

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

This study applied time-series models for the short-term forecasting of wind speed for a site in Rayong, in the Eastern region of Thailand. In particular, univariate ARIMA and multivariate VAR classes of models were presented. The univariate case considered wind speed recorded at 100-m while the multivariate models involved the wind speed and global solar radiation, vertical temperature difference, and land-sea temperature difference. The time series analysis aims at capturing the important features of the observed data such as the time-dependence, co-dependence, and periodic structure. This would in turn be useful for fitting appropriate models and forecasting for the wind speed over a time horizon of 24-hours. The models were selected for each month separately and forecasts done over different episodes for each case.

For each month, a set of models was identified and the values of their model orders were varied, parameter estimation was done by fitting the models with the data, and then the *AIC* criterion was used to select the most appropriate model. From the residual diagnostics, it was found that all of the models picked for all the months were in fair agreement with the underlying assumptions in showing goodness-of-fit. However, the performance of the selected models in terms of their forecasting capability varied for each month and as per the class of models. From the validation period, set from January 1, 2005-December 30, 2006, the performance evaluation was based on the prediction and observation pairs. The time-series models were mostly seen to out-perform the persistence model, with the monthly mean error (ME) ranging from 1.03-1.83 m s<sup>-1</sup>. It was also found that the process of de-diurnalization on the input detrended series in dARIMA and VAR effectively deals with diurnality and leads to better performance.

As for the question of how well the models perform with respect to varying magnitude of wind speed, it was found that it was more difficult to forecast very low wind speeds (< 2 m s<sup>-1</sup>) and high wind speeds (10 m s<sup>-1</sup> or larger), which implies that for the months with

relatively higher mean wind speed and gusts, such as in June-August, the performance of the time series models will be poor.

For the VAR model, the fitting was shown to be valid for the set of variables that were picked and the selected models were able to capture very well the co-dependence structure between multiple time series components as well as the autocorrelations in each component. The variables considered in the selected VAR model specification were wind speed, vertical temperature difference and land-sea temperature difference. The performance of the VAR model in terms of monthly correlation compared favorably with the rest of the time-series models, with a range of 0.34-0.58, and also in agreement with performance evaluation as per monthly mean error. The performance of all models in terms of correlations was reasonable considering the entire evaluation period ( $> 0.52$ ), with dARIMA showing the best performance ( $\approx 0.6$ ).

The accuracy of the predictions decreases as the window moves away from the last observed point, and therefore it may be valid to consider only very short-term forecasts. By application of these models, forecasts of up to 6 hours ahead can be done with the percentage of the ME with respect to the mean wind speed lower than 25%, except in October and November. The improvement over PS in terms of ME relative to mean wind speed was 1% for 1 hour in advance and 23-27% for 6 hours ahead, considering the overall evaluation period. For the monthly cases, the improvement varied from 0-2% for 1-hour time step and 3-27% for 6 hours ahead. The operational criteria for wind farms are mainly focused on a look-ahead time of six hours for transmission system operators scheduling. According to the above results, dARIMA, SARIMA and VAR exhibit the best overall performance and have positive merit over the persistence model.

## 5.2 Recommendations

This study has produced results based on the use of time-series models for the short-term forecast of wind speed. dARIMA and VAR are suggested for the months of February-April, and September, while SARIMA is more suitable for January and December. dARIMA is suitable for all monthly cases. For practical applications, for the site located

in Rayong, ensemble forecasts could be used to give a better overall performance from the time-series models, considering that one particular model has better performance in some months compared to the others. The time-series models could be tested on other sites with different topography and characteristics such as in urban areas, or hilly sites to assess their applicability and versatility. The results can be used as a basis for the development of improved models for the purpose of forecasting wind speed and wind power. There are other numerically advanced models available that could be used to improve on the results, such as vector autoregressive moving average (VARMA) models, and dynamical models e.g. WRF and RAMS. A more in-depth analysis of the observation data, including various forms of pre-processing could be explored in order to give better results. The results from this study can be viewed as a first step in gaining an insight in wind speed and wind power forecasting, which can be considered as important tools for the integration of wind energy for electricity generation.