Enhancing the Operation of Highly Varying Industrial Loads to Increase Electric Reliability, Quality, and Economics

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Enhancing the Operation of Highly Varying Industrial Loads to Increase Electric Reliability, Quality, and Economics

Research Team Members:

Principal Investigator: Dr. Robert Kramer, NiSource Energy Technologies (NET), Merrillville, IN

Sub-tier Principal Investigator 1: Dr. Rahmat Shoureshi, Colorado School of Mines (CSM), Golden, CO

Sub-tier Principal Investigator 2: Dr. Chee-mun Ong, Purdue University, W. Lafayette, IN

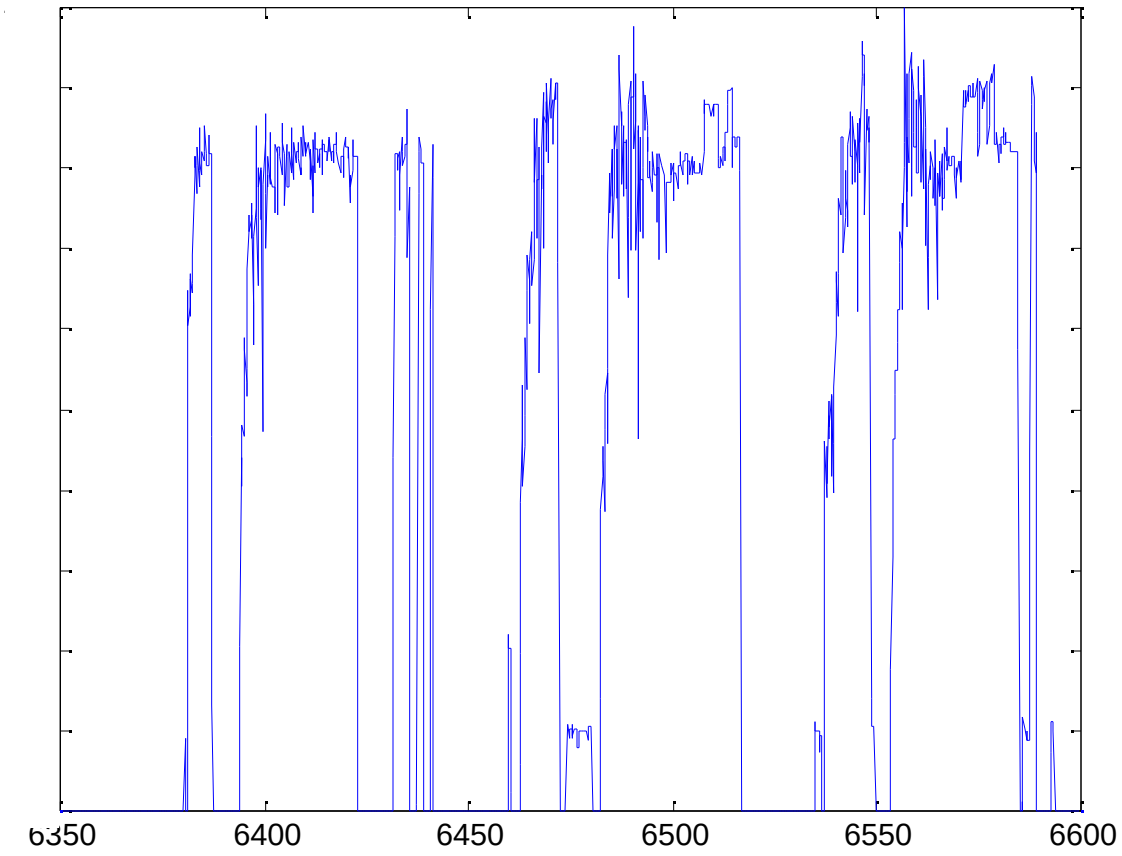
Sub-tier Principal Investigator 3: Dr. Thomas Sparrow, Purdue University, W. Lafayette, IN

Sub-tier Principal Investigator 4: Dr. Thomas Brady, Valparaiso, Indiana

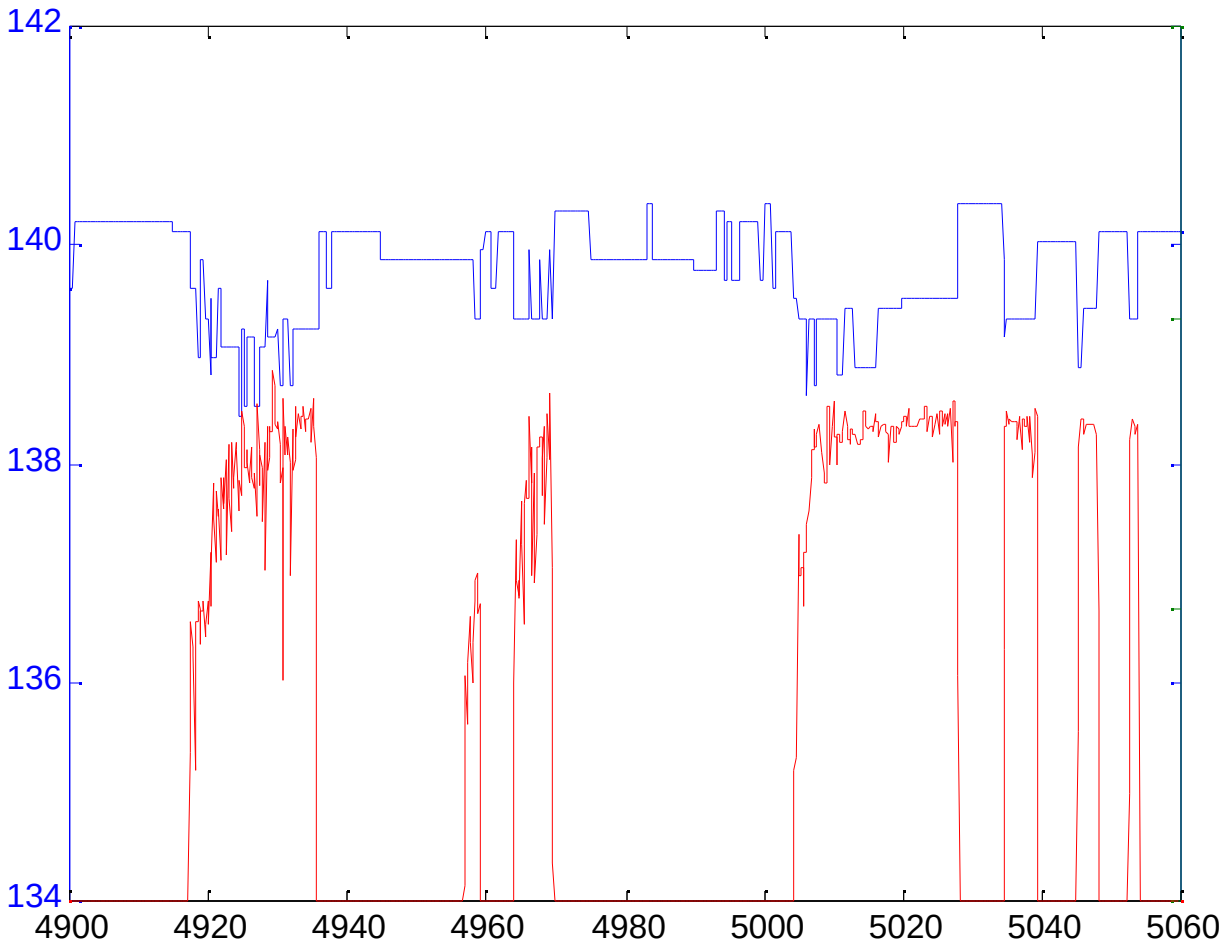
Goals and Methodologies

- Goal
  - **Develop a way to increase electric reliability and quality by reducing the electric fluctuations caused by large industrial loads without reducing productivity. Enhance energy utilization and reduce environmental emissions.**
- Method
  - **Develop ways to coordinate startup of large loads so that they tend to cancel out the electric transients from each other.**

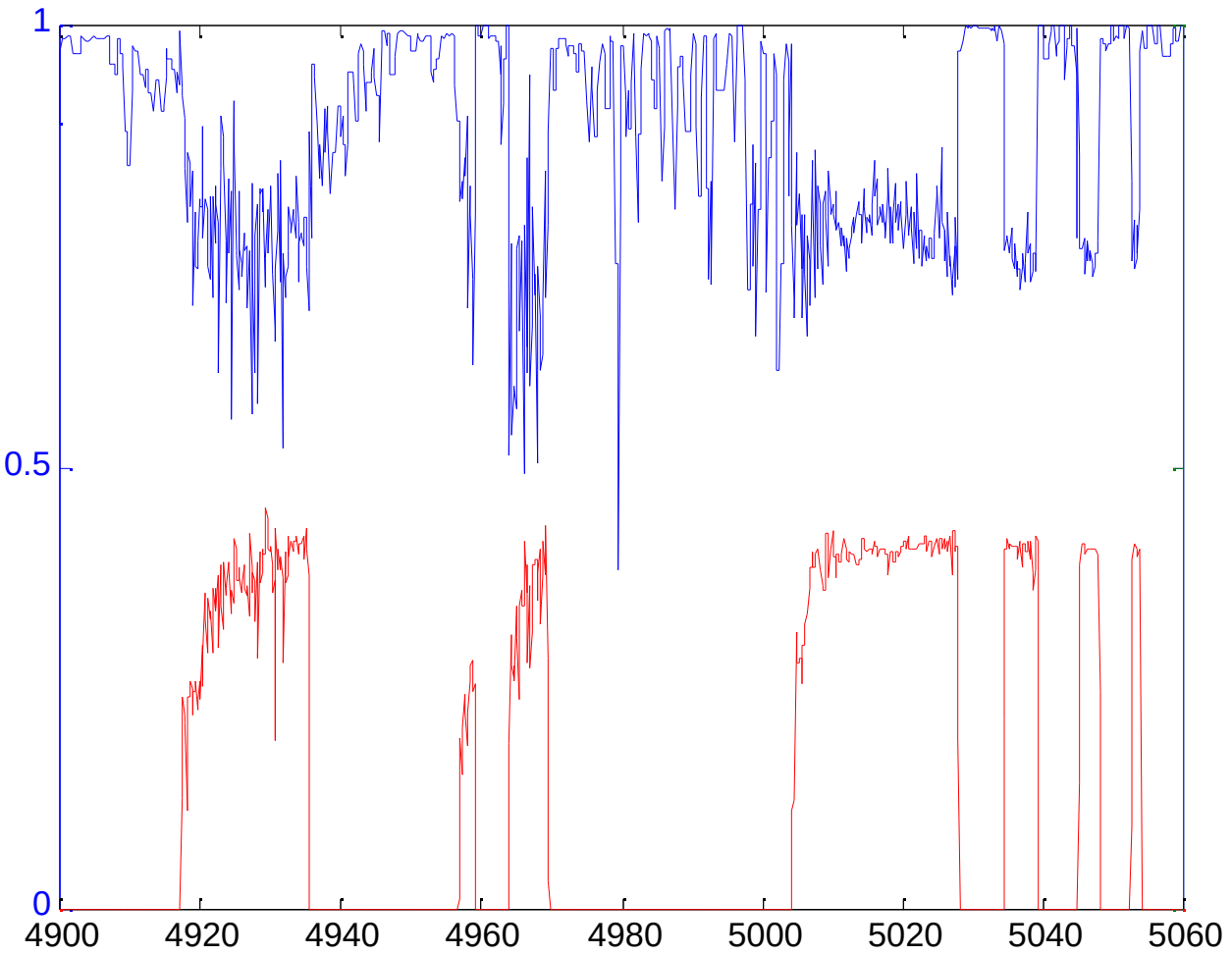
Large Load Swings



Impact of HVL on Voltage



Impact of HVL on Power Factor



Research Focus Areas

- **Modeling, prediction, and coordination of highly varying loads.**
  - **Prediction of roughly 168 stochastic loads and their interaction.**
  - **Interaction with the electric grid.**
  - **Improved Automatic Generation Control.**
  - **Operational Coordination Efforts**
    - **Arc Furnaces**
    - **Rolling Mills**
- **Sub allocation of Control Responsibility**
- **Economic and Regulatory Considerations**

Economic Considerations

(Principal Investigator: Dr. Thomas Sparrow, Purdue University)

- **In an ideal system, generating units would be able to follow all load fluctuations perfectly, with generation matching load exactly.**
- **In the real world, the ideal system is unachievable**
  - **Limitations of control systems**
  - **Slow response of generating units**
  - **Unpredictable nature of load variations**

Economic Considerations

The costs associated with providing regulation have been categorized into 9 types of costs:

1) Wear & Tear Costs (including Fixed, and Variable Operation & Maintenance Costs)

-- Cycling of generators causes increased wear and tear.

2) Cost of Departure from Optimum Heat Rate

-- Individual units on AGC are not usually operated at the optimum heat rate, resulting in higher fuel costs.

3) Cost of Departure from Optimum Dispatch Order (Ramp Limits)

-- Having units available for AGC results in a departure from the optimum dispatch order, resulting in higher fuel costs.

4) Cost of Departure from Optimum Unit Commitment

-- This is the cost of committing extra units in anticipation of having to serve highly varying loads.

Economic Considerations

5) Decreased Revenue/Increased Cost due to Transmission (Opportunity Cost)

-- Highly varying loads cause short-term imports/exports from/to neighboring control areas.

6) Environmental Costs/Benefits

-- The change in dispatch resulting from AGC as compared to the optimal dispatch order causes the environmental impacts (e.g., air emissions, water discharge) to change.

7) Cost of AGC System

8) Cost of Anticipating Highly Varying Load (Extra Spinning Reserve to allow AGC to function)

-- Units on AGC may have a more limited range of operation. The utility could be confronted with either an opportunity cost when operating below the maximum operating limit or be forced to purchase power when the load increases.

9) Penalty for Not Meeting NERC Standards (CPS1 & CPS2)

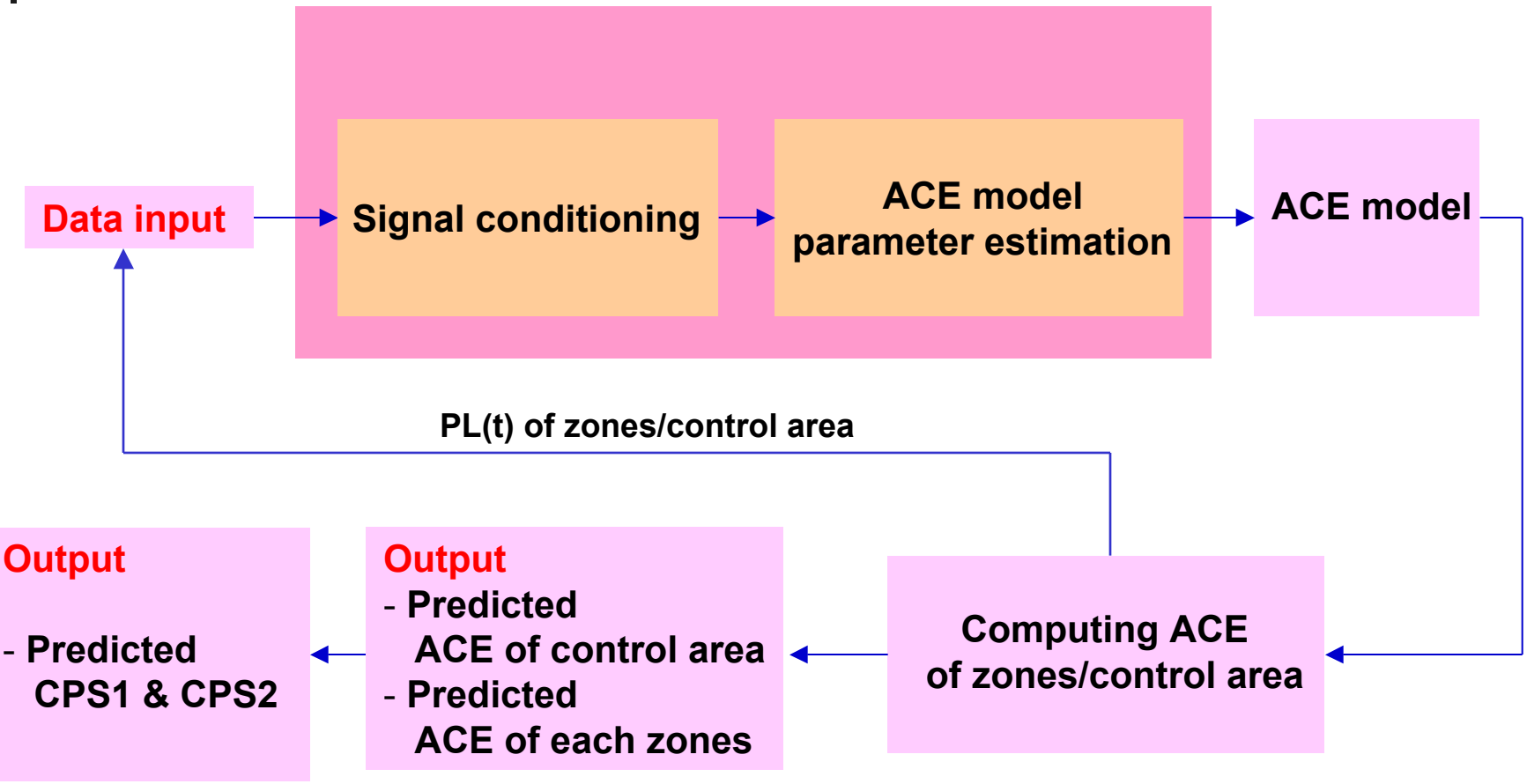
-- In the future, there may be a financial penalty incurred should the utility fail to meet certain standards. Alternatively, the utility may have to purchase this service from someone else.

Sub Allocation of Control

(Principal Investigator: Dr. *Chee-mun Ong, Purdue University)*

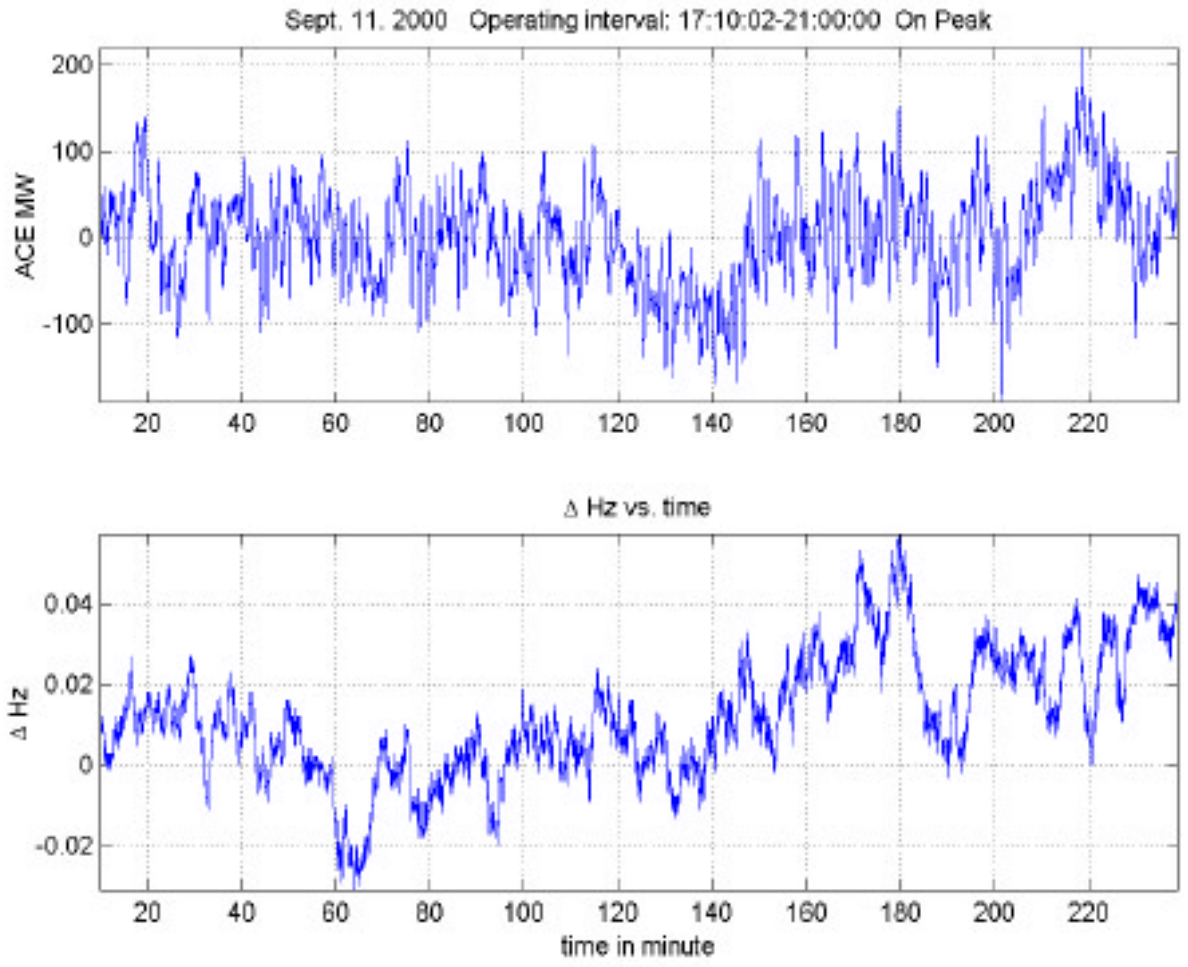
- **Crucial that control responsibility be allocated correctly to the entity that causes power fluctuations.**
  - **Economics**
    - **Penalty avoidance**
    - **Equity in operations with adjacent facilities**
    - **Improved energy utilization**
  - **Reliability**
    - **Internal**
    - **Neighbors**
    - **National Electric Grid**
  - **Power Quality**

Sub Allocation of Control



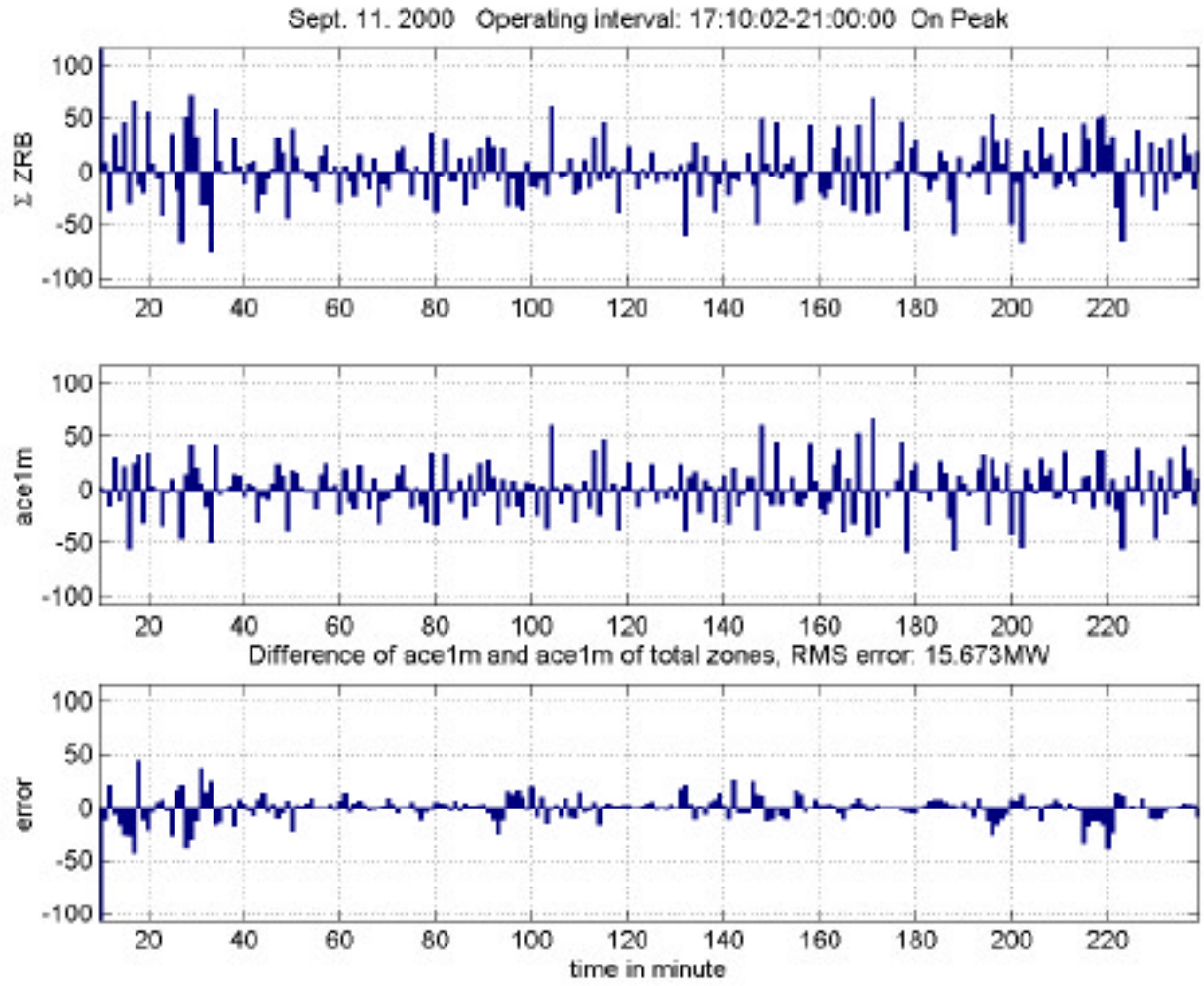
Sub Allocation of Control

Ace and ΔF



Sub Allocation of Control

Predicted and Experimental ACE Comparison



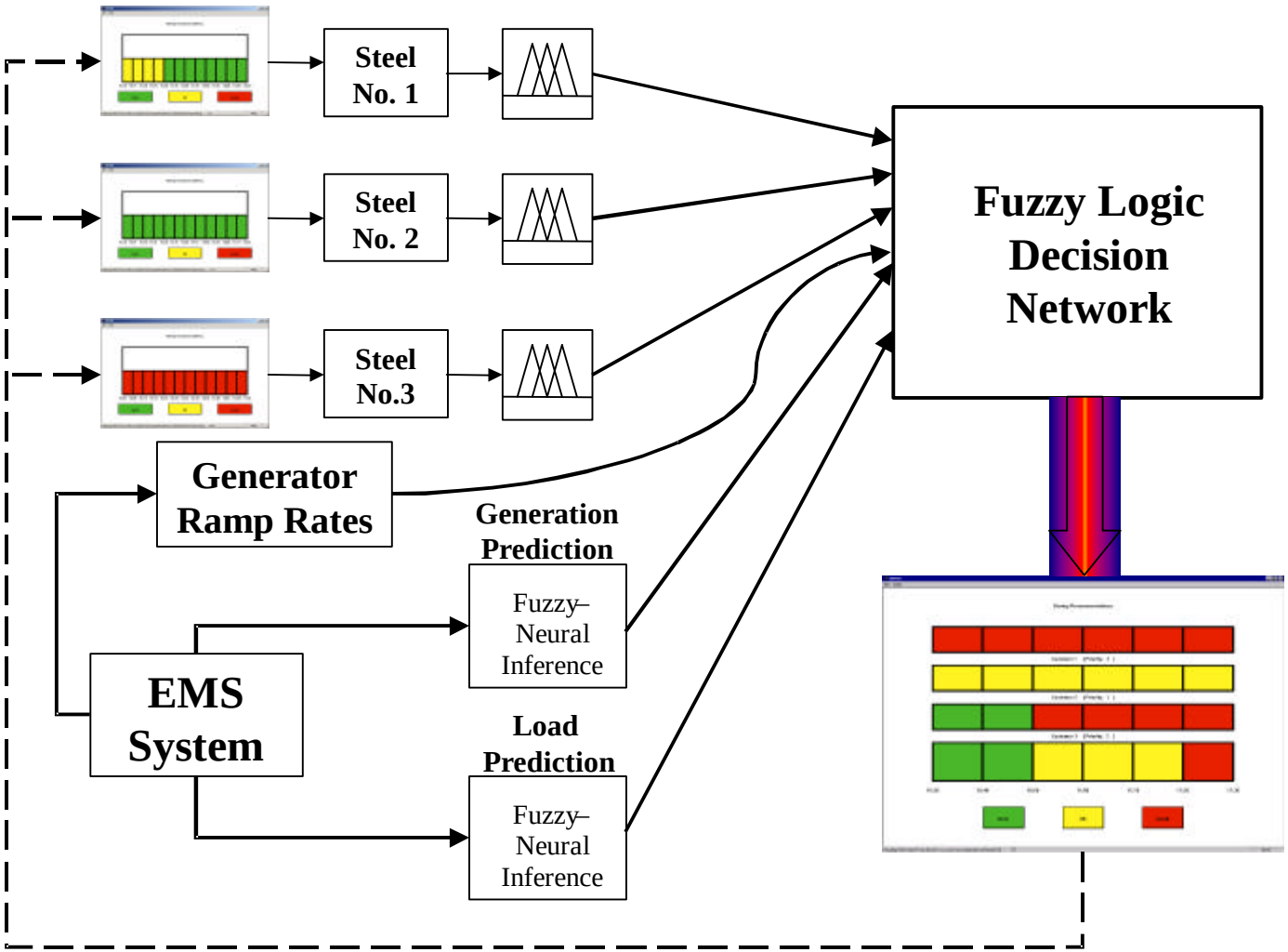
Prediction of Highly Varying Loads

(Principal Investigator: *Dr. Rahmat Shoureshi, Colorado School of Mines)*

- **To coordinate highly varying loads and thereby reduce transients, necessary to predict load levels.**
  - **Highly complicated due to stochastic nature of over 175 major loads.**
    - **Feed forward control scheme**
    - **Fuzzy logic**
    - **Neural Networks**
- **Improved AGC needed to respond to highly varying loads.**

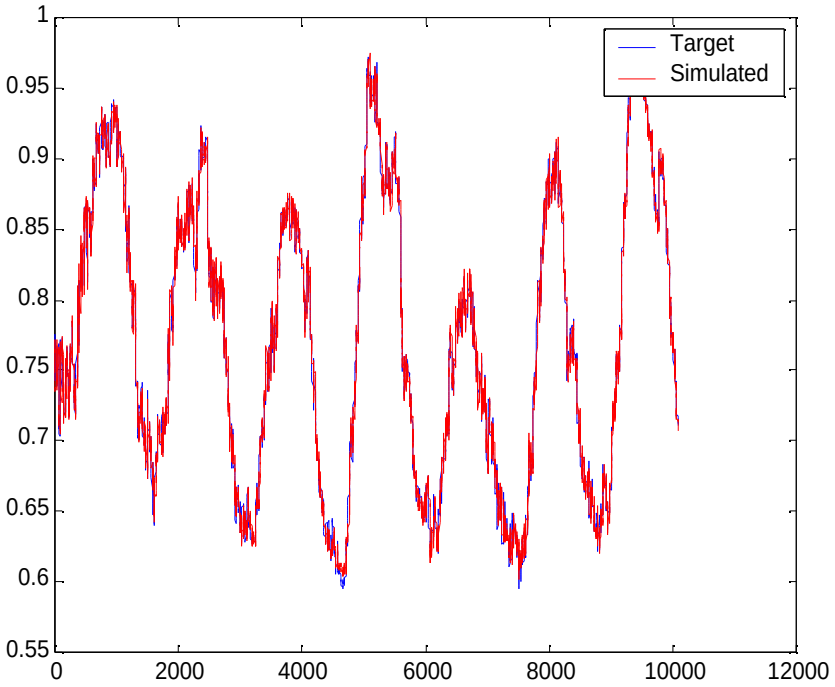
Prediction of Highly Varying Loads

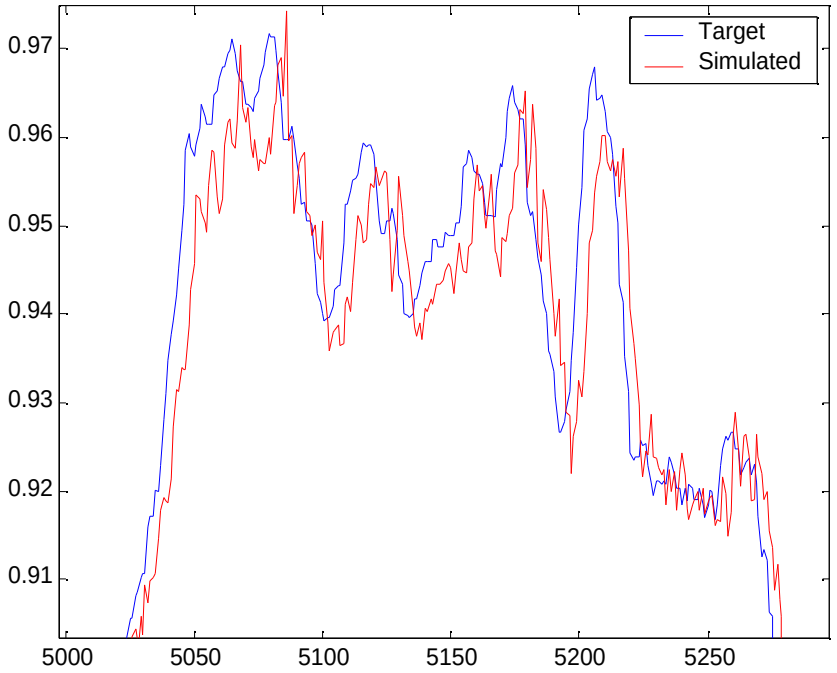
HVL Coordination System



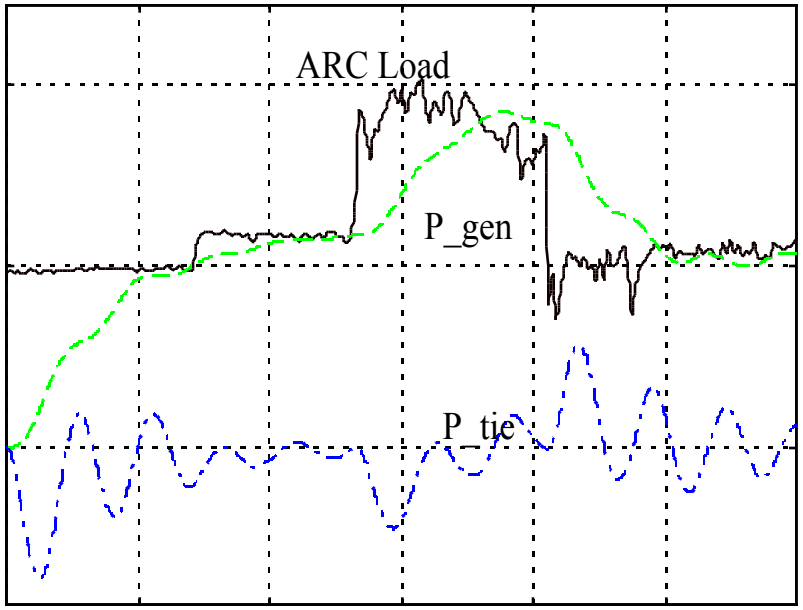
Prediction of Highly Varying Loads

Comparison of Results

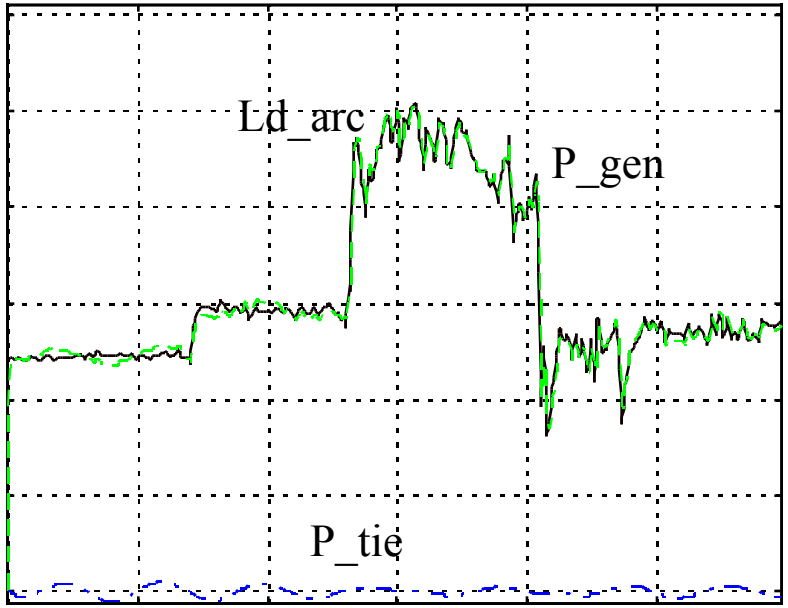




Next Generation AGC



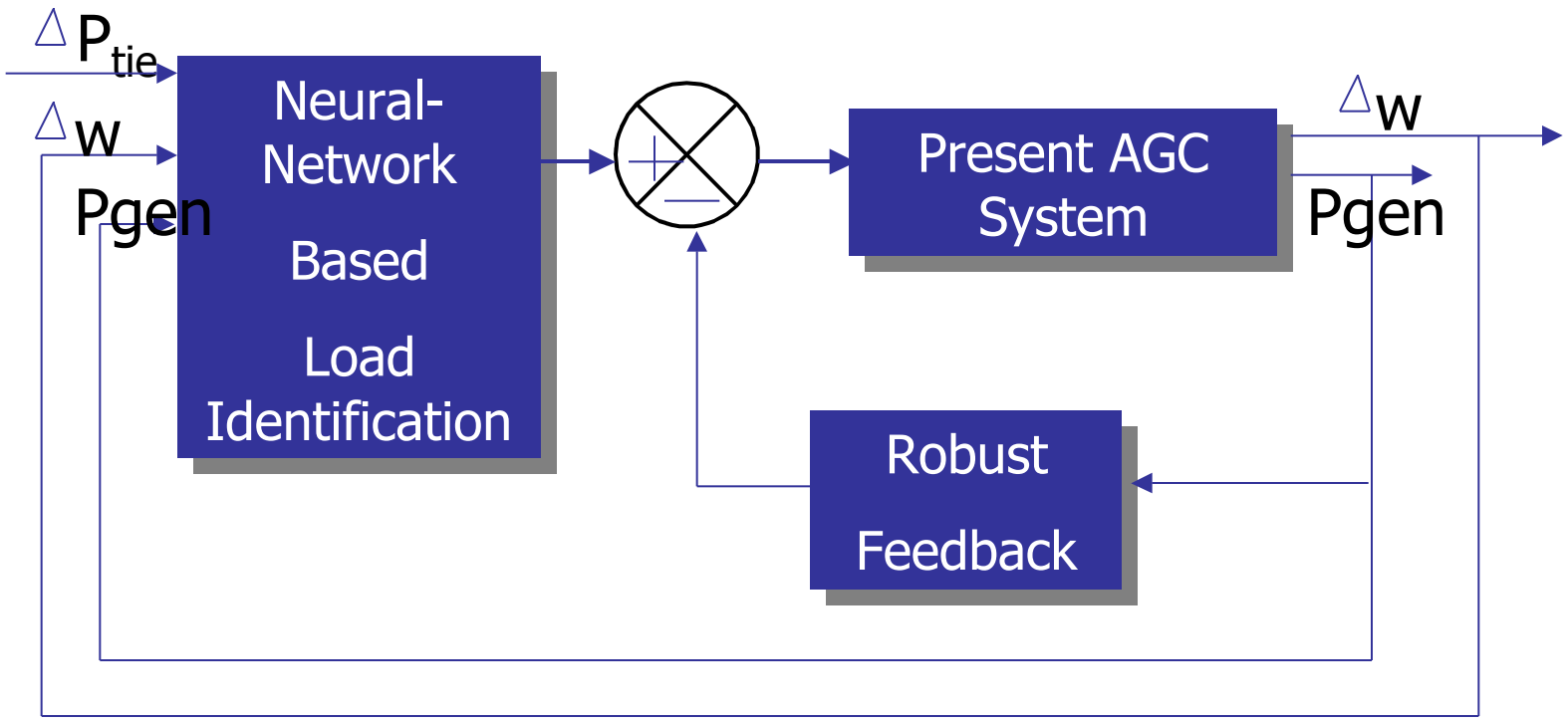
Current AGC



Intelligent AGC

INTELLIGENT AUTOMATION GENERATION CONTROL (IAGC)

The proposed IAGC incorporates a neural-based load identification as feedforward control, and a robust feedback control into the current AGC system.

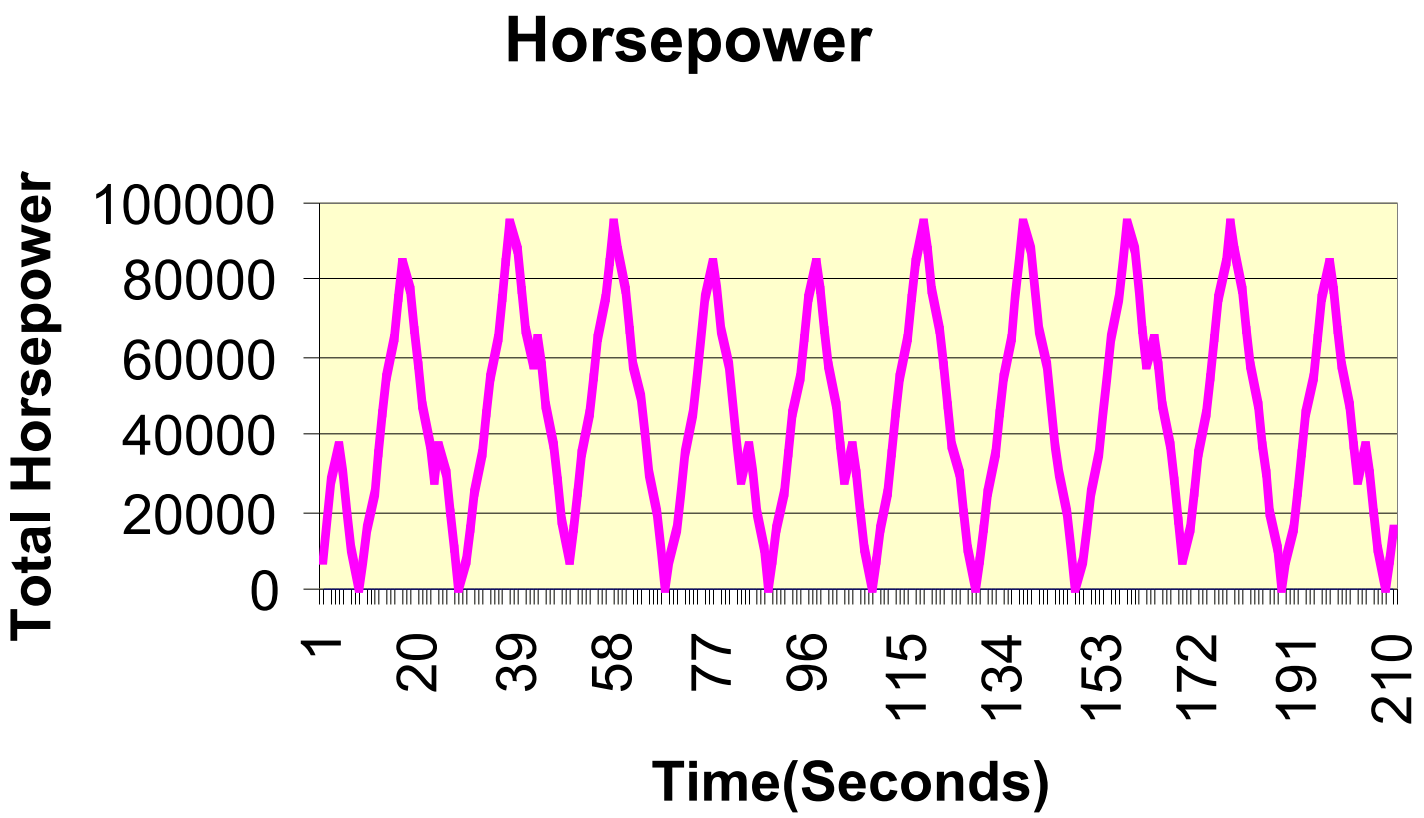


Hot Strip Mill Simulation Model

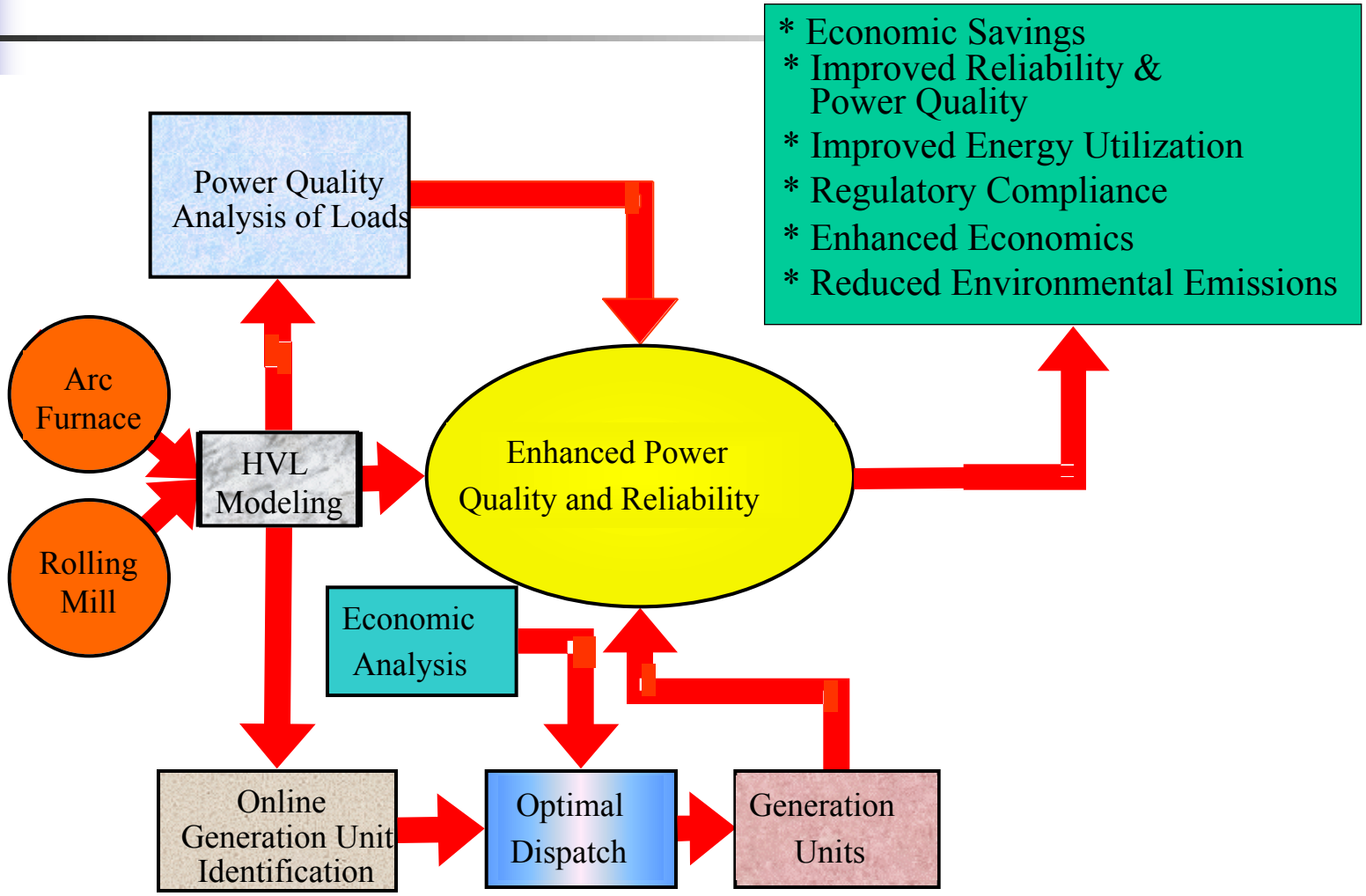
(Principal Investigator: Dr. Thomas Brady, consultant)

- **Representative of Large, Integrated Mill**
  - **Width Range of 30 to 84 inches**
  - **3 Reheat Furnaces**
  - **4 Roughing Stands**
  - **6 Finishing Stands**
  - **Productivity Range of 400 to 900 Tons/Hour**
  - **2 Coilers**

Hot Strip Mill Horsepower Consumption



Final Deliverable



Accomplishments

- Load prediction models near completion
- Arc furnace and rolling mill models being finalized
- Economic optimization models in final stages of development
- Sub allocation of control models in final stages of development
- Test system operating at one steel facility
- Central data base of modeling information established and is being used by all researchers
- Two public update meetings were held during 2001
- Steel Manufacturing Association to provide review and additional input on the operation and design of the system

Future Activities

- Plans underway to expand industrial involvement
- Complete final development of models
- Interface and benchmark into one consistent product
- Steel Manufacturing Association to provide review and additional input on the operation and design of the system
- Additional public information meetings planned for 2002