause 2.3.1.5 and is provided Must Dispatch."*

[19] **WESM Rules Clause 2.3.1.5** *"A generating unit or group of generating units connected at a common connection point that is intermittent renewable energy resource-based, whether or not under the Feed-In Tariff system, such as wind, solar, run-of-river hydro or ocean energy with the corresponding DOE certification shall be classified as a must dispatch generating unit, but may at its option be classified as a scheduled generating unit or a non-scheduled generating unit subject to Clause 2.3.1.4."*

during a particular trading interval shall be automatically included in the merit order table for that particular trading interval.

Following this procedure, the Market Operator constituted the WESM Manual on Procedures for the Monitoring of Forecast Accuracy Standards for Must Dispatch Generation Units to monitor the Mean Absolute Percentage Error (MAPE) of the VRE resources. The manual likewise adopted the thresholds set by the ERC-approved PGC 2016 Edition for solar and wind farms at 18% MAPE.

With the constituted monitoring procedures, Figure 11 provides the results of the MAPE computation for all registered wind farms with some power plants' MAPE exceeding the 18% threshold. It can also be observed that forecast errors are higher at the early months of the year. However, with only a single-year data, it remains to be seen (in the succeeding years) if this difference in forecast accuracies varies significantly across months of the year. The subsequent effects of these performances may affect the system stability of the power system noting the large amount of installed capacities of wind farms in the Philippines.

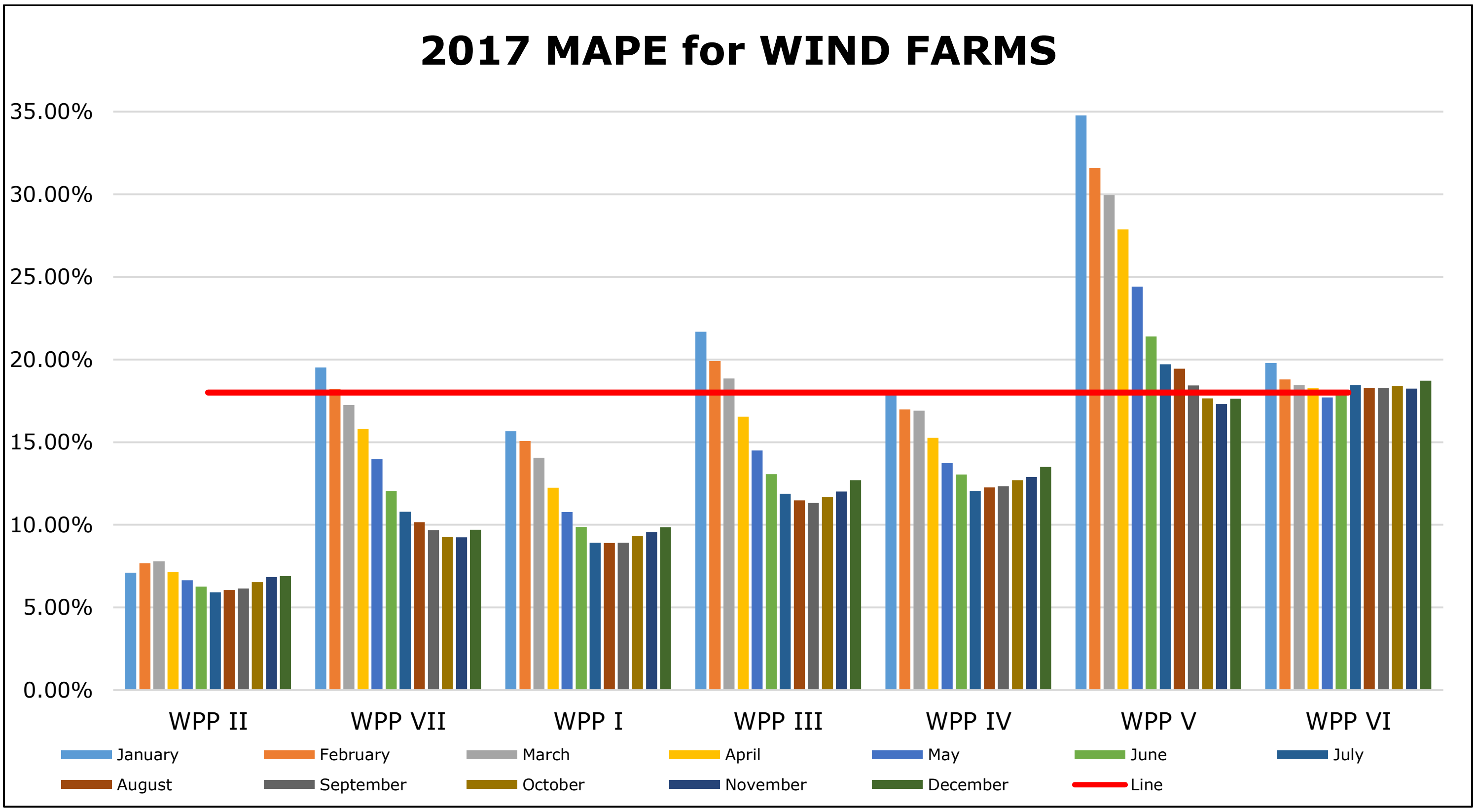

Figure 11 MAPE of Wind Farms

On the other hand, as Figure 12 shows, majority of solar farms were able to meet the set thresholds for their MAPE. This can be attributed to the fact that nomination and generation of solar farms during night time is both zero causing their MAPE to improve.

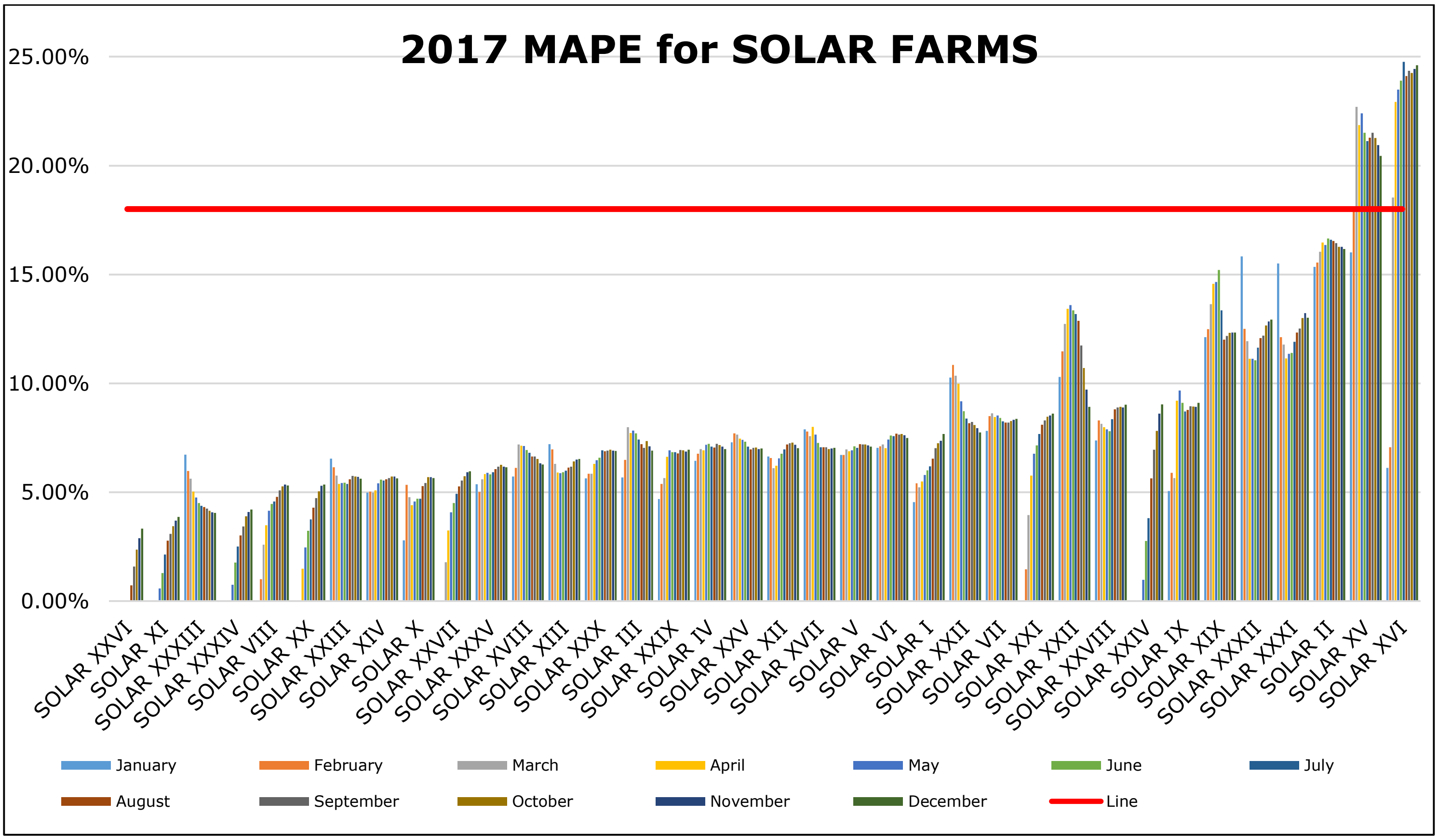

Figure 12 MAPE of Solar Farms

Since wind and solar farms are categorized as must-dispatch generating units, large forecasting errors may result to real-time imbalance between the supply and demand. The System Operator is expected to secure sufficient reserve to mitigate this imbalance. In addressing the uncertainty of solar and wind farms, participants are encouraged to improve their respective forecasting schemes. The current 18% target MAPE may have to be reviewed in the light of increased penetration of VRE resources.

3.2.2. Forecasting Schemes

In terms of forecasting available energy from VRE resources such as solar and wind farms, it is imperative to specify relevant timescales depending on the grid-related procedures. Related to market operation, short term forecasting for these technologies are conducted hours ahead, typically from 0 to 36 hours ahead.

There are various short-term forecasting methodologies that are currently available. Broadly, these can be classified as (a) Time Series - based, (b) Numerical Weather Prediction (NWP) – based, or (c) combination thereof. Comprehensive reviews of these methodologies applied to wind power forecast are presented by Monteiro (2009)[20] and Giebel (2011)[21] while, reviews of methodologies applied to solar PV power forecast is presented in Espinar (2010)[22]. Likewise, a report to the California Energy Commission covers various types of intermittent energy sources.[23]

For time series based forecasting, the latest set of measured quantities such as wind speed or solar irradiance, are used to predict the values including generated power for upcoming immediate time periods. The simplest form for this is referred to as the Persistence Model, wherein, the forecast for all times ahead is set equal to the current value. In fact, this Persistence Model is used as the reference whose performance shall be surpassed by any other forecasting

[20] Monteiro. (06 November 2009). *Wind Power Forecasting: State-of-the-Art 2009.* Tennessee: Argonne National Laboratory.

[21] Giebel, G. (2011). *The State-of-the-Art in Short-Term Prediction of Wind Power.* Technical University of Denmark.

[22] Espinar, B. (2010). Photovoltaic Forecasting: A state of the art. *5th European PV-Hybrid and Mini-Grid* (pp. 250-255). Tarragona, Spain: OTTI - Ostbayerisches Technologie-Transfer-Institut.

[23] (October 2012). *California Renewable Energy Forecasting, Resource Data, and Mapping.* California Energy Commission.

methodology. Other methods include Autoregressive with Moving Average (ARMA), Autoregressive Integrated Moving Average (ARIMA), Kalman Filter Approaches, and even Artificial Neural Networks (ANN).

Shown in Figure 13 is a typical root mean square error (RMSE) for different forecast lengths using various techniques. Without discussing the other techniques, it is emphasized that the percent error for Persistence Method is at 15% for a three-hour ahead wind forecast. Numerical weather prediction models on the other hand, uses weather data to predict wind speed or solar irradiance, then to predict electric power using power curves.

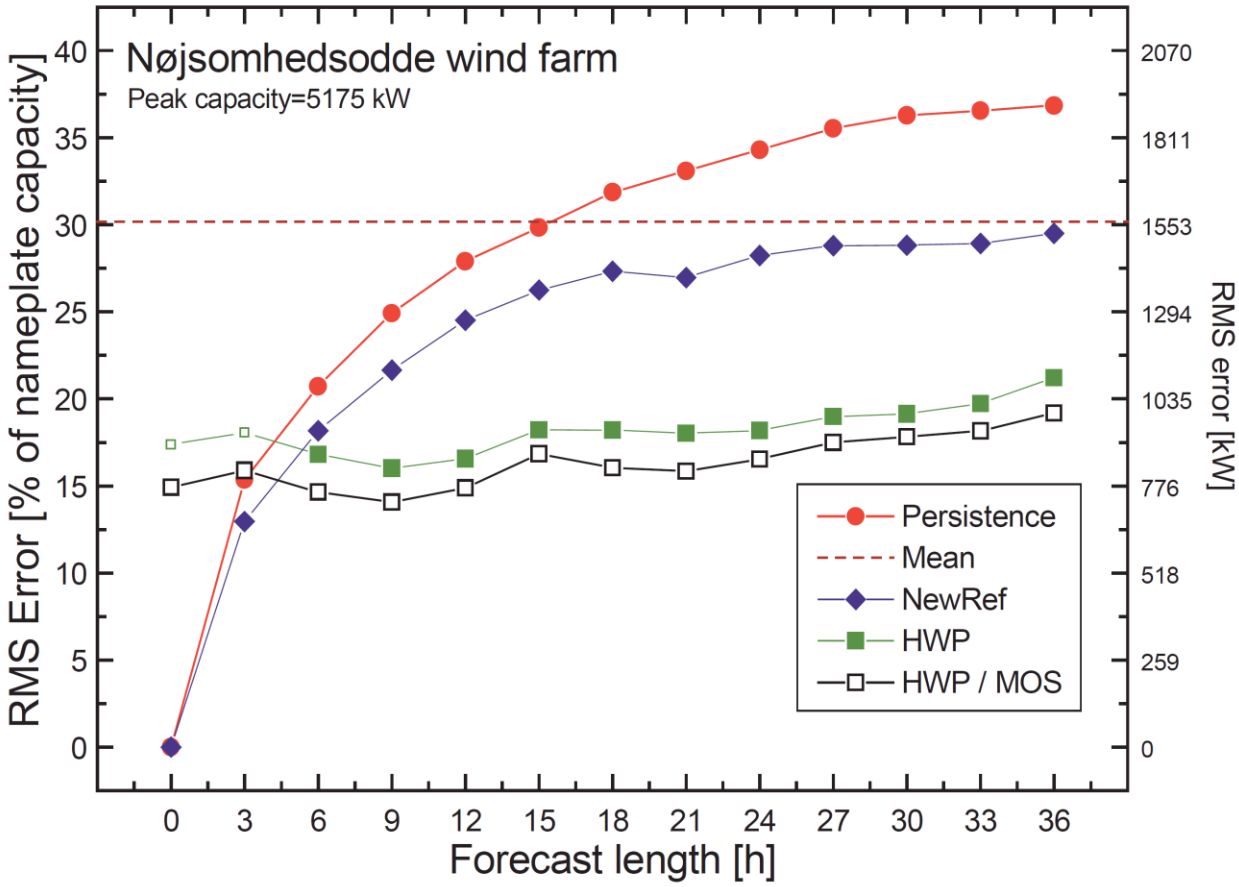

Figure 13 Typical RMS Error of Different Forecasting Schemes[21]

Another important issue on wind power forecasting is Ramp Forecasting. This includes prediction of significant variation, either an increase or a decrease, in power delivery over a relatively short period of time. This becomes more pronounced with the advent of large wind farms where sudden variations may cause significant effect on the network's power balance. Similarly, significant ramp in PV output has been observed due to shifting cloud cover.

With numerous state-of-the-art ways to forecast the output of VRE resources, it is recommended that policy-making and regulating bodies encourage the investment in these facilities to address incertainty and perhaps reducing the reserve requirement.

3.3. Concentration of VRE Resources

As of 2017, concentration of VRE resources is observed in Northern Ilocos Region and Negros Island. With the increase in the number of committed and indicative VRE projects, concentration of VRE resources may also be observed in other locations soon. This can be beneficial in terms of increase in power supply of the country and lower carbon emissions. However, concentrated installations of VRE resources pose risks to the stability and reliability of that part of the system.

Various projects initiated by the current Transmission Network Provider, National Grid Corporation of the Philippines (NGCP), aim to address the power curtailment due to excess generation in Negros and Panay Island. Furthermore, a DOE Department Circular is currently being drafted pertaining to the establishment and development of Competitive

Renewable Energy Zones (CREZ) to address the concentrated installations of VRE resources.

3.3.1. Locational Maps of WESM-Registered Wind and Solar Farms

To illustrate the concentration of wind and solar farms in some of the regions in the country, locational maps of the following are provided in this section: a) WESM-registered wind and solar farms as of 17 August 2018; and b) indicative and committed wind and solar projects initiated by the private sector as of December 2017. However, it must be noted that the locations of wind and solar farms pinned in these maps presented in this section are approximated and no precision-level has been guaranteed.

Currently, there is a total of 282.9 MW of WESM-registered wind farm-capacity concentrated in Northern Ilocos Region. This can still be expected to grow to 642.9 MW considering four indicative wind farm projects targeted to be completed in 2019 (see Figure 14).

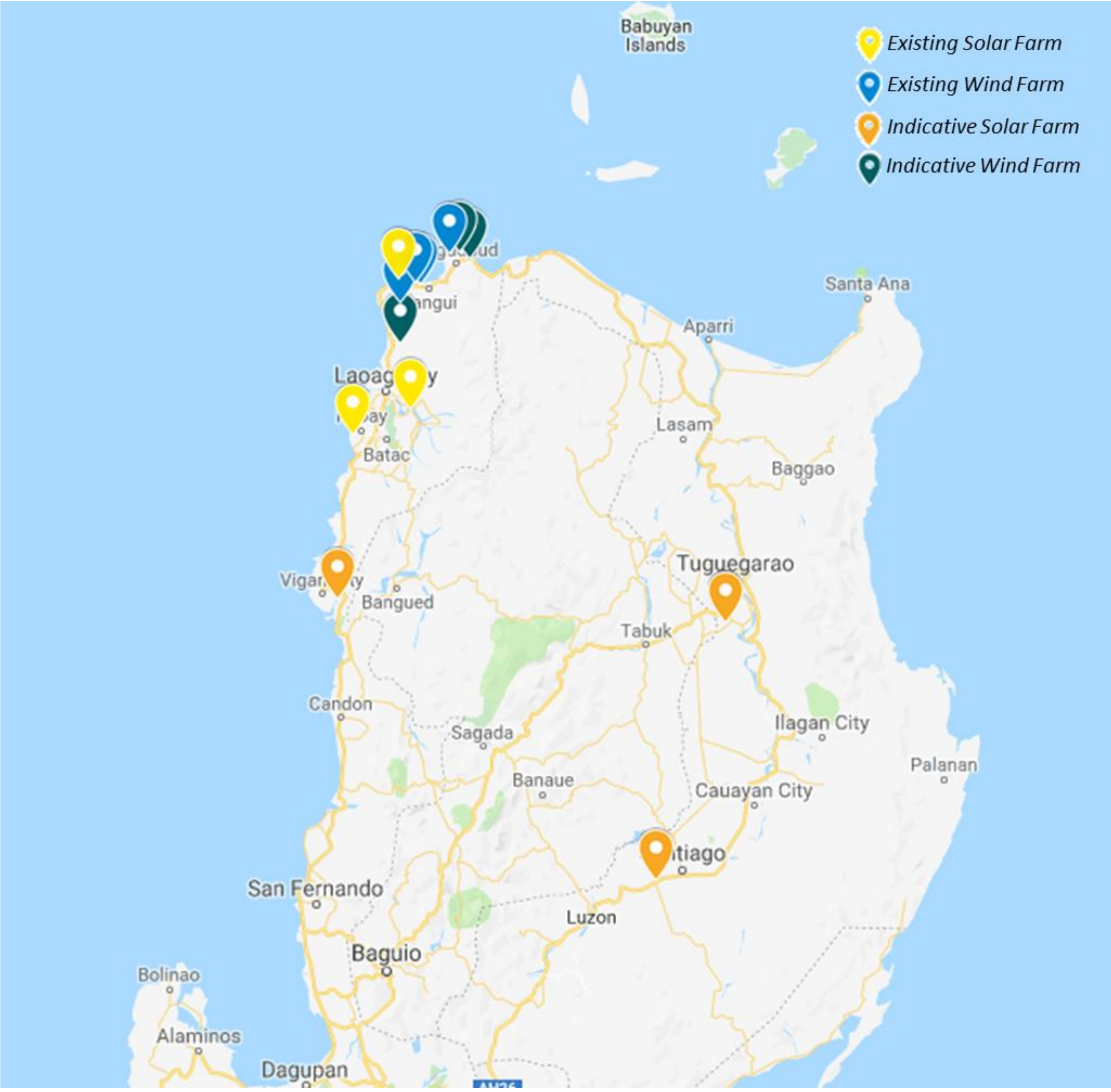

Figure 14 Locational Map of VRE Resources in North Luzon

In Central Luzon, 11 existing WESM-registered solar farms are located in the region as shown in Figure 15. Out of 165 MW of WESM-registered solar farm capacity in the region, 58.5 MW is located in Tarlac where concentration of solar farms is starting to become salient. Upon completion of committed and indicative solar projects for the region in 2022, the capacity of solar farms can be expected to increase to 729.82 MW. Aside from Tarlac, concentrated installations of solar farms is observed in Bataan and Nueva Ecija where 165.16 MW and 245 MW of future capacity of solar farms in Central Luzon are to be located, respectively.

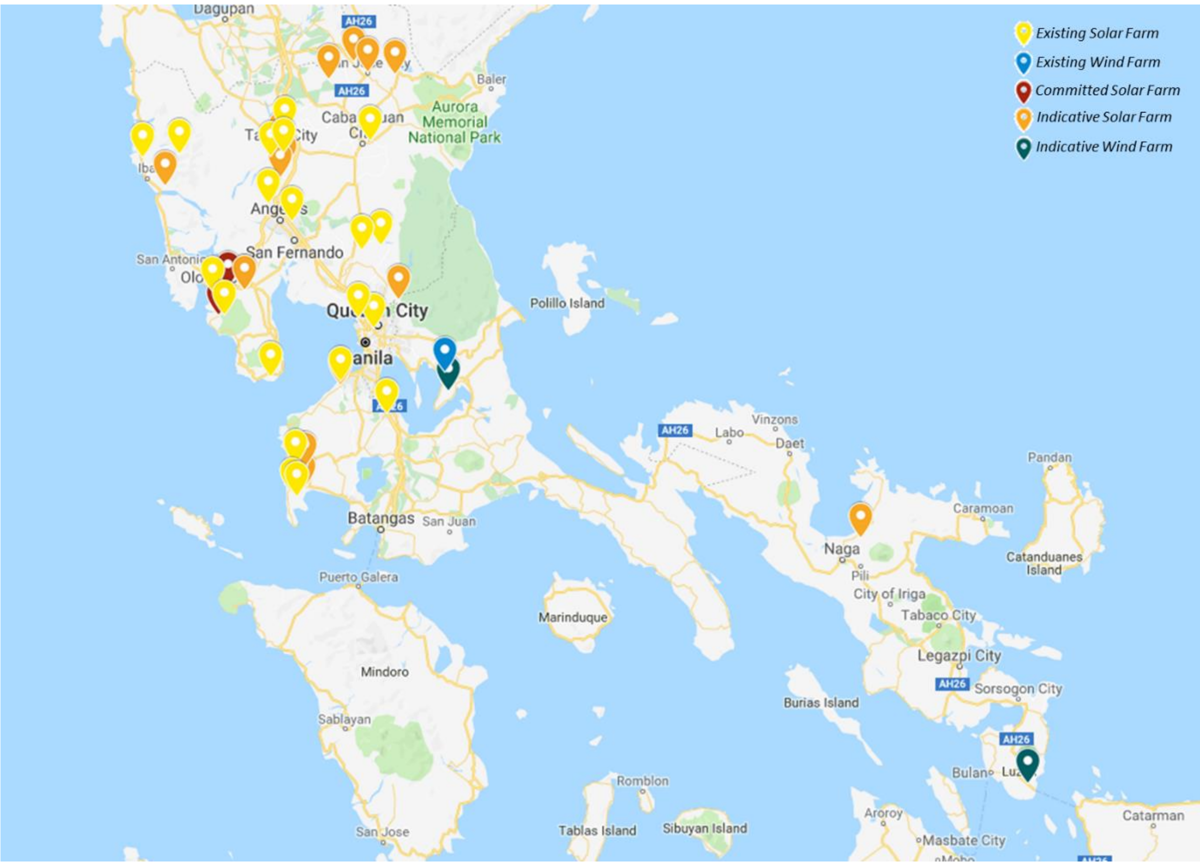

Figure 15 Locational Map of VRE Resources in Central and South Luzon

On the other hand, in South Luzon, 51.3 MW of WESM-registered capacity of solar farms in the region (i.e. 85.7 MW) is located in Batangas. With the completion of all indicative solar projects in the region by 2019, the capacity of solar farms can be expected to increase to 195.7 MW where 111.3 MW will be located in Batangas.

In Visayas Region, majority of existing solar farms are located in Negros Island as shown in Figure 16. A total of 242.6 MW or 7.13%

of the total WESM-registered capacity of Visayas grid comes from solar farms in Negros Occidental. Upon the completion of all the indicative solar and wind projects in Visayas Region by 2022, 466 MW of capacity is expected in Negros Island.

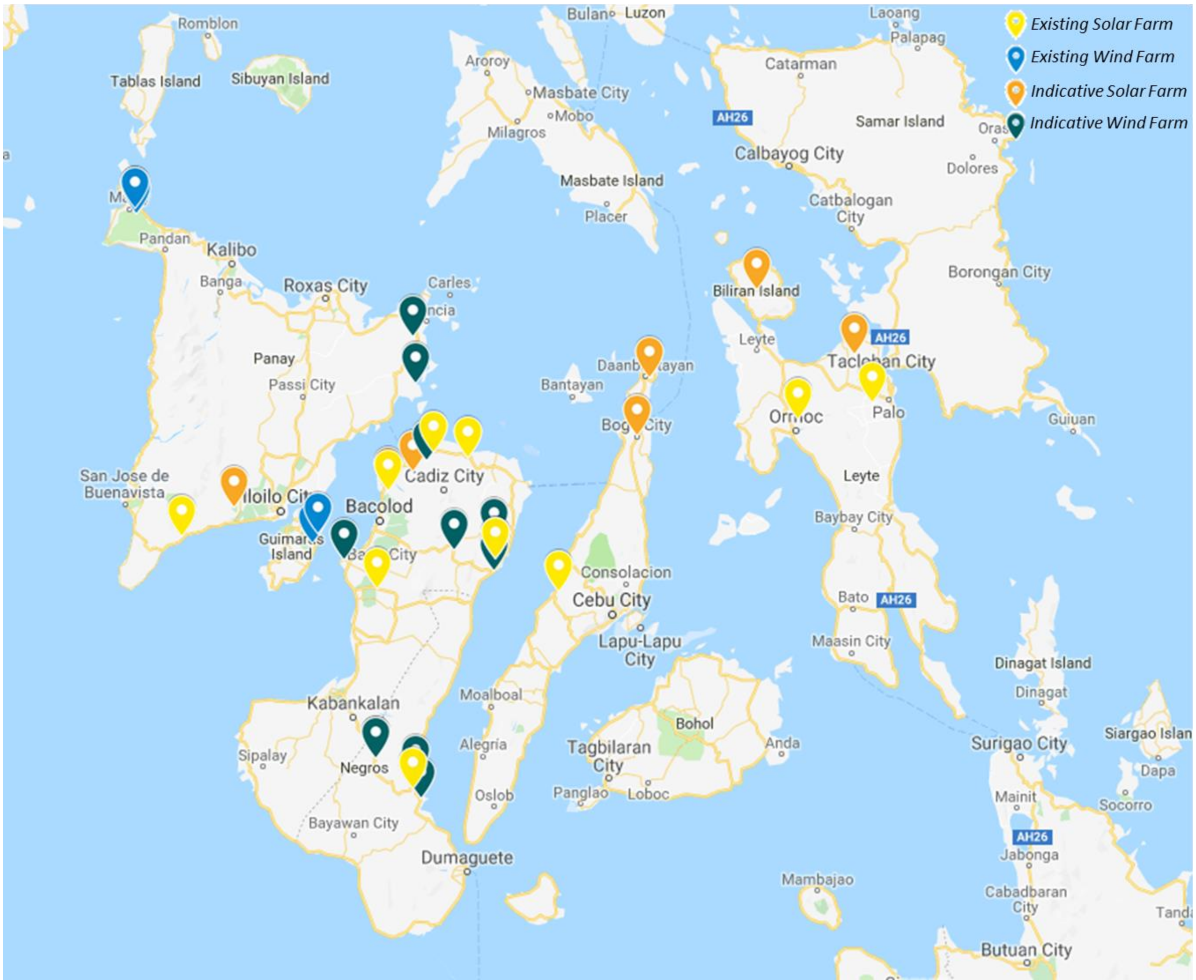

Figure 16 Locational Map of VRE Resources in Visayas

The concentrated installations of solar farms in Negros Occidental led to the increase in the power supply of Negros Island starting February 2016, as shown in Figure 17. However, the demand in the said area did not change significantly causing excess generation. The transmission constraints further exacerbated the situation since excess power coming from Negros and Panay Islands cannot be accommodated by the Cebu-Negros interconnection resulting to power curtailment.

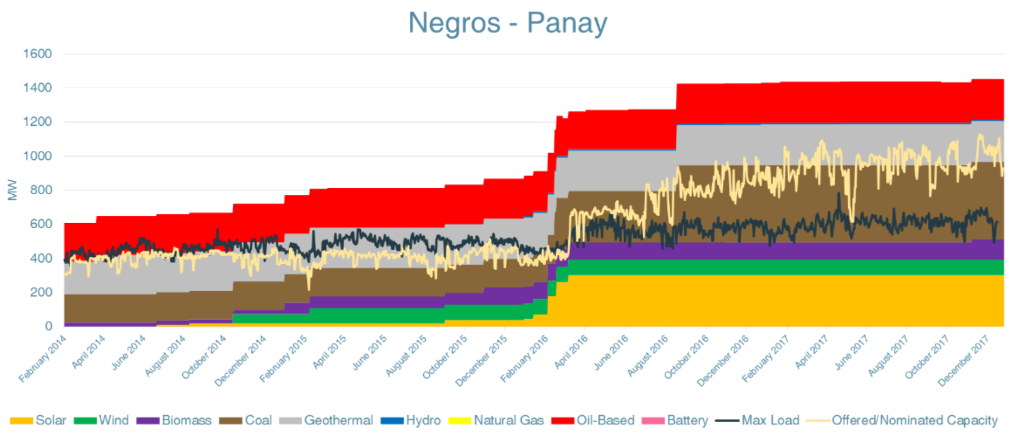

Figure 17 Negros-Panay Power Generation Mix

In order to mitigate overcrowding of VRE resources, a DOE Department Circular is currently being drafted pertaining to the establishment and development of Competitive Renewable Energy Zones (CREZ) to address the concentrated installations of VRE resources. Furthermore, various projects initiated by the System Operator may address the power curtailment due to excess generation in Negros and Panay Island. The Cebu-Negros-Panay 230 kV backbone is expected to be completed by 2020.[6]

3.3.2. Promulgation of Policies in VRE Installation

As the policy-making body of the energy industry, the DOE has exerted efforts to carefully review and manage the installation of VRE Resources in the Philippines. As a matter of fact, to facilitate a transparent and competitive system of awarding RE

Service/Operating Contracts and to provide the registration process of RE Developers, the DOE issued Department Circular No. 2009-07-0011 which provides that the DOE shall publish in its website all the areas that are open for RE Project Proposals. Likewise, a Review Committee was constituted by virtue of the said circular to evaluate all the proposed VRE installations received and select the developer based mainly on legal, technical, and financial aspects.

Additionally, the DOE is currently in the process of developing a Department Circular to support the establishment and development of CREZ. The said circular likewise aims to enhance the planning process and strengthen the implementation of the country's power system in view of the increasing number of RE projects.

According to the draft of the said Department Circular regarding CREZ, the first stage in establishing CREZ is identifying the areas to be CREZ candidates based on the cost and quality of the RE resource and the level of interest of the private sector (to develop an RE project in the zone). After the identification of CREZ candidates, scenario analyses will be done on transmission enhancements which will assess the cost, benefit, and operational impacts of each scenario. The cost-effective transmission enhancements will then be proposed to be included in the TDP, as reviewed and approved by the DOE.

The establishment of CREZ will ensure that the transmission planning and development will be in line with the growth of the VRE and RE plants. To mitigate the problems caused by concentration of VRE resources, it is recommended that along with the establishment and development of CREZ, optimal siting of VRE plants must be done as well. However, this will not completely address the existing concentration of VRE installations in some specific locations in the country.

3.3.3. Development of Transmission Network

It is clear that one of the challenges to be addressed in the locations where VRE resources are concentrated is the availability of the network in order for the excess power to be transmitted to other areas. With the completion of relevant transmission projects proposed by the NGCP in the Transmission Development Plan[6], the challenges posed by concentration of VRE Resources may be addressed.

In the said document, it is proposed to have a 230-kV Loop Project to connect Ilocos Region and Cagayan Valley which is expected to be completed by June 2024. This will ensure, among other objectives, that the power generated by future wind farms in the northern coast of Luzon will be properly accommodated by the grid to avoid power curtailment due to excess power. This will also improve the reliability of the transmission network in the region. Figure 18 shows the proposed Luzon transmission outlook for 2025.

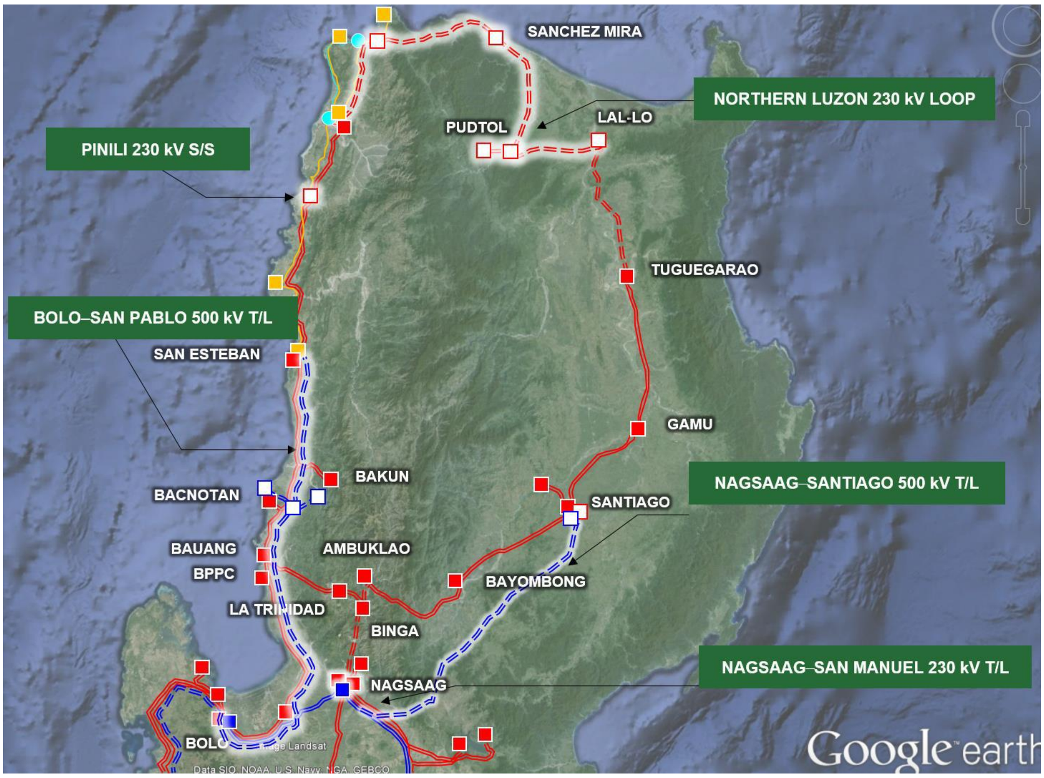

Figure 18 North Luzon 230-kV Loop Project[6]

In the present, the Tugegarao-Lal-lo 230-kV transmission line which is part of the project was already approved by the ERC and is expected to be completed by December 2019.

For the Visayas region, where there is increasing number of solar farm installations, NGCP proposed the Cebu-Negros-Panay (CNP) 230-kV Backbone Project which will ensure the effective transmission of excess power in Panay and Negros towards Cebu – the metropolis of the Visayas Region. Figure 19 shows the transmission outlook of Visayas for 2020.

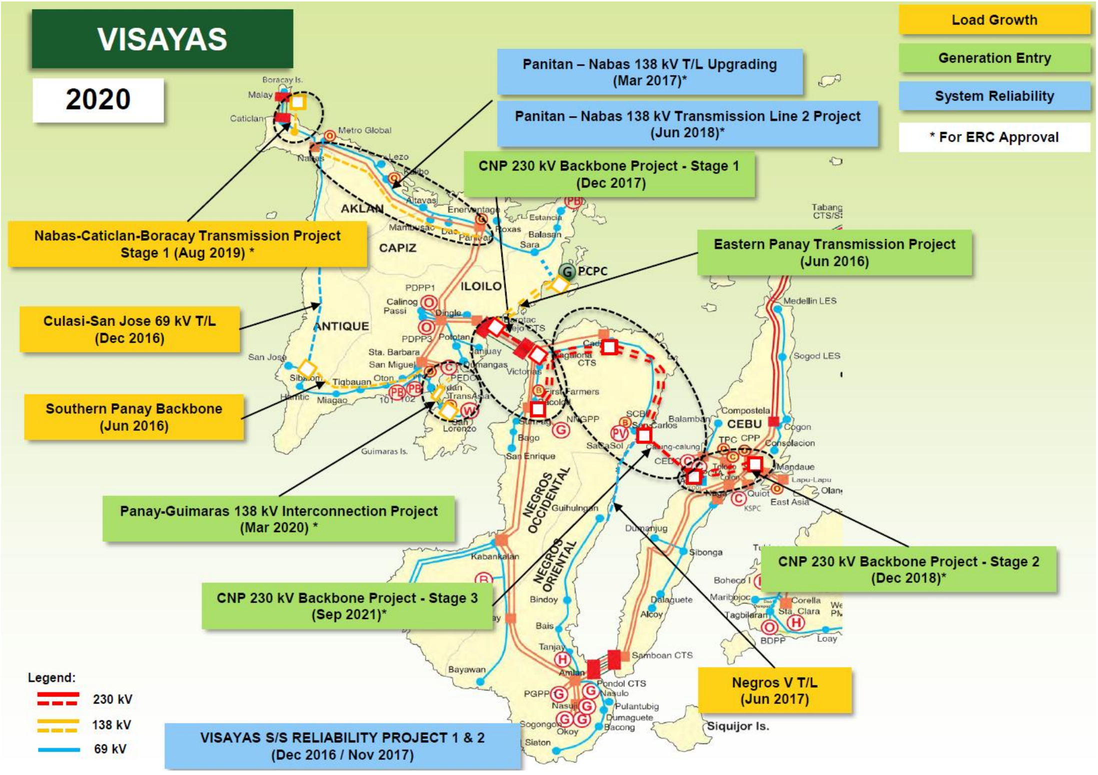

Figure 19 Cebu-Negros-Panay 230-kV Backbone Project

These projects, together with others as proposed by the System Operator, will accommodate further increase of VRE penetration from various areas of the country.

4. RESERVE MARKET

In 2014, the DOE promulgated the Protocol for the Central Scheduling and Dispatch of Energy and Contracted Reserves in the WESM through the Department Circular 2014-12-0022. Following this, the DOE issued Department Circular 2015-11-0018 declaring the commercial operation of Central Scheduling and Dispatch of Energy and Contracted Reserves in the WESM which aims to provide a better monitoring of energy and reserve capacities in the WESM in preparation for the eventual commercial operation of the WESM Reserve Market.

Currently, the Reserve Market is still under development. However, it is already supported in the New Market Management System acquired by PEMC with the directive of the DOE through the Department Circular No. 2015-10-0015[24]. The commercial operation of the Reserve Market is hinged on the fulfilment of activities by the System and the Market Operator and with the review and approval of the affected documents by the ERC. With the increasing VRE penetration which is characterized by higher power output variability, it is envisioned that a reserve market may help address any additional requirement for reserve through the promotion of competition among reserve providers.

The following sections discuss the current design of the reserve market (i.e. currently, the Central Scheduling and Dispatch of Energy and Contracted Reserves), the current issues the power industry is facing with regards to reserves and likewise the recommendations pertaining to reserves and increasing penetration level of VRE resources.

[24] DOE DC No. 2015-10-0015.

4.1. Reserves in the Philippines

Although the full implementation of Reserve Market is yet to be achieved, the Philippine Grid Code (PGC) 2016 Edition[9] already provided for the new reserve categories in the market. Meanwhile, the current Ancillary Services Procurement Plan (ASPP) 2006[2] Edition as aligned with the amendments in the Ancillary Services Cost Recovery Mechanism (ASCRM) in 2009, provides the reserve requirements currently fulfilled by the System Operator for every trading interval to maintain system security and reliability.

4.1.1. Reserve Categories

Section 7.6.1 of the PGC 2001 Edition[7] provides the reserve categories that was adopted in the currently approved version of the ASPP (ASPP 2006 Edition). These categories were then revised through the approved PGC 2009[8] Edition which mainly restructured the said categorizations of reserves. Moreover, with the approval of the PGC 2016 Edition through the ERC Resolution No. 22 Series of 2016, new categorization for reserves was introduced. Table 3 shows the revisions in the reserve categories from the earlier version of the PGC to the currently approved.

Table 3 Reserve Categories

PGC 2001 Edition[7]	PGC 2009 Edition[8]	PGC 2016 Edition[9]
Spinning Reserve	Contingency Reserve	Primary Reserve
Load Following and Frequency Regulation	Frequency Regulating Reserve	Secondary Reserve
Back-up Reserve	Demand Control	Tertiary Reserve

The functions and control modes of the introduced reserve categories are provided in Section 6.6 of the PGC 2016 Edition. Table 4 provides a brief summary of the said section.

Table 4 Control Modes and Functions of Reserves[9]

Reserve Category	Control Mode	Function
Primary Reserve	Governor Control Mode	To replace lost capacity when a contingent event occurred in the grid
Secondary Reserve	Automatic Generation Control (AGC)	To restore the system frequency from quasi-steady state value to the nominal frequency of 60 Hz
Tertiary Reserve	Manual (for providers coming from shutdown) or AGC (for on-line providers)	To replenish the secondary reserve

The PGC 2016 Edition likewise introduced three (3) components of Frequency Control in the power system. These are Primary Control, Secondary Control, and Tertiary Control. The Primary Control has two (2) defined purposes: (a) to minimize the frequency nadir during the loss of the largest unit online; and (b) to replenish the lost capacity. This may be compared with the previous reserve categorization – Contingency Reserve.

Frequency Response Obligation (FRO) is introduced under Primary Control which shall be maintained by the System Operator to secure the reliability of the power system and to prevent the occurrence of Under-frequency Load Shedding, as mandated by the PGC 2016 Edition. Frequency Response Obligation in the PGC 2016 Edition sets the megawatt (MW) values which is 75 MW for Luzon and 20 MW for both Visayas and Mindanao – to be secured by the System Operator per 0.1 hertz of deviation from the standard frequency (60 Hertz) of the power system. These values have been derived in consideration of the standard frequency, target minimum frequency and the Resource Contingency Protection Criteria or load of the highest unit online for a specific interval per specific grids of the power system. The formula was likewise simulated based on the 5% droop setting of the turbine and zero Hz frequency deadband setting which is not reflective of the actual setting of the majority of available generating units in the grid. Only a few generating units has the capability of zero Hz frequency deadband setting. Initial simulations by the System Operator forLuzon resulted in a 20-50 MW/0.1Hz FRO range versus the required 75MW/0.1Hz FRO level considering the total available headroom for both Ancillary Services Procurement Agreement (ASPA) and non-ASPA Providers. The frequency control in Visayas on the other hand is more complex as compared to Luzon considering the insufficiency of AS Providers and major VRE installations in the area.

Implementing FRO shall address frequency deviations which may be caused by intermittent VRE resources.

Still relate to reserve categories, the WESM Manual on Price Determination Methodology has undergone necessary rules change procedures to incorporate the mechanism for reserve market functionalities. The reserve categorization that has been adopted by the Price Determination Methodology Manual is aligned with the Stephen Wallace Advisory study on the Pricing and Cost Recovery Mechanism for Reserves in the WESM.[10] With the on-going hearing on the approval of the Price Determination Methodology Manual, the proposed categorization was aligned with the categories provided in the PGC 2016 Edition as presented in Table 5. These changes are subject to ERC approval since the manual provides for the pricing mechanism in the WESM and likewise for the commercial operation of the reserve market.

Table 5 Reserve Categories in the WESM PDM Manual

PGC 2016 Edition	WESM Manual on Price Determination Methodology
Primary Reserve	Fast Contingency – *Raise and Lower* Slow Contingency – *Raise and Lower*
Secondary Reserve	Regulation – *Raise and Lower*
Tertiary Reserve	Delayed Contingency – *Raise and Lower*

4.1.2. Reserve Level Requirement

The System Operator is mandated by the PGC to be responsible in maintaining the normal state of the power system. Hence, it shall ensure that the market has enough reserve capacities to address any event that may occur in the system. The ASPP 2006 Edition, provides the rules, terms and conditions, and procedures in the implementation of the reserve provision in the power system. With the approval of the PGC 2016, the System Operator filed the amendments for the ASPP 2006 to align with the details of the grid code, specifically on the categorization of reserves. Currently, the proposed version of the ASPP is undergoing public consultation.

The level required for each reserve categories are specified in the Section 3.3 of the ASPP 2006 Edition. Table 6 provides the reserve requirements and categorization of reserves in the prevailing and the proposed version of the ASPP.

Table 6 Reserve Level Requirement

ASPP 2006 Edition[2]		Proposed ASPP[3]	
Reserve Category	**Required Minimum Level**	**Reserve Category**	**Required Minimum Level**
Contingency Reserve	Sum of the load of the largest generating unit of the particular grid and the scheduled reserve level, if any, of that generator for the trading hour	Primary Reserve	Luzon: 600 MW Visayas: 150 MW Mindanao: 150 MW
Regulating Reserve	4% of the forecasted demand of the particular grid for the trading hour	Secondary Reserve	4% of the forecasted demand of the particular grid for the trading hour
Dispatchable Reserve	Equivalent to the amount allocated to the spinning reserve service	Tertiary Reserve	Equivalent to the Secondary Reserve required level in the particular grid for the trading hour

4.2. Ancillary Services Providers

One of the major steps for generating plants to participate in the proposed Reserve Market is the certification to be done by the System Operator. Initially, the WESM Rules mandates the System Operator to use reasonable endeavors to ensure that sufficient facilities are available and operable to maintain system security and reliability of the power system through ancillary services contracting.[25] With this, the System Operator tests and accredits generating plants intending to have their capacities be contracted as reserves. Currently, the ASPA is then settled between the generating plant and the System Operator which must be approved by the ERC before the generating plant can supply reserves in the market. In general, various generation technologies are suitable to provide specific reserve categories as shown in Table 7.

[25] **WESM Rules Clause 3.3.2** *Ancillary Services Contracting by the System Operator*.

Table 7 Generator Types and Reserve Categories

Generator Type	Category of Reserve Capable of Providing
Coal	Contingency
Diesel	Contingency/Dispatchable
Geothermal	Regulating
Hydro	Regulating/Contingency/Dispatchable
ESS	Regulating

Table 8 shows the current total of reserve capacities contracted by the System Operator for Luzon duly approved by the ERC. It can be noted that the contracted A/S capacities in Luzon generally meets the required level for regulating, contingency, and dispatchable reserves. However, the availability and capacity of the different A/S Providers depend on the type of resource of their generators. The following factors affect the availability and capacity of a generating unit: (a) reservoir level and multi-purpose constraints for hydropower plants; (b) steam supply for geothermal plants; (c) atmospheric temperature for diesel and gas turbine plants; and (d) coal quality for coal thermal plants.

Table 8 Luzon A/S Contracted Capacity

Type	Total Number	WESM Registered Capacity, MW	Luzon Contracted Capacity, MW		
			Regulating Reserve	Contingency Reserve	Dispatchable Reserve
Hydro*	20	1900	1026	940	1894
Diesel**	4	381.3	0	0	354
Gas Turbine*	8	410	406	196	290
Coal*	2	764	0	60	0
Total	34	3455.3	1432	1196	2538

**per unit; **per plant*

In Visayas, only diesel and geothermal plants were contracted and accredited as A/S providers as shown in Table 9. This is due to the fact that most of the generators in the region have their own respective bilateral contracts to supply energy.

Table 9 Visayas A/S Contracted Capacity

Type	Total Number	WESM Registered Capacity, MW	Visayas Contracted Capacity, MW		
			Regulating Reserve	Contingency Reserve	Dispatchable Reserve
Diesel*	20	365	0	60	118.6
Geothermal*	3	88.3	20	0	0
Total	23	453.3	20	60	118.6

**per unit; **per plant*

Furthermore, it must be noted that a single unit can be certified to provide the three types of reserves (i.e. regulating, contingency, and dispatchable) but only one service can be scheduled in a given time for compliance monitoring, thus, ensuring performance level of A/S providers. This likewise affects the availability of a generating unit to supply other categories of reserve in the system.

4.3. Reserve Deficits

The reserve level requirements, as presented in Section 4.1.2, are determined through forecasting at each dispatch interval. Upon generating the requirements, generation companies which have existing contracts with NGCP submit their nominations for reserves through the Day-Ahead Ancillary Services Schedule (DAASS) which will then be considered in the market dispatch optimization model. However, due to several factors affecting the availability of reserve providers as discussed in the previous section, there are times when deficiency in reserves arises.

Based on the submitted DAASS, the figures in the succeeding discussions aim to show the deficiency in various types of reserves that need to be fulfilled at every dispatch interval for Luzon and Visayas. The data provided are limited to 15-21 October 2017.

Reserve deficits in the presented figures are calculated by subtracting scheduled reserve capacity from the required reserve capacity as submitted in the DAASS.

As provided in Figure 20, it is noted that in Luzon, the required level for Contingency Reserve is not met by the current accredited A/S providers in the entire sample data. Meanwhile, it may likewise be noted that the required Regulating and Dispatchable Reserves are most of the time met by A/S providers.

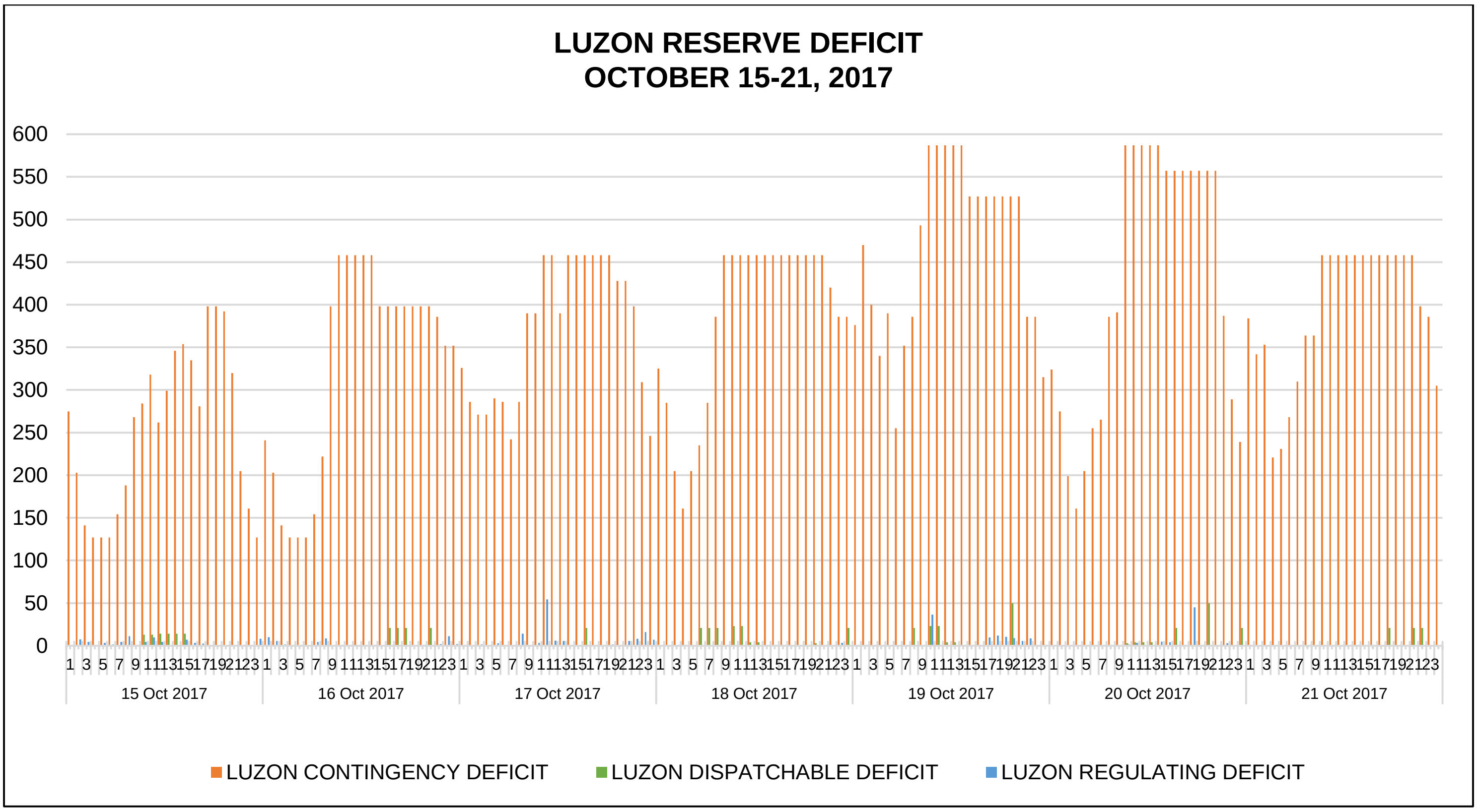

Figure 20 Luzon Reserve Deficit

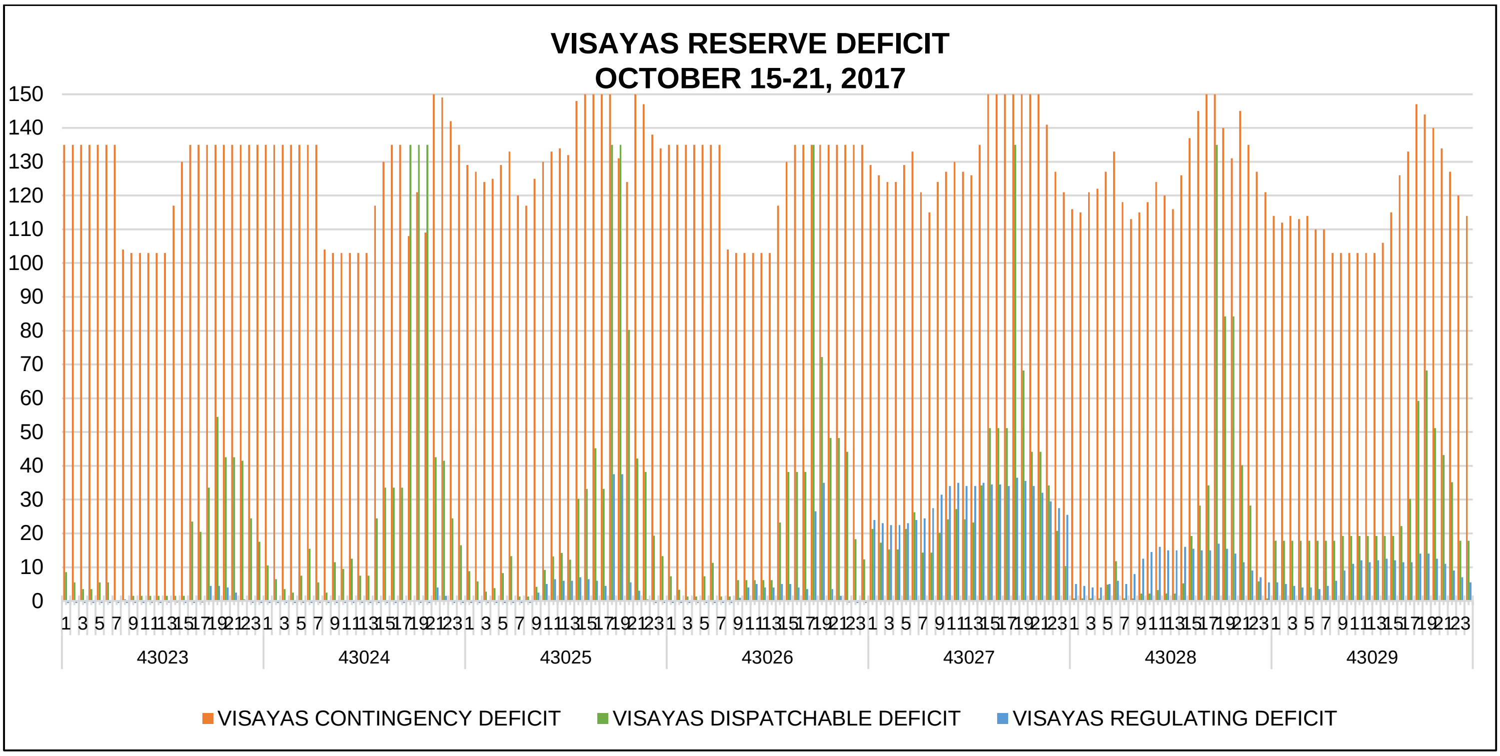

Figure 21 Visayas Reserve Deficit

Similarly, in Visayas, Contingency Reserve requirement is not met most of the time. However, unlike in Luzon where the deficits in Regulating and Dispatchable Reserves are minimal, multiple dispatch intervals for Visayas region show evident deficit in the said reserve categories.

Furthermore, capacities which are available but not scheduled during the sample intervals are presented in Figure 22 for Luzon and in Figure 23 for Visayas. The data considered for the capacity not scheduled is presented in the equation as follows:

$$Capacity\ Not\ Scheduled = Offered\ Capacity - RTD\ Schedule - Generation\ Capacities\ of\ Generators\ Scheduled\ for\ Reserve$$

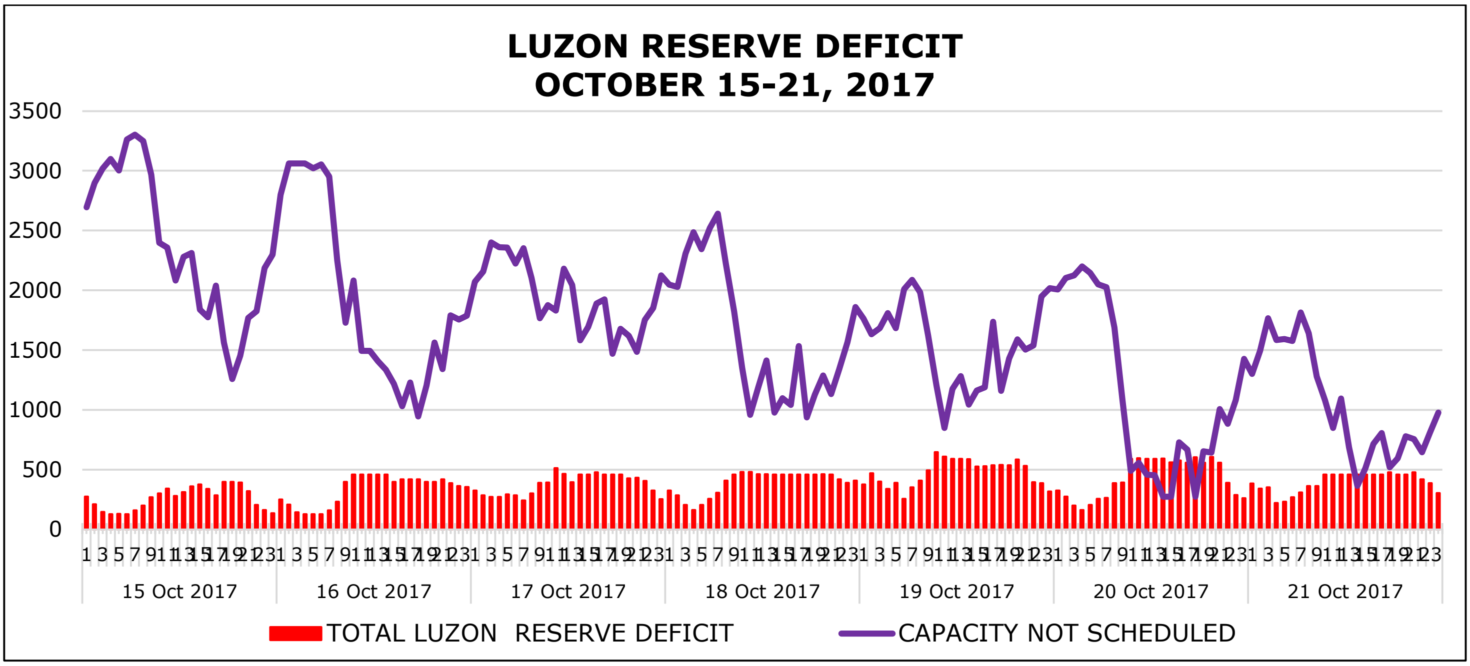

Figure 22 Total Reserve Deficit VS Capacity Not Scheduled in Luzon

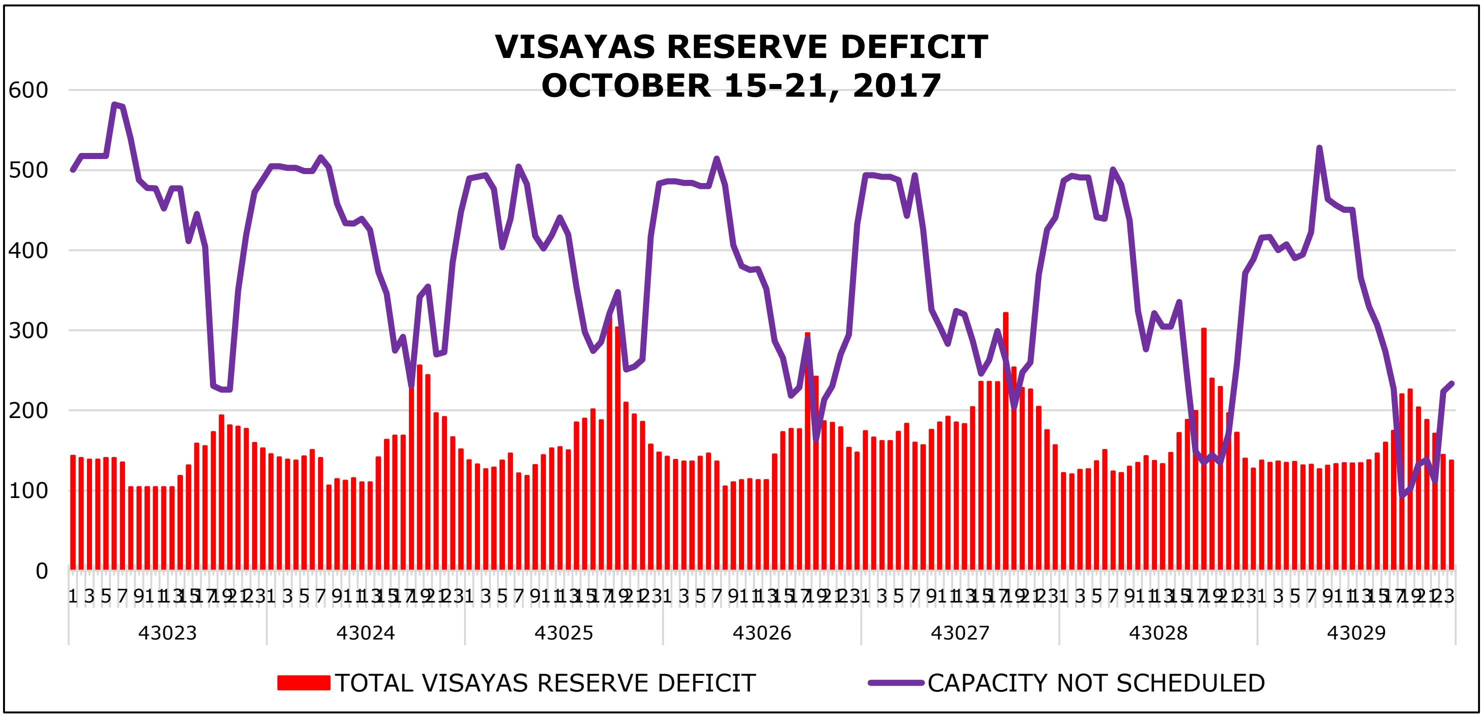

Figure 23 Total Reserve Deficit VS Capacity Not Scheduled in Visayas

As shown in Figure 22 and Figure 23, most of the time, there are capacities not scheduled that may cover for the reserve deficits both in

Luzon and in Visayas, hence some opportunities for reserves. It should however be noted that prior to participating as A/S provider, technical requirements provided in the prevailing PGC Edition must be met and necessary certification from the System Operator must likewise be obtained by the intending generation companies.

With the implementation of the Reserve Market, generation companies which are certified by the System Operator will be able to trade in the reserve market in order to generate the appropriate prices by which the offered capacities shall be settled. Although contracting by the NGCP will still be upheld by the involved parties, offers shall still be made through the Reserve Market in order to deliver for its existing contracts billed to the appropriate WESM participants.

It is envisioned that competition provided by the Reserve Market will result to optimal pricing of various reserve categories. Also, greater participation from more reserve providers can be expected.

4.4. Review of VRE Integration Studies

With the aim to shift to cleaner energy resources, various VRE integration studies were done in various jurisdictions to assess the impact of increasing penetration level of VRE resources. Different methodologies and scenarios were considered to calculate their respective reserve requirements.

For the following studies presented in this section, the reserve requirements and the penetration levels of VRE were calculated as percentage of peak demand of their respective jurisdictions.

4.4.1. DOE-USAID's Greening the Grid Study[26]

In the Philippines, the adequacy of reserves in Luzon and Visayas grids with 30% and 50% penetration level of RE resources in the country was assessed in a 2018 study published by the United States Agency for International Development (USAID) and the DOE entitled "Greening the Grid: Solar and Wind Grid Integration Study for the Luzon-Visayas System of the Philippines".

Table 10 shows the different scenarios considered in the study and the siting strategy performed. The study assumed that for the 2030 Base Case, no new RE plant was commissioned beyond 2016. To reach the 30% and 50% penetration level of RE resources in 2030, the installed capacities of solar and wind farms were then iterated since the study focuses mainly on the impacts of VRE resources. In siting the solar and wind farms to be iterated, two approaches were used: a) siting the best solar and wind resources regardless of transmission capacity (Best Resource - BR) and b) siting the solar and wind farms that will potentially minimize the need for new transmission capacity (Low Transmission - lowTX).

[26] DOE-USAID. (2018). *GREENING THE GRID: Solar and Wind Grid Integration Study for the Luzon-Visayas System of the Philippines.* USAID and NREL.

Table 10 Descriptions of the Considered Scenarios

Scenario	Renewable energy penetration (as a percentage of annual electricity demand)	Solar and wind siting strategy
2014 Reference Case	25.7%	Existing locations
2030 Base Case	15.0%	Existing and planned (committed) locations
"BR30"	30% (target)	Best resource
"lowTx30"	30% (target)	Minimize new transmission
"BR50"	50% (target)	Best resource
"lowTx50"	50% (target)	Minimize new transmission

The study applied the reserve allocations and reserve categories as shown in Table 11 in assessing the annual reserve provision for the 2030 scenarios shown in Table 10. Figure 24 provides the results of the assessment and simulation done by the study on reserve provision.

Table 11 Reserve Allocations

Type	Direction	Minimum Provision	Response Timeframe (saturation)
Primary	Up	Load of the largest unit in each interconnection: • Luzon: 660 MW • Visayas: 170 MW	25 seconds
	Down	Half the load of the largest unit in each interconnection: • Luzon: 330 MW • Visayas: 85 MW	
Secondary	Up	2% of hourly demand in each interconnection	60 seconds
	Down	2% of hourly demand in each interconnection	
Tertiary	Up	4% of hourly demand in each interconnection	1 hour

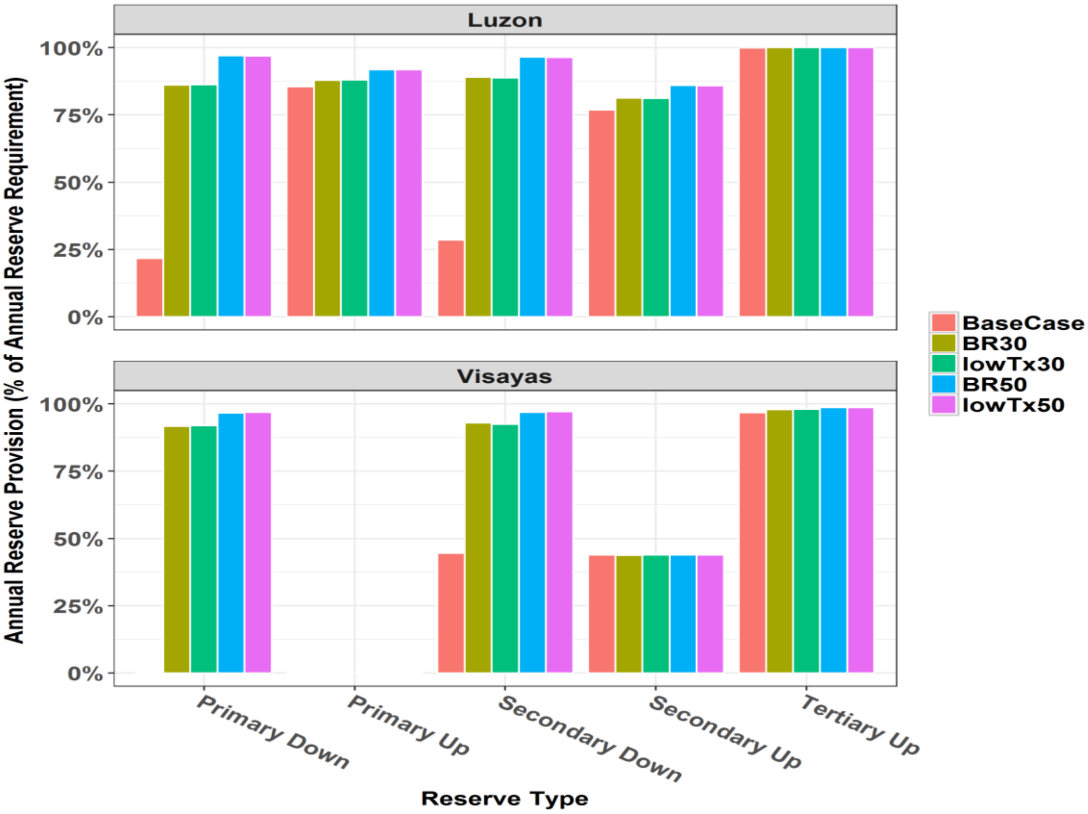

Figure 24 Annual Reserve Provision

Based on the assumptions of the study, both Luzon and Visayas grids will experience reserve shortages by 2030, with the latter being more affected. The improvement in reserve provisions from Base Case to the 30% and 50% penetration level cases can be attributed to the assumption that wind farms that did not exist in the 2030 Base Case were able to provide downward reserves. This was done to illustrate the utility of allowing VRE generators to provide reserves as well.

Currently, wind or solar farm are not options as reserve providers. With these, the study recommended the following: a) new or updated institutional measures may be needed to encourage wind and solar farms to provide variety of reserves along with the implementation of technologies that will enable them to do so, and b) there should be additional reserve providers, particularly in Visayas, as well as sharing of A/S between Luzon and Visayas grids through their interconnection.

4.4.2. New York Independent System Operator (NYISO) / New York State Energy Research and Development Authority (NYSERDA): The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations[4]

For NYISO in 2005, the NYSERDA conducted its study on the effects of 10% wind penetration in the New York Control Area. The study looked into the 6-second variability of the net load to calculate the regulating reserve requirement and into the 5-second variability of net load to calculate the following reserve requirement. Thrice the standard deviation of the variability in the net load was used to calculate the regulating reserve requirement.

4.4.3. Minnesota: 2006 Minnesota Wind Integration Study[4]

The 2006 Minnesota Wind Integration Study evaluated the penetration of wind in three cases: 16%, 22%, and 27%. The study calculated the regulating reserve requirement with the integration of wind assuming that the standard deviation of wind is 2-MW for every 100-MW wind power plant installed. The following equation was used to calculate the regulating reserve requirement:

$$Reg\ Req = k\sqrt{\sigma_{load}^2 + N(\sigma_{W100}^2)}$$

Where,

k = a factor relating the regulation reserve capacity requirement to the standard deviation of the variations

σ_{load} = standard deviation of the variations of the load

N = wind generation capacity in consideration divided by 100

σ_{W100} = standard deviation of the variations of a 100-MW wind power plant (calculated to be 2-MW standard deviation for every 100-MW wind plant installed)

On the other hand, twice the standard deviation of the 5-minute interval of the variation from load to net load was used in calculating the following reserve.

4.4.4. Western Wind and Solar Integration Study[4]

The effects of integrating 5% solar energy together with 30% wind energy and 1% solar energy together with 20% wind energy in the rest of the interconnection was evaluated in 2010 by Western Wind and Solar Integration Study. Western Electricity Coordinating Council (WECC) proposed to require the balancing areas to hold 3% of their generation and 3% of their load as contingency reserve. Using this rule and the analysis that 1% of the load is equivalent to one standard deviation of the 10-minute load variability, the study assumed that the following reserve requirement is thrice the standard deviation of the 10-minute load variability. One standard deviation was recommended to be the regulating reserve requirement. Comparing the 3σ rule with the 3% rule for following reserve requirement, it was shown that the requirement changed significantly when 3% rule was used for areas with high wind and relatively low load.

Another rule was considered with 3% load plus 5% wind. With this rule, the quantity of reserves held was always greater than or equal to that of the 3σ rule. However, it was observed that this rule can be over-carrying the reserve in majority of wind and load level scenarios. Also, this rule made individual regions short of the 3σ requirement.

For further analysis, three degrees of freedom was used: the coefficient to load level, the coefficient to wind level, and an amount of wind capacity where further incremental increases in reserve are not needed. This rule was shown to be a good compromise between capturing the 3σ need for following reserve requirement and simplicity.

The results of the analyses of the studies discussed are summarized in Table 12.

Table 12 Summary of Results of the Integration Studies in Other Jurisdictions

Wind and Solar Integration Study	Peak Load	Penetration Level of VRE	Reserve Requirement (% of Peak Load)		
			Primary Reserve	Secondary Reserve	Following Reserve
NYSERDA	33, 000 MW	10% (wind)	No Additional Capacity Required	0.79%-0.94%	No Additional Capacity Required
Minnesota	20,984 MW	case 1: 16% (wind) case 2: 22% (wind) case 3: 27% (wind)	No Additional Capacity Required	case 1: 0.71% case 2: 0.73% case 3 : 0.75%	case 1: 0.52% case 2: 0.54% case 3: 0.59%
WWSIT	-----	30% (wind) 5% (solar)	3% of Generation and 3% of Load	One Standard Deviation of Wind Variability	3δ rule, 3% rule, and 3% load + 5% wind

4.4.5. Case Study on Regulating Reserve Requirement

To provide a brief assessment on the level of regulating reserve of the country in relation to the penetration level of VRE resources, a sample calculation of regulating reserve requirement was undertaken utilizing the methodology applied in Minnesota study presented in Section 4.4.3 of this study. Sample data of the recorded five-minute snapshot of the metered quantities of VRE farms and loads of Luzon and Visayas were obtained.

For Luzon, metered quantities of wind farms were obtained at two different weeks: a) Habagat Season (04 to 10 June 2017); and b) Amihan Season (05 to 11 November 2017). Figure 25 shows the load and net load during the weeks mentioned.

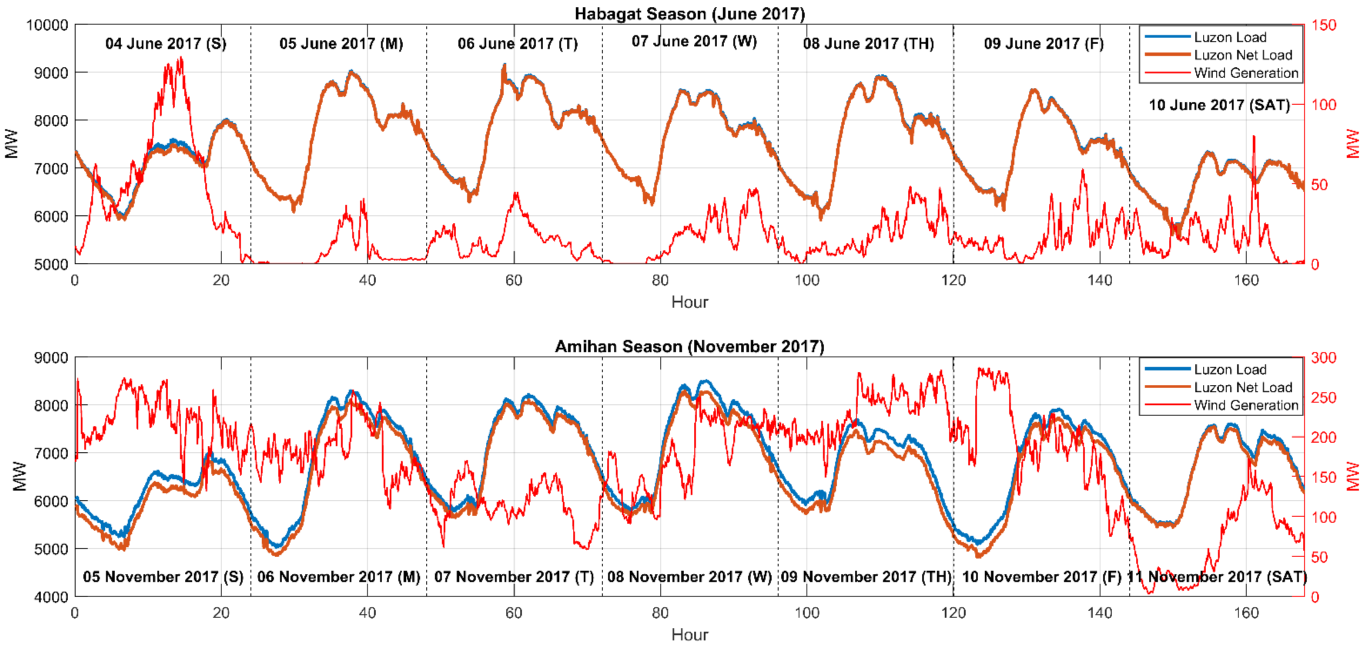

Figure 25 Load and Net Load Profile of Luzon

It is of importance to note that the definition of load used in this section is equivalent to the demand minus the transmission losses incurred. The net load shown in the figure accounts for the additional variation introduced by wind farms to the system. It is given by the equation,

$$NL_i = L_i - P_{VRE_i}$$

Where,

NL_i = net load at interval i

L_i = total load at interval i which is the demand minus transmission losses

P_{VRE_i} = generation metered quantity of VRE resource at interval i

Ideally, the system should only see variations from the load. However, with the integration of VRE resources, the system variability increases causing the net load to deviate from the load. The magnitude of the deviation gives an insight on the penetration level of the VRE resource to the system. As can be seen in the figure above, the deviation caused by wind farms in Luzon is minimal during the Habagat season where wind speeds are low. On the other hand, during the Amihan season where wind speeds are high, there is a notable deviation of the net load from the load.

With both load and net load variations, duration curve for Luzon is shown in Figure 26. In this data there is no notable difference between the two variations. Any difference in the duration curves indicates that more regulating reserve is required when the VRE resource is added to the system.[27] Thus, based on Figure 26, with the 2.81% penetration level of wind farms in Luzon for 2017, the regulating reserve of the region may be sufficient to address the additional variability of wind farms. Also it can be discerned from the figure that approximately 40% of the time, there is a considerable variation in the output of wind farms with 100 MW maximum and -60 MW minimum.

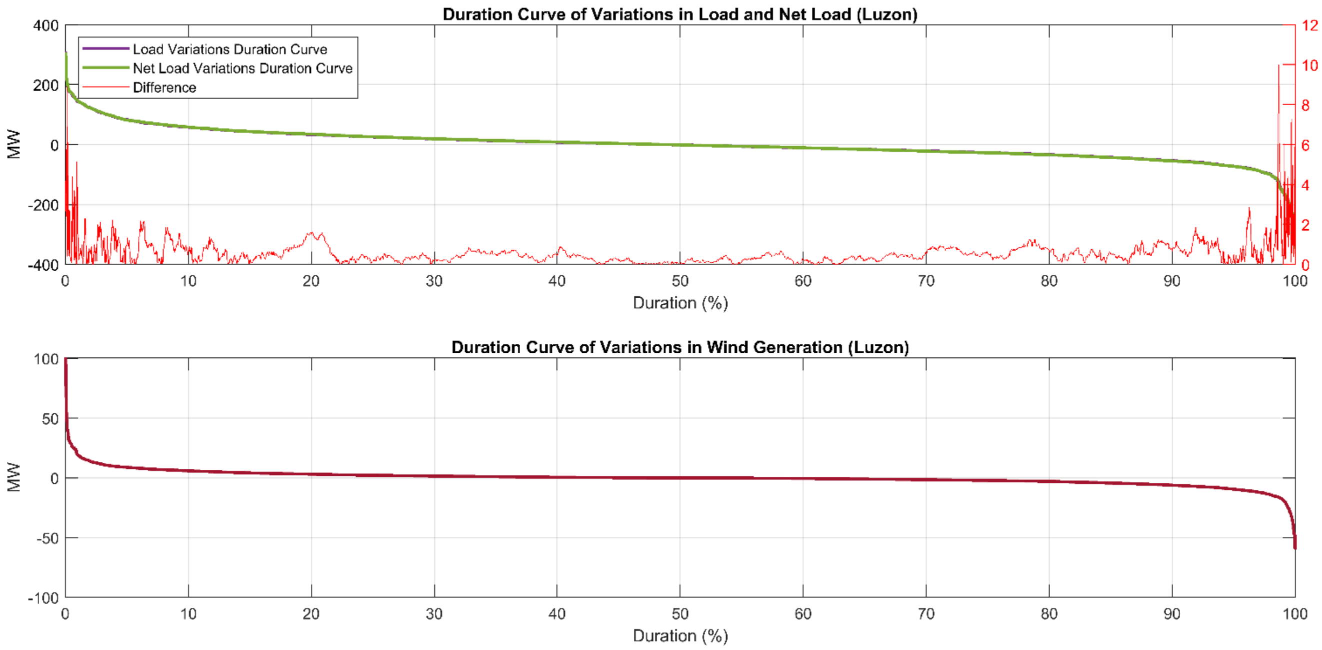

Figure 26 Luzon Duration Curve

For Visayas, a Summer season (23 to 29 April 2017) representing a period of high solar irradiance and a Rainy season (04 to 10 June 2017) representing a period of low solar irradiance was analyzed. Some dates with inconsistent information were removed from these week-long data sets. As expected, solar farms only operate during daytime (6am to 5pm), and significant deviation between net load

[27] Hannele Holttinen, "*Hourly wind power variations and their impact on the Nordic power system operation*" (Helsinki University of Technology, 2003).

and load is observed (see Figure 27) indicating significant penetration levels from solar farms.

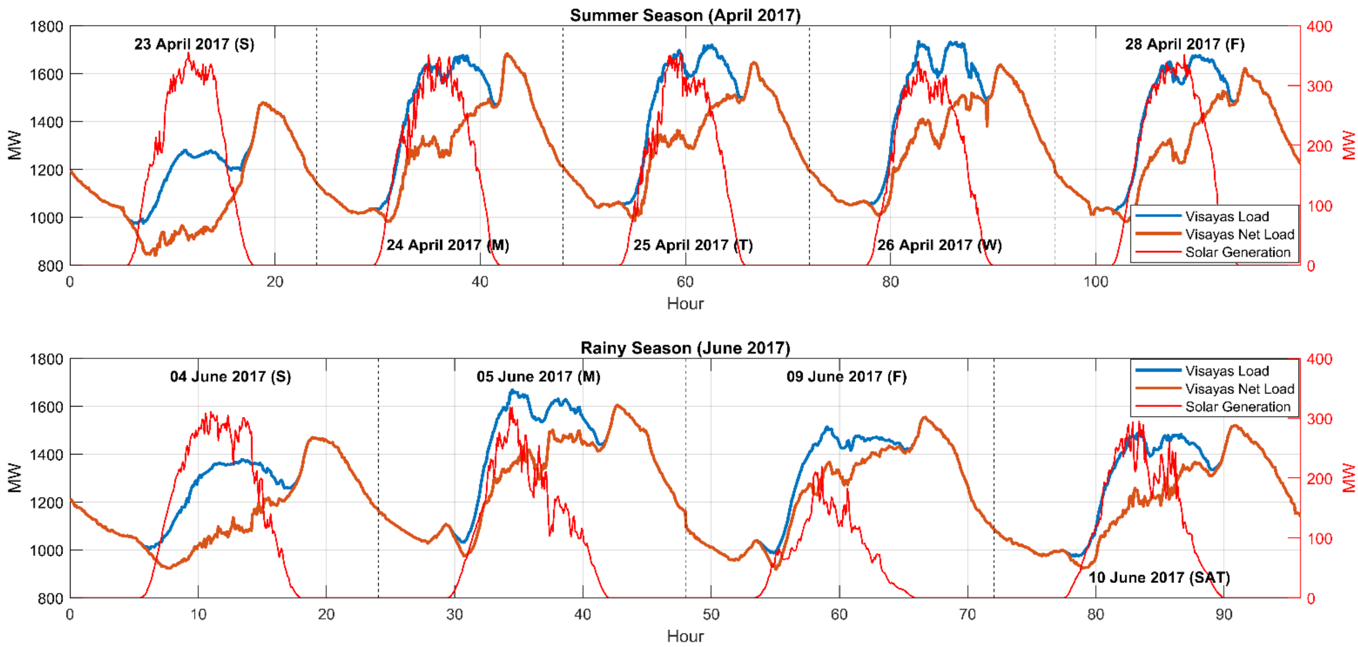

Figure 27 Load and Net Load Profile of Visayas

The duration curve of load and net load in Visayas is shown in Figure 28. For approximately 9% of the time where there is a notable difference between variations in the load and net load. This requires increased regulating reserves. Thus, the regulating reserve requirement as currently set in the region may be insufficient to address the 23.52% penetration level of solar farms located in Negros Island to the Visayas grid. Moreover, from the figure, around 40% of the time, there is a considerable variation in the generation of solar farms with 73 MW maximum and -76 MW minimum.

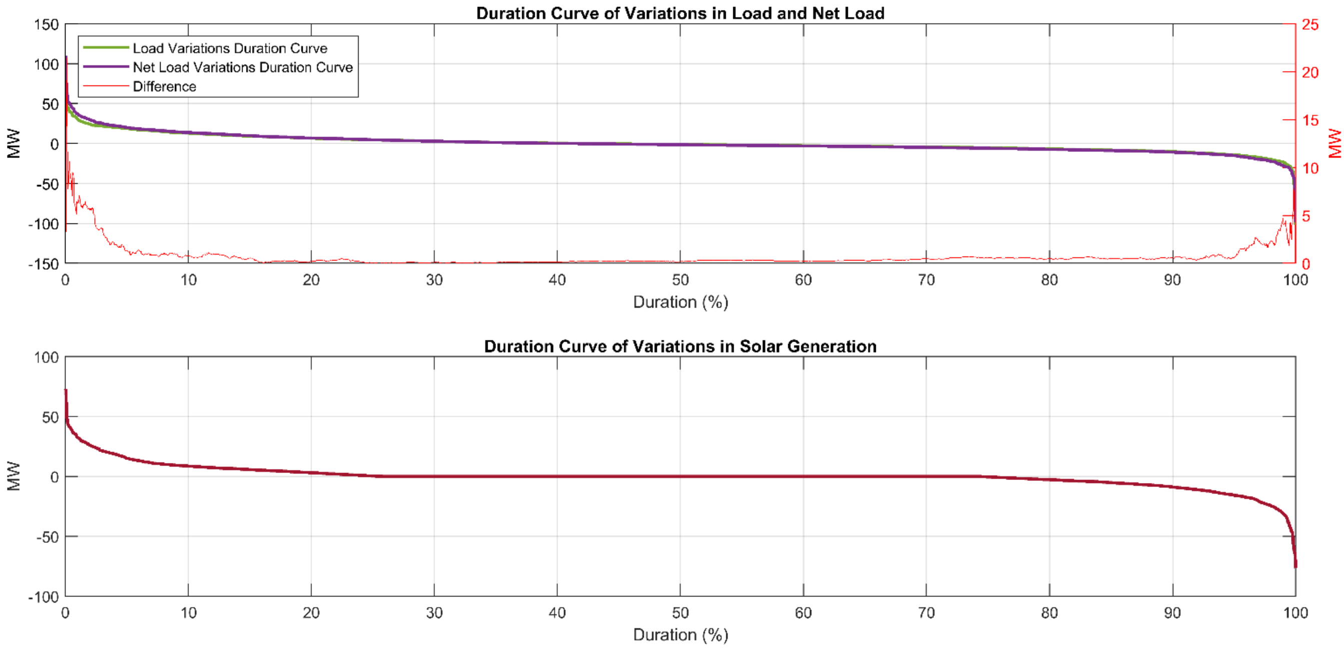

Figure 28 Visayas Duration Curve

For the following calculations, it was assumed that the system is operating at normal condition.

To estimate the regulating reserve requirement for Luzon and Visayas, an equation similar to the one used in the 2006 Minnesota Wind Integration Study was applied. The standard deviation of the net load can be calculated as follows assuming that the variations in the load and in the power generated by the VRE resource are uncorrelated,

$$\sigma_{NL\_var} = \sqrt{\sigma_{load\_var}^2 + \sigma_{VRE\_var}^2}$$

A confidence level of five times the standard deviation of the net load was considered in order to incorporate in the calculation 99.999% of the variations in the net load. The following equation provides the equation used in the calculation of the regulating reserve requirement for Luzon and Visayas grids.

$$Reg\ Req = 5\sqrt{\sigma_{load\_var}^2 + \sigma_{VRE\_var}^2}$$

As a basis of comparison, this regulating reserve requirement was compared to the case with no VRE variations corresponding to 0% VRE penetration.

Table 13 Comparison of Regulating Reserve Requirements

Region	Luzon	Visayas
Load Variation Standard Deviation (σ_{load_var})	51.358 MW	10.579 MW
VRE Resource Variation Standard Deviation (σ_{VRE_var})	6.840 MW	9.992 MW
Net Load Variation Standard Deviation (σ_{NL_var})	51.812 MW	14.552 MW
0% VRE Regulating Reserve Requirement ($5\sigma_{load\_var}$)	256.790 MW	49.960 MW
Regulating Reserve Requirement ($5\sigma_{NL\_var}$)	259.061 MW	72.760 MW

From the table, the variation introduced by wind farms in Luzon grid only increased the system variability by 0.454 MW (51.812 MW – 51.358 MW). The calculated regulating reserve requirement increased only by 2.271 MW (259.061 MW – 256.790 MW) from when the penetration level of wind farms is assumed to be at 0% Thus, the current regulating reserve setting in Luzon grid is effectively sufficient considering the current penetration level.

For Visayas, it was shown in the table that even though solar farms only operate at daytime, the system variability increased by 3.973 MW (14.552 MW – 10.579 MW) and the regulating reserve requirement increased by 22.80 MW (72.760 MW – 49.960 MW) compared to 0% VRE penetration. This illustrates that based on the assessment and calculations done for Visayas grid, the penetration level of solar farms in Negros Island is significant enough and must be considered in setting the regulating reserve requirement of the region.

The calculated regulating reserve requirements for Luzon and Visayas are still subject to change if additional data are to be considered in order to adequately incorporate the variations introduced by VRE resources to the system. Thus, it is recommended that a more substantial study on reserve requirements has to be done based on the recommendations in earlier studies in various jurisdictions presented in Sections 4.4.1 to 4.4.4.

5. SUMMARY

WESM Data in recent years has clearly shown the increasing penetration of VRE resources in the Philippine grids. Although beneficial in many ways, this development has introduced increased variability and uncertainty in electricity supply. Expectedly, there will be an impact in the reserve requirements. Such challenges are currently managed by the System Operator through contracts with various A/S Providers.

It is envisioned that an effective Reserve Market shall provide trading of various reserve categories at competitive prices. This will happen when there is larger trading from more market participants. Presently, there are substantial capacities available in the Luzon grid. However, not all of these are certified A/S providers. Aligned with the preparation for a full implementation of a reserve market, it is hoped that more power plants can be certified to provide ancillary services.

Even prior to a reserve market, the reserve requirements for various categories may have to be reviewed in the light of increasing VRE penetration. Included in this study is a straightforward analysis on possible sizing of reserve based on load and supply variabilities. The TC recommends that further studies accommodating more sophisticated models be conducted in order to specify options for new reserve requirements.

In addition, there are other opportunities to cushion the impact of larger penetration of VRE. To address the natural variability of VRE resources, energy storage systems (ESS) are being introduced at the grid-scale. Currently, wind turbine generators are not expected to provide any service to address variability, however we envision that further technology development is making possible services such as that of synthetic inertia.

To address supply uncertainty brought about by VRE resources, we expect improved forecasting both from the supply side and from the operators (i.e. both the system operator and the market operator). The existing target performance of 18% MAPE is consistently achieved by many participants. With ever improving forecasting techniques, we envision that this industry-wide target can be reduced, thus assuring more accurate forecasts.

Another concern that was described in this study is the apparent concentration of VRE developments in some areas. To address this, the TC supports the existing policy and on-going efforts from the DOE for optimal location of VRE developments. A full implementation of DOE DC No. 2009-07-0011 and the on-going activities to establish Competitive Renewable Energy Zones (CREZ) are expected to avoid further overcrowding.

Lastly, the TC acknowledges that the transmission development undertaken by the transmission network provider (TNP) to strengthen EHV corridors in Luzon and to connect inter-islands in Visayas and Mindanao provides for better transport of supply from various VRE resources.

ABOUT THE TECHNICAL COMMITTEE

Under Clause 1.7.2 of the WESM Rules, the Technical Committee shall from time to time as necessary and appropriate, and whenever the PEM Board directs: *(a) Monitor technical matters relating to the operation of the spot market; xxx (c) Assist the PEM Board by providing expertise in relation to: xxx (3) Any other matter of a technical nature relating to the spot market; (d) From time to time if the Technical Committee in its discretion deems necessary or appropriate, propose amendments to the WESM Rules in relation to technical matters, in accordance with chapter 8 with a view to: (1) improving the efficiency and the effectiveness of the operation of the spot market; and (2) improving or enhancing the prospects for the achievement of the WESM objectives; and (e) Assist the Rules Change Committee in relation to its assessment of proposals of a technical nature to amend the WESM Rules under chapter 8.*

Further, Section 4 of the Technical Committee Market Manual (TCMM) provides that the Technical Committee shall conduct technical reviews and studies in relation to (a) power plant technical parameters; (f) improvements and new trends in technology relating to the WESM that may enhance efficiency and effectiveness of the operation of the spot market and the prospects for the achievement of the WESM objectives; and (g) any other matter of technical nature relating to the sport market.

The TC is currently composed of three (3) members, namely, Prof. Jordan Rel C. Orillaza, Chairperson of the Committee; Engr. Jaime V. Mendoza, Distribution Management Committee (DMC) Representative; and Engr. Fidel D. Dagsaan, Jr., Systems Operator (SO) Representative. Mr. Ermelindo R. Bugaoisan, Jr. was recently appointed by the PEM Board, replacing Engr. Dagsaan, as the SO Representative to the TC during its meeting held on 30 August 2018.

This report is prepared with the assistance of the Market Assessment Group of the Philippine Electricity Market Corporation.

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