#### Homage to Jorge F. Dopazo

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#### Introduction – three themes

- Jorge Dopazo made key contributions to power system operations in the dawn of the computer era.
- His greatest technical contributions were as an organizer, leader and teacher.
- But he should be remembered above all as a great and noble human being.



## Early days in Cuba

March 21, 2011

## The Cuban Electric Company



#### Jorge, the consummate teacher



#### Cuba after the revolution



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### War-time leadership



## Leaving Cuba



### Home in New York



## Jorge and family in New York



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#### The world in the 1950s and 1960s

- US load growth: 6%-7% per year
- Interconnectedness
- **Drivannevar Bush:** "The more complex a society, the more chance that will get fouled up.... Power systems have grown enormously
- Applications interconnected overview regions And we have have had two severe blackouts and are undoubtedly headed for more."
- The Sputnik era

## Technical contributions at AEP

- First digital-computer-based control center, around 1964
- Computer Methods for Power System
  Analysis, Stagg and El-Abiad, 1967
  - Teaching activities and papers
- Second digital-computer-based control center
  - State estimation, 1972

# AEP's first Digital Control Center, around 1964

- Automatic generation control
  - Economic dispatch
  - Load frequency control
- Real-time purchases/sales
- Billing

## The concept of state estimation

Fred Schweppe and Jorge Dopazo

Goal: increase trust-worthiness of real-time data (prevent bad data and model-error corruption).

How? Using redundant information. Address Garbage In = Garbage Out Issue

# The mathematics

 $\underline{z} = \underline{f}(\underline{x}) \approx \underline{Fx}$  $\underline{z} = \underline{f}(\underline{x}) + \underline{n} \approx \underline{Fx} + \underline{n}$ 

Three problems:

- 1. Equal number of measurements (equations) & states (unknowns) (the power flow problem)
- 2. More measurements than states (state estimation increases accuracy/reliability)
- 3. More states than measurements (the external system problem; 2003 blackout)

A fourth problem: what if you don't know <u>F</u>?

# The November 1965 northeast blackout

- First major blackout of an interconnected system
- Operators were blind to what was happening in the power system
- Stagg was on the investigation team
- Main recommendation:
  - Develop comprehensive real-time tools for operating interconnected power system

## Jorge Receiving Award at AEP



## The concept of state estimation

- Auspicious interaction between Fred Schweppe and Jorge
  - Fred teaches Jorge state estimation
  - Jorge teaches Fred power systems analysis
- Planning applications were not appropriate for real-time operating decisions
- Glen and Jorge convinced AEP to implement a state estimator
  - Jorge heads new team including Oscar Klitin, Louis Van Slyck, Steve Ehrmann and Mayer Sasson

# Implementation of the state estimator

- Implementation started in earnest in 1971
  - Jorge: General formulation
  - Oscar: Statistical analysis Implementation
  - Mayer: Tinney sparse matrix concepts, configurator formulation
  - Steve: Configurator implementation
  - Lou: Data acquisition and on-site responsibility

# Implementation of the state estimator

- On-site debugging started early 1972
  - Difficult to debug program and data at the same time
- Targeted announcement at PSCC, Grenoble, France, 1972
  - Months of work did not yield clean results before trip
  - Team telegraphed Jorge:
  - SUCCESS

# Implementation of the state estimator

- 50s and 60s had seen great thinkers develop computer methods for system analysis
  - J. Ward & H. Hale, Homer Brown, A. Glimn & Glen Stagg, Ahmed El-Abiad; Alfred Brameller, Bill Tinney
  - Analysts were in full control of data; results fit data perfectly
- Getting the first State Estimator results was a humbling experience
  - Felt like a veil taken off our eyes; we were "seeing" the power system for the first time
  - We were no longer masters but slaves to actual system conditions

## Jorge at his AEP Office



# Jorge's remaining years at AEP

- Generation Maintenance Scheduling System (1974)
  With Hyde Merrill who joined the team in 1972
- Fellow of the IEEE (1977)
  - for "contributions in the development of computer methods for analysis, real-time monitoring and economic operations of power systems"
- IEEE PES Price Paper Award (1981)
  - With Guillermo Irisarri and Mayer Sasson
- Responsible for AEP's new control center in Columbus, Ohio (1984)
  - AEP closed down NYC office (1983)
  - Jorge persuaded AEP to let his group stay behind to complete project

## Jorge Receiving an IEEE Award



# DKS, DMS, and SYSTEMS CONTROL

- Jorge formed DKS (Dopazo, Klitin and Sasson) to assist foreign utilities
- After Klitin left AEP, changed to DMS when Hyde Merrill joined
- DMS enlisted other members of the team as the AEP New York shutdown date approached
- Finally, negotiated the transfer of Jorge's entire team into Systems Control (1984)
  - People trusted Jorge

# RETIREMENT

- Jorge became uncomfortable with the unhealthy competiveness in the control center vendor field
  - In 1993, Mayer would write a paper on this experience
- Retired to Miami in 1987
- Jorge F. Dopazo passed away on August 24, 2005

# CONCLUSIONS

- We felt we had lost our mentor
- He was a consummate professional who loved his work
- His strengths included organizing, leading, and inspiring teams of top-notch technical people
- He treasured tolerance
- Man of great culture
- Hyde and I are grateful for this opportunity to pay homage to our friend Jorge