Integrated Prediction of Wind-Farm Power Output

Jingxing Wang¹, Abdullah Alshelahi¹, Mingdi You¹, Eunshin Byon¹, Romesh Saigal
¹. Industrial and Operations Engineering, University of Michigan

Introduction

As the market share of wind energy in the electricity market has been increasing significantly during the recent decade, prediction of wind-farm power output is critical to manage its production process.

Objectives

Propose a wind farm power output prediction model which:
- Captures the time-dependent wind-power relations.
- Quantifies the variability by providing the distributions of both wind speed and power output.
- Achieves better prediction accuracy.

Wind Speed Model

- The wind speed S(t) follows an inhomogeneous geometric Brownian motion:
  \[ dS(t) = \mu_S(t) S(t) dt + \sigma_S(t) S(t) dW(t) \]
- \( \mu_S(t) \) and \( \sigma_S(t) \) are time-dependent parameters.
- \( W(t) \) is a standard Brownian process.
- The parameters are estimated by a dual Kalman filter.
- Let \( x(t) = \ln(S(t)) \) in Figure 2 below.

Dynamic Power Curve

- Quantify the relationship between wind speed and power output, \( F(t, S(t)) \), in a dynamic manner.
- The adaptive learning method [2] is employed to capture the dynamic dependency.

Power Output Model

- The power output \( P(t) \) follows an inhomogeneous geometric Brownian motion:
  \[ dP(t) = \mu_P(t) P(t) dt + \sigma_P(t) P(t) dW(t) \]
- \( W(t) \) is a standard Brownian process and
  \[ \mu_P = \frac{\mu_F + \mu_L S_F + \frac{1}{2} \sigma_F^2 S_F^2}{F} \]
- \[ \sigma_P = \frac{\sigma_F S_F}{F} \]
- The initial condition \( P(t) = p_0 \)
- The predicted power output at \( t+1 \) is \( K \).
- The price of a real call option, \( c(K; t; p_0) \), quantifies the amount of under-estimation.
- The price of a real put option, \( p(K; t; p_0) \), quantifies the amount of under-estimation.

Results and Discussion

- The algorithm is tested using data sets from two land-based commercial wind farms with \( w_c = w_p \)
- Less prediction error is obtained when compared to benchmark methods: persistent and ARMA.

- Calculate the prices of the real call and put options [3].
- Minimize the weighted sum of real call and put options
  \[ \min_w w_c(K; t; p_0) + w_p p(K; t; p_0) \]

References