

An Advanced Study of the Wind Power Variability on the Federal Columbia River Power System (FCRPS)

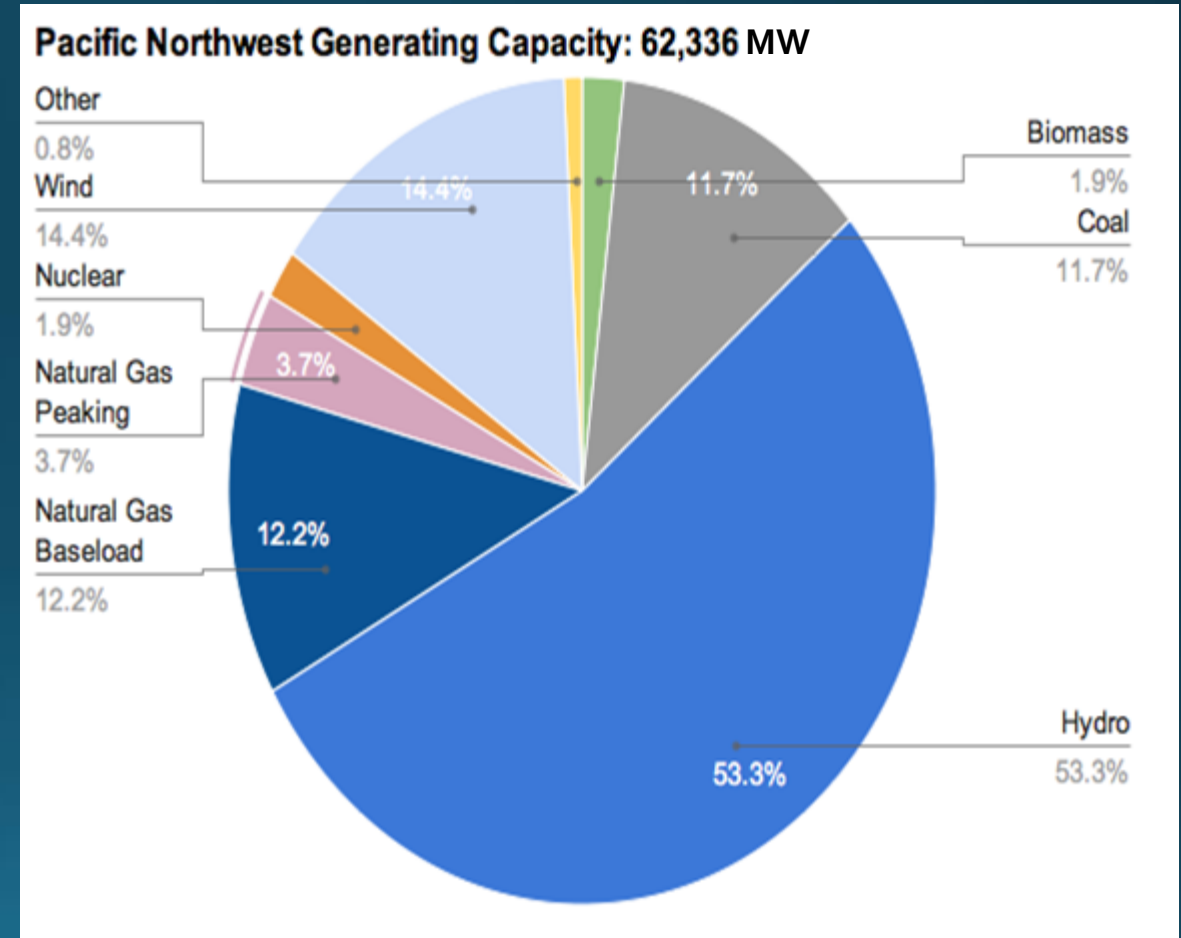
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Overview

- Introduction
- Background
- Study of the Wind Power Variation
- Correlation Coefficient Analysis
- Regression Analysis
- Conclusion

Introduction

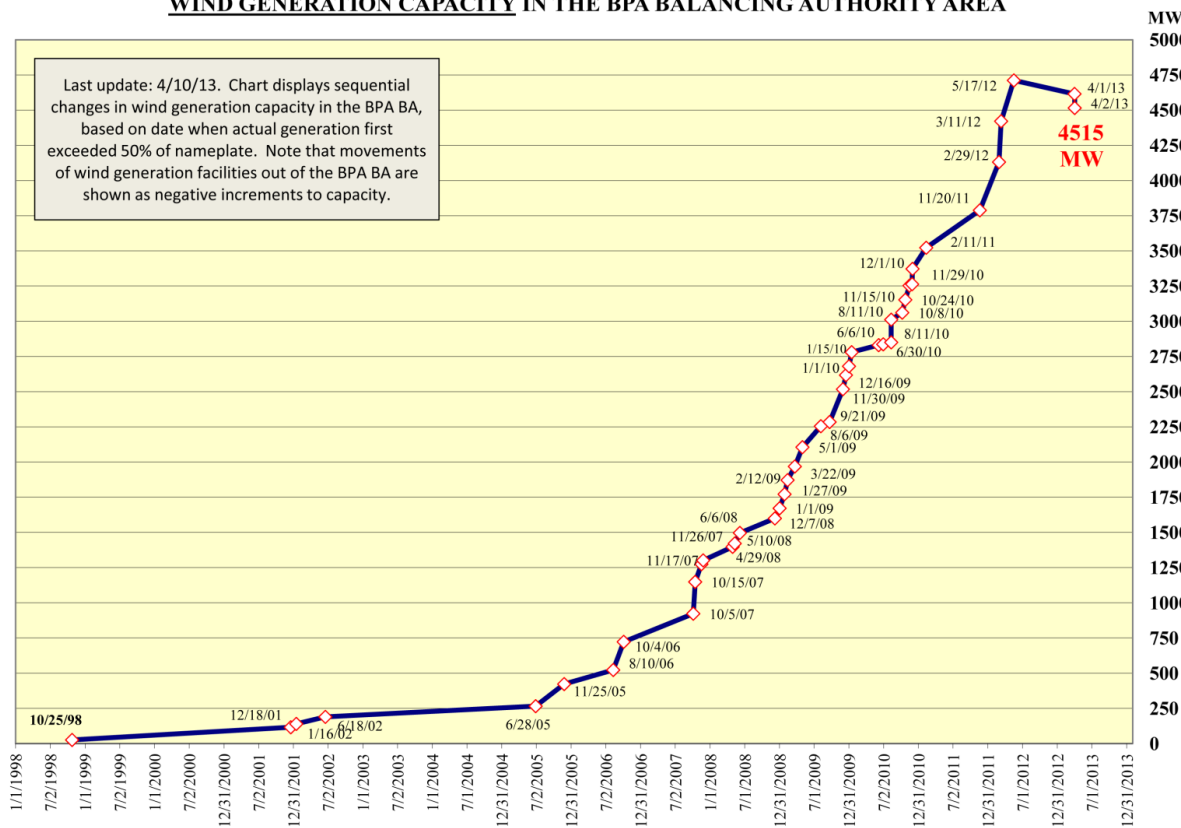
- Wind Power is highly non dispatchable.
- Other resources critical to compensate for wind power generation.
- Suitable Balancing Reserves –
 - Hydro Power
 - Thermal Power
 - Interchange Power



Wind Power

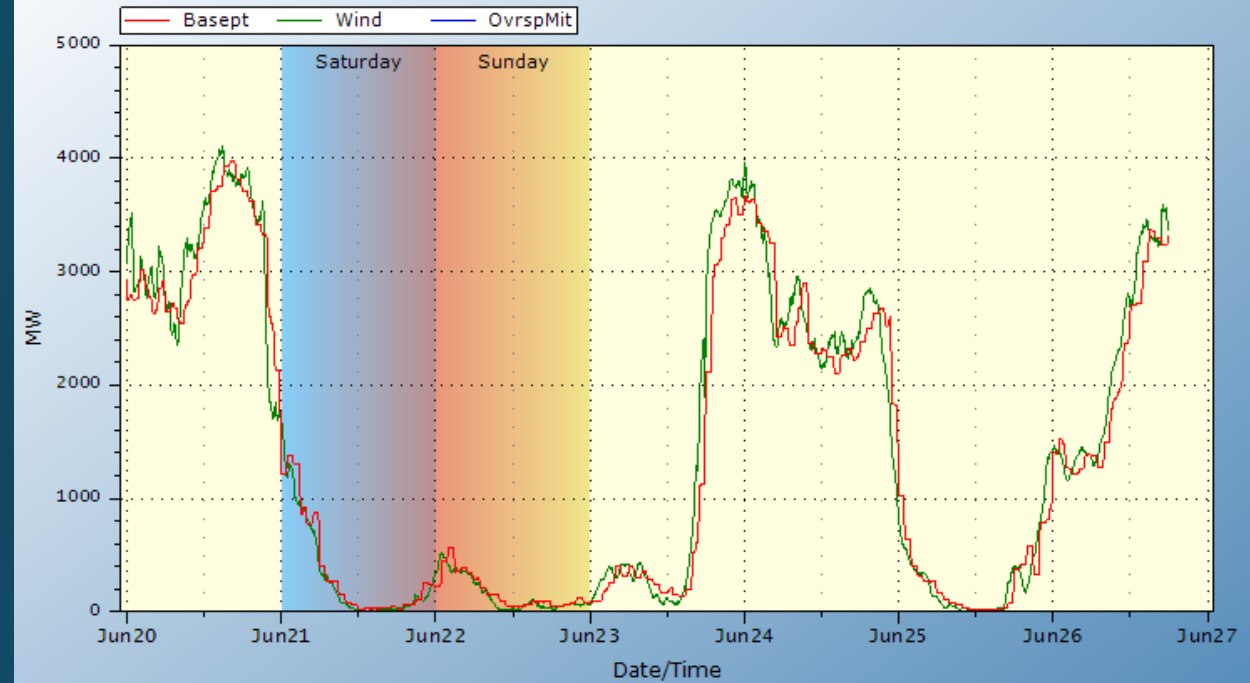
WIND GENERATION CAPACITY IN THE BPA BALANCING AUTHORITY AREA

Last update: 4/10/13. Chart displays sequential changes in wind generation capacity in the BPA BA, based on date when actual generation first exceeded 50% of nameplate. Note that movements of wind generation facilities out of the BPA BA are shown as negative increments to capacity.



WIND_InstalledCapacity_current.xls 4/10/2013

BPA Balancing Authority Total Wind Generation, Wind Basepoint, and Oversupply Mitigation, Last 7 days 20Jun2014 - 27Jun2014 (last updated 26Jun2014 18:06:51)



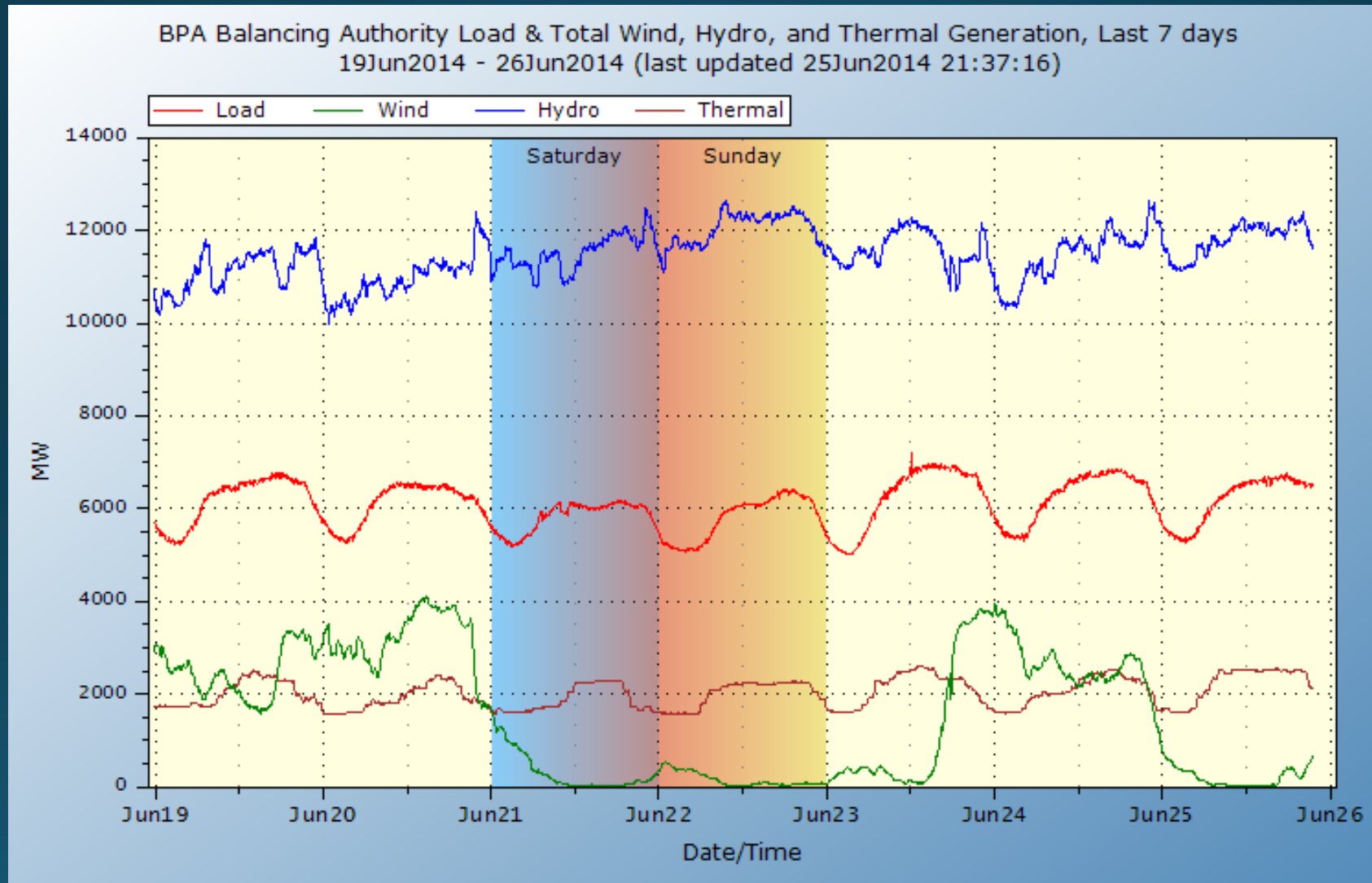
Based on 5-min readings from the BPA SCADA system for points 79687, 103349, 114476
Balancing Authority Wind Generation in Green, Wind Basepoint in Red, Oversupply Mitigation
(value equaling how much we are reducing the wind generation in our BA) in Blue
Click chart for installed capacity info
BPA Technical Operations (TOT-OpInfo@bpa.gov)

Federal Columbia River Power System

- 31 Dams built over Columbia River and its tributaries.
- Owned and operated by –
 - US Army Corps of Engineers
 - Bureau of Reclamation
- Balancing Authority – Bonneville Power Administration.



Comparison of Generation and Load



Study of the Wind Power Variation

- Analysis important to determine impact of wind power variation on the remaining power system.
- Statistical methods used for analysis-
 - Correlation Coefficient Analysis
 - Regression Analysis
- Analysis performed on data obtained from SCADA measurements from 2007 to 2013 at an interval of every 5 minutes

Correlation Coefficient Analysis

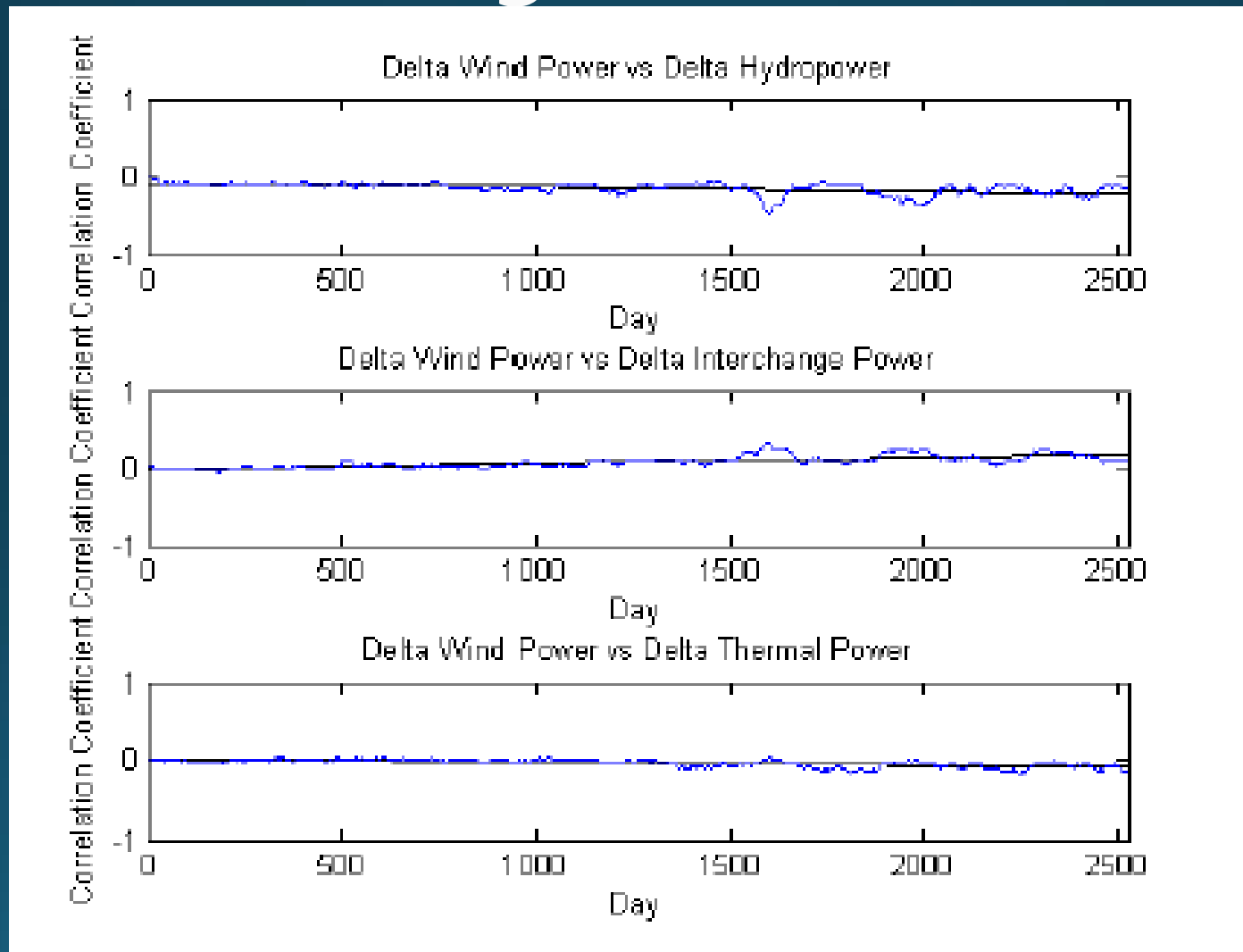
- Correlation Coefficient Analysis to determine the strength of a relationship.

- Correlation Coefficient calculated by –

$$R = S_{xy} / S_x S_y$$

- Calculated for 30 days with a sliding window of one day.

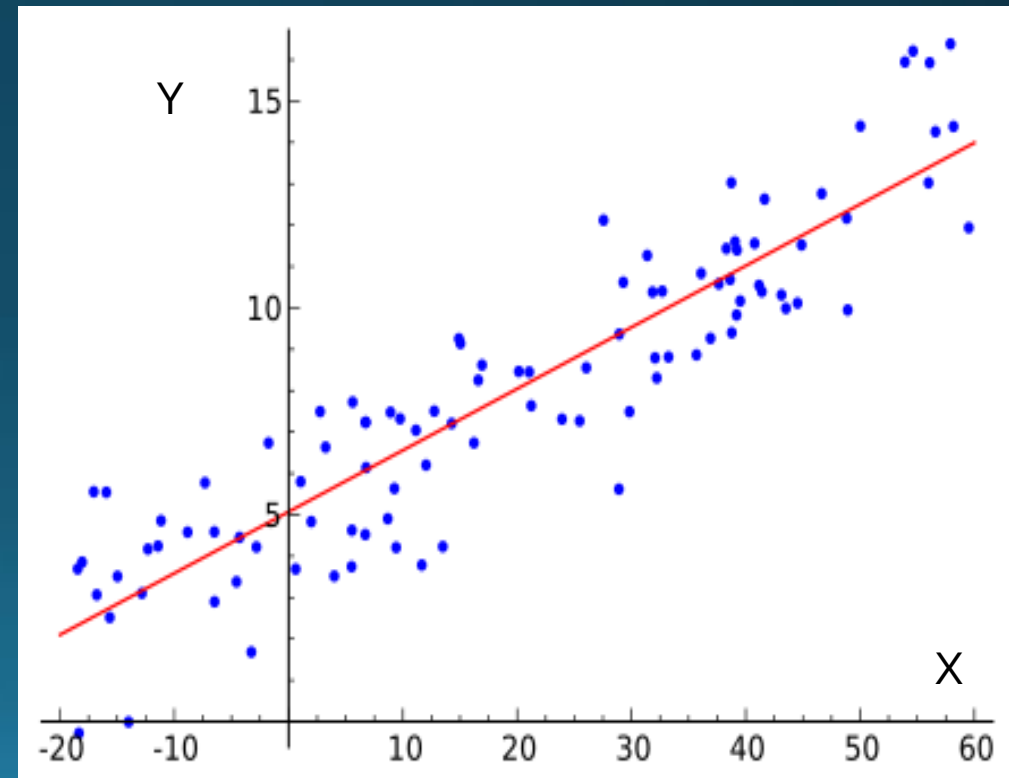
Changes in Wind Power vs. Changes in Hydro, Interchange & Thermal Power



Regression Analysis

- Regression Analysis creates a mathematical model to determine relationship between two variables.

- Regression Analysis calculated by –
$$Y = \beta_1 x + \beta_0$$



Regression Analysis and R^2

- To determine the effect of wind power on the hydro, thermal and interchange power -

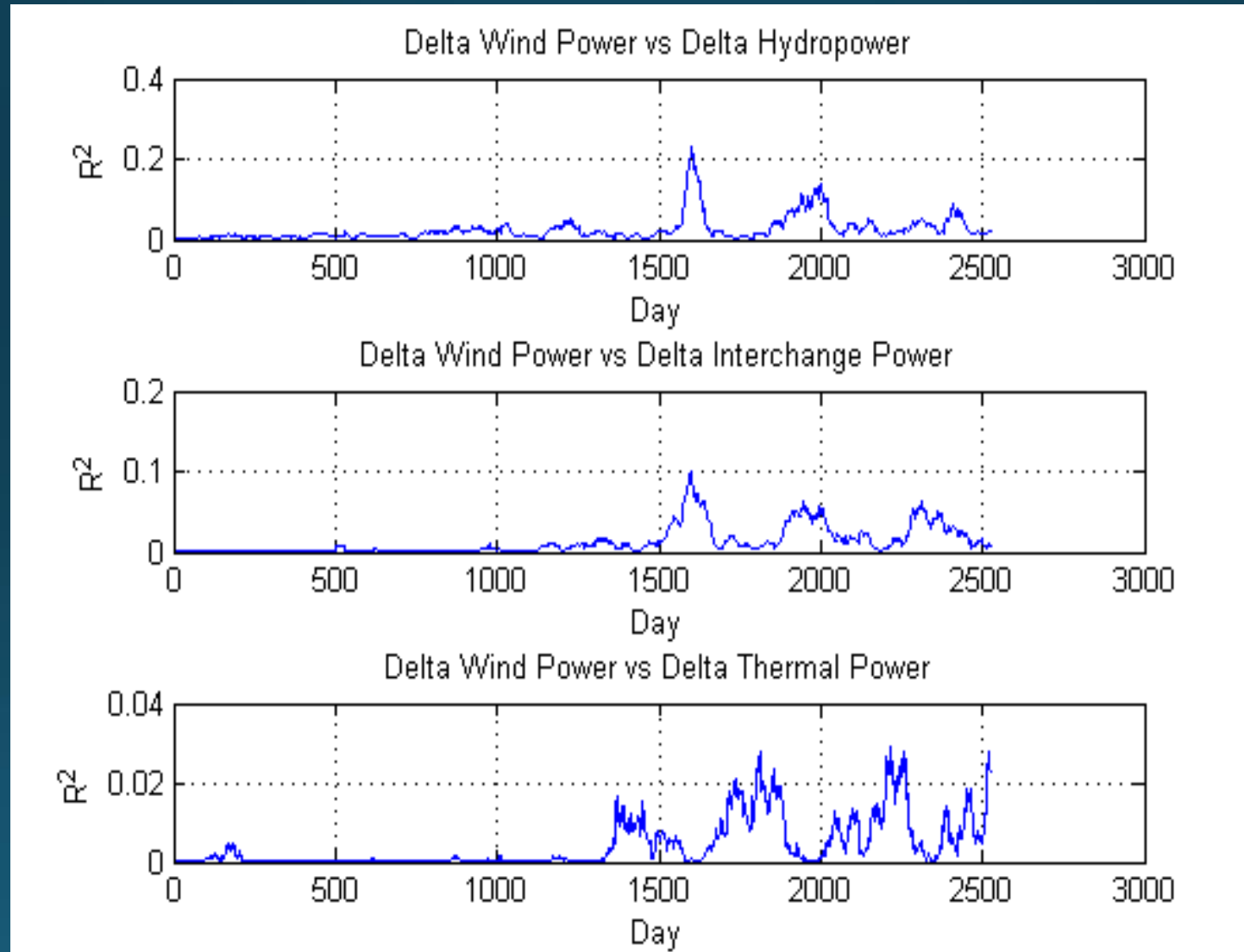
$$\Delta P_{\text{hydro}} = \beta_1 \Delta P_{\text{wind}} + \beta_0$$

$$\Delta P_{\text{thermal}} = \beta_1 \Delta P_{\text{wind}} + \beta_0$$

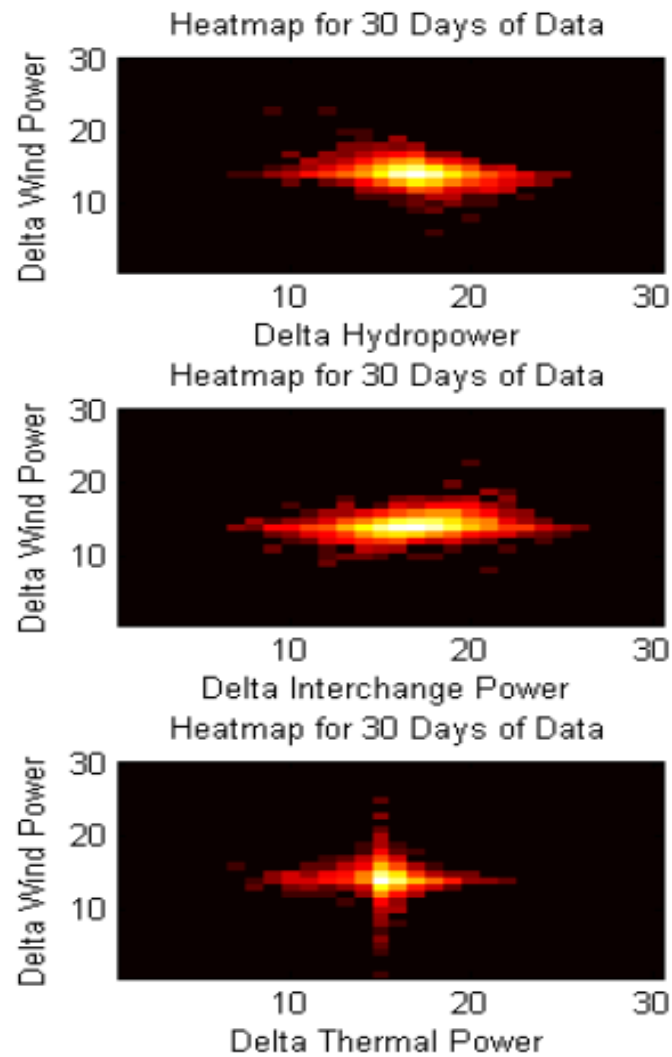
$$\Delta P_{\text{interchange}} = \beta_1 \Delta P_{\text{wind}} + \beta_0$$

- R^2 to determine how well the line fits the data.

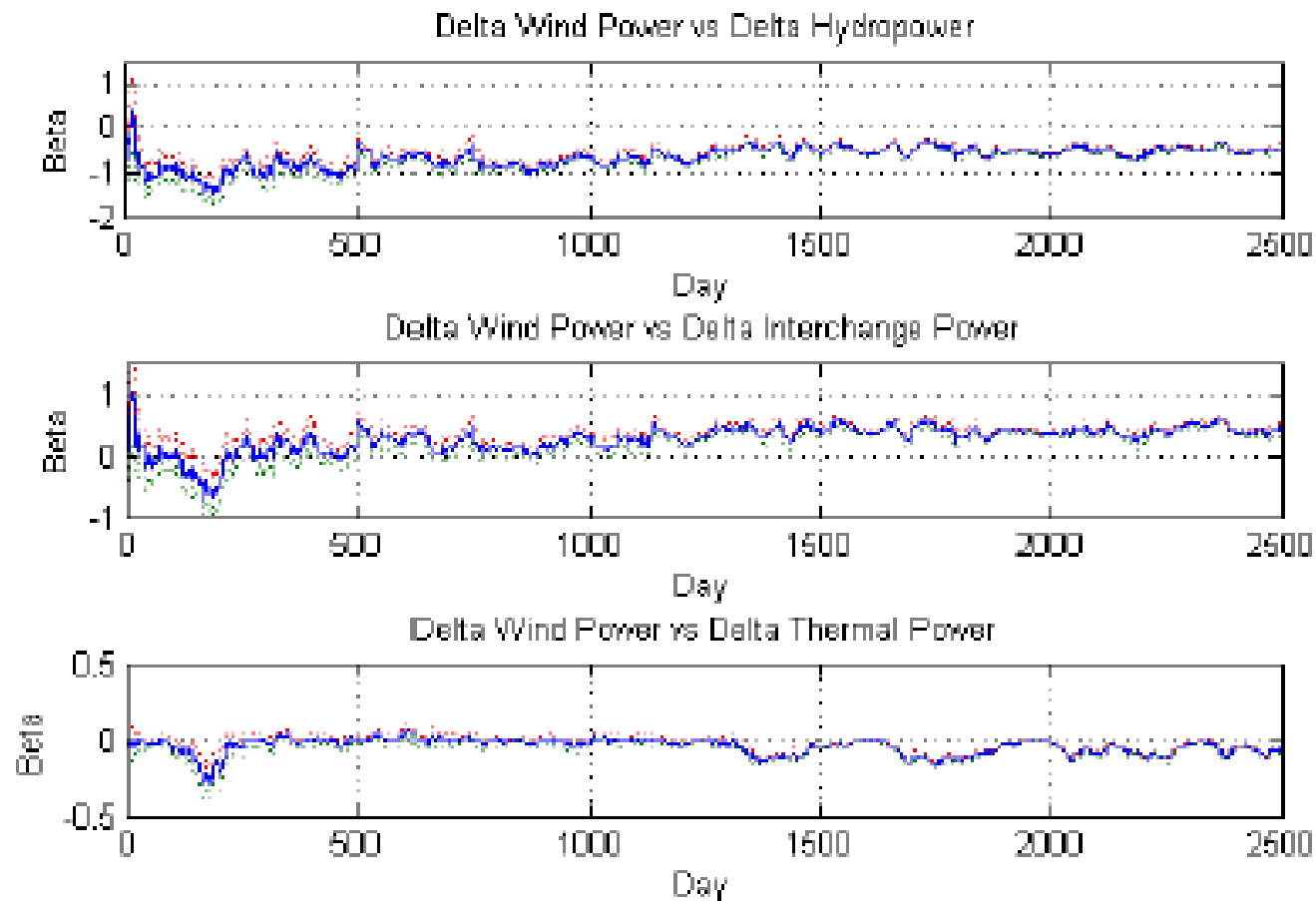
'R squared' - Goodness of the fit



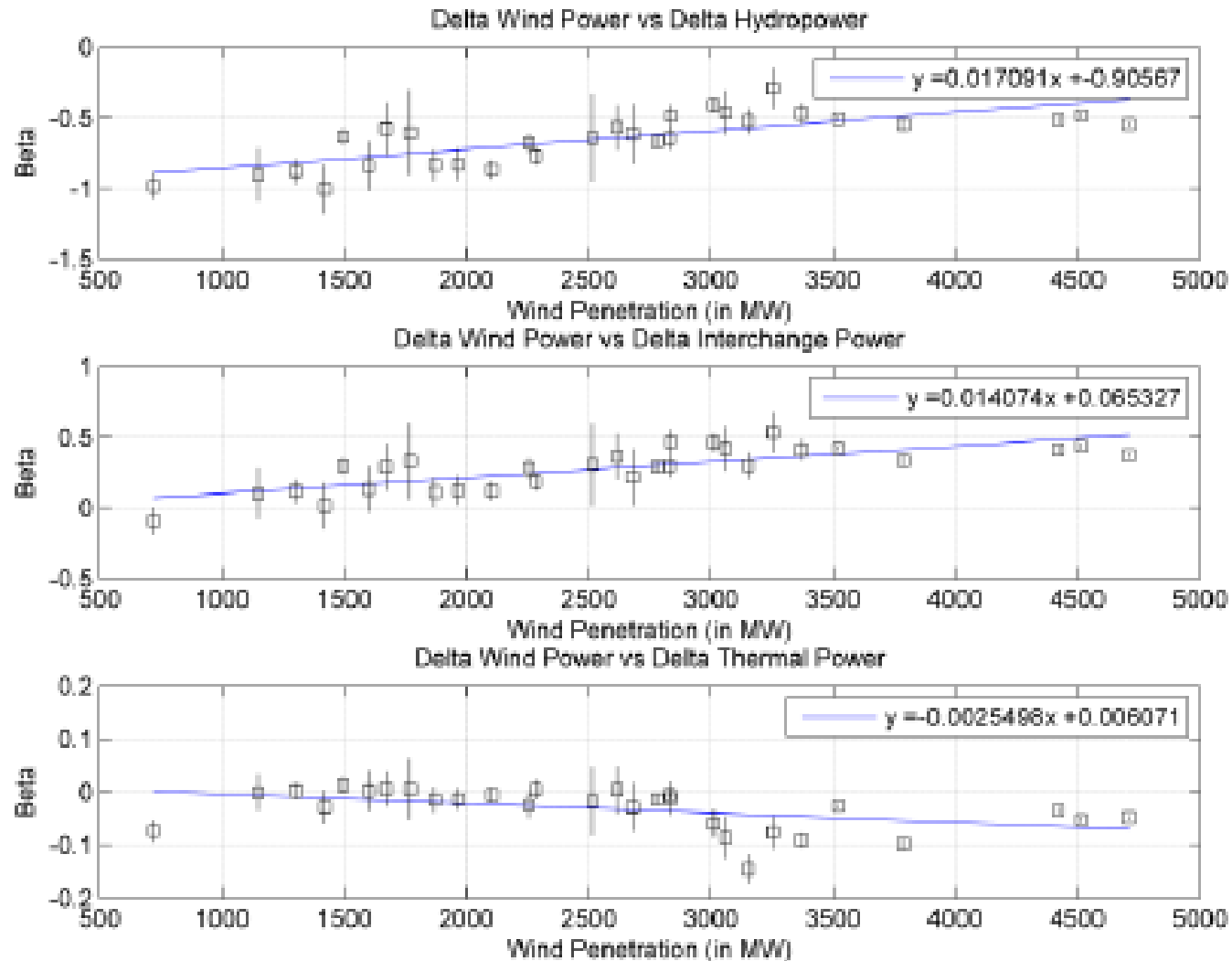
Data Density



Values of Beta for Changes in Wind Power vs. Changes in Hydro, Interchange & Thermal Power



Values of Beta for Wind Penetration



Conclusion

- Saturation of hydro power as a source of balancing reserve for wind power.
- Slight increase in the use of thermal power to balance wind.
- Use of AC interchanges to export variability has greatly increased.
- Changes in the dynamics of power system with the addition of wind power capacity.

Thank You.