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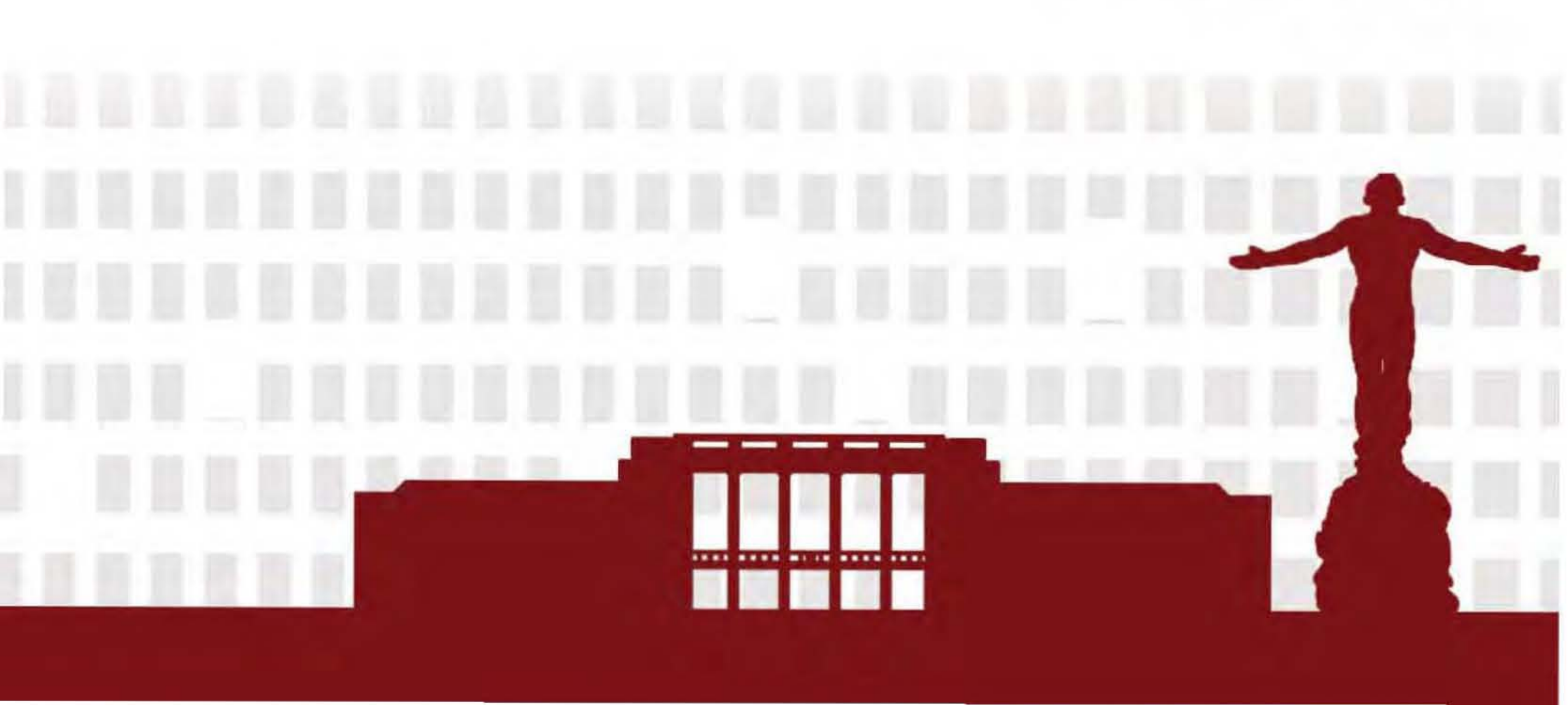

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RELIABILITY EVALUATION OF TWO INTERCONNECTED POWER SYSTEMS INCORPORATING INTERMITTENCY AND SEASONAL VARIATION IN GENERATION AND LOAD FORECAST UNCERTAINTY

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SUMMARY

This study developed analytical and probabilistic models and methodology that simultaneously take into account the intermittency of wind power, the seasonal variation in hydro power, and the load forecast uncertainty in evaluating the reliability of two interconnected power systems. The intermittency of wind power was incorporated by using a sliding window approach with 7-hour period while the seasonal variation in hydro power was incorporated by considering the hourly generation. A seven-step approximation of the normal distribution was used for the load forecast uncertainty considerations. The Loss-of-Load Expectation (LOLE) in the Luzon Grid in 2014, when assisted by the Visayas Grid, increased from 52.97 hours/year to 95.13 hours/year when the intermittency of wind power, the seasonal variation in hydro power, and the load forecast uncertainty were considered. On the other hand, when the Luzon Grid is the assisting system, the LOLE in the Visayas Grid increased from 12.25 hours/year to 32.46 hours/year. There was a significant improvement in the calculated LOLE in two interconnected power systems when the intermittency and seasonal variation in generation and the load forecast uncertainty were simultaneously considered.

Keywords: Reliability, Loss-of-Load Expectation, Intermittency, Seasonal Variation, Load Forecast Uncertainty

Introduction

Power systems should be able to supply electrical energy while satisfying economic constraints and acceptable levels of reliability and service quality. However, uncertainties in energy supply, which are brought about by several factors such as random system component failures, seasonal variation, intermittency of resource, and fluctuation of load, affect the operation of the power system, which may cause interruption to load customers [1]. To prevent this from happening, the reliability of a power system must be studied.

Interconnected power systems are composed of several individual power systems connected by tie-lines. Interconnecting a power system to other power systems generally improves the adequacy of the generating capacity since the capacity deficiency may be accommodated by available assistance from other systems [2].

The Philippine power system is composed of three main grids: the Luzon grid, the Visayas Grid, and the Mindanao Grid. As of the moment, the Luzon and the Visayas Grids are interconnected by a 440 MW HVDC link [3]. By 2016, the National Grid Corporation of the Philippines (NGCP) will start the construction of the $500-million Leyte-Mindanao Interconnection Project. This project involves linking of the Visayas and Mindanao Grids into a unified Philippine National Grid – the "One Grid, One Nation" goal [4].

Materials and Methods

This study developed models and methodology that simultaneously take into account the intermittency in wind power, the seasonal variation in hydro power, and the load forecast uncertainty in evaluating the reliability of two interconnected power systems.

To incorporate the effects of intermittency in wind power, a sliding window approach [5] with 7-hour period was used for the generation model of the wind power generating unit. To incorporate the effects of seasonal variation in hydro power, the hourly generation profile was used for the generation models of the hydro power generating units. The hourly load profile was used for the load models to match the hourly generation profiles of the generating units. The Tie-Line Constrained Equivalent Assisting Unit (TCEAU) models were derived from the hourly COPTs using the Equivalent Assisting Unit approach [2]. For the load forecast uncertainty (LFU) considerations, a seven-step approximation of the normal distribution [6] was used.

The methodology developed was used to calculate the LOLE and the Reserve and by convolving the models and incorporating the probability of existence of the TCEAU in the calculation of the weighted LOLE. The methodology and models developed were used to evaluate the reliability of the Luzon-Visayas interconnected power system. A program was developed in MATLAB® to obtain the results.

Results

The LOLE values in the Luzon Grid when assisted by the Visayas Grid and the LOLE values in the Visayas Grid when assisted by the Luzon Grid are shown in Figures 1 and 2, respectively. Different scenarios are considered depending on the factors considered. All three cases considered seasonal variation in hydro power.

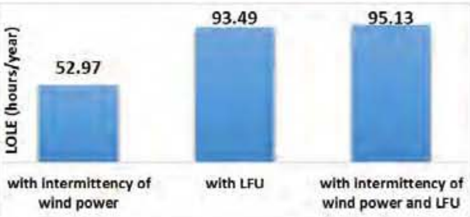

Fig 1. LOLE in the Luzon Grid when assisted by the Visayas Grid considering different factors

Fig 2. LOLE in the Visayas Grid when assisted by the Luzon Grid considering different factors

Tables 1 and 2 show the different cases considered by varying the percentage standard deviation of forecast error (%S.D.) of the system and the TCEAU when the intermittency in wind power, the seasonal variation in hydro power, and the load forecast uncertainty are simultaneously incorporated in the simulations, for the assisted systems Luzon Grid and the Visayas Grid, respectively.

Table 1. Reserve and LOLE values when the Luzon Grid is assisted by the Visayas Grid (all factors considered)

Luzon Assisted by Visayas				
Case	%S.D.		%Reserve	LOLE (hours/year)
	System	TCEAU		
1	4.51%	6.68%	30.78%	95.13
2		16.64%	30.45%	95.34
3	25.94%	6.68%	30.78%	1197.25
4		16.64%	30.45%	1204.02

Table 2. Reserve and LOLE values when the Visayas Grid is assisted by the Luzon Grid (all factors considered)

Scenario 4 (Luzon Assisted by Visayas)				
Case	%S.D.		%Reserve	LOLE (hours/year)
	System	TCEAU		
1	6.68%	4.51%	43.86%	32.46
2		25.94%	40.59%	150.03
3	16.64%	4.51%	43.86%	128.96
4		25.94%	40.59%	337.34

Discussion

The intermittency of wind power, the seasonal variation in hydro power, and the load forecast uncertainty have a significant impact on the reliability risks of two interconnected power systems. The LOLE in the Luzon Grid in 2014 when assisted by the Visayas Grid increased from 52.97 hours/year to 95.13 hours/year when all the factors are present. When the Luzon Grid is the assisting system, the LOLE in the Visayas Grid increased from 12.25 hours/year to 32.46 hours/year.

The impact of the intermittency and seasonal variation in generation and the load forecast uncertainty on the LOLE varies depending on the generation mix and the accuracy of load forecast, respectively. Knowing the weight of impact of the factors on the reliability of interconnected power systems is important in determining the policies needed to be developed to achieve higher reliability at low cost.

The intermittency and seasonal variation in generation of the assisting system affects the reliability of its assisted system. The generation mix of both the assisting and the assisted systems should therefore be carefully considered in reliability planning for interconnected power systems. Similarly, for the load forecast uncertainty considerations, the load forecast accuracy in the assisting system affects the reliability of the assisted system. High load forecast accuracy, which can be achieved by using an effective load forecasting methodology, is desired to avoid overestimation of the reliability risks.

The improvement in calculated LOLE in two interconnected power systems significantly increases when the intermittency of wind power, the seasonal variation in hydro power, and the load forecast uncertainty are all considered simultaneously. The calculated LOLE significantly improves when these factors are considered as compared to assuming a constant level of generation throughout the year and negligible deviation between the forecasted and the actual load values. Therefore, there is a definite and imperative need to consider the factors simultaneously to avoid considerable underestimation of the reliability risks.

Acknowledgments

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