we *energize* the South

Southern Company
Transmission

Providing Reactive Reserves in Real-time Operations.

Doug McLaughlin

1/12/06

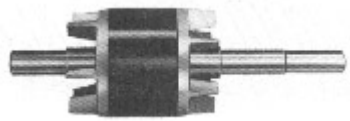
Topics

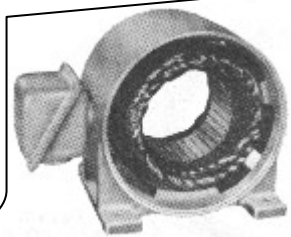
- Basic Overview of Reactive Support and Dynamic Reserves.
- Determining Dynamic Reserves in Real-Time.
- Operator Screens for viewing Real-Time reactive information.

What is Reactive Power?

- Total or Apparent Power is a combination of the **Real Power (Watts)** which performs work and the **Reactive Power (VARs)** which supports the magnetic fields required for induction.
- Circuits that include Inductive elements, require Reactive Power.
  - Motors and Transformers require reactive power to support the magnetic fields required for induction.
  - Power Lines also create magnetic fields which require reactive support.

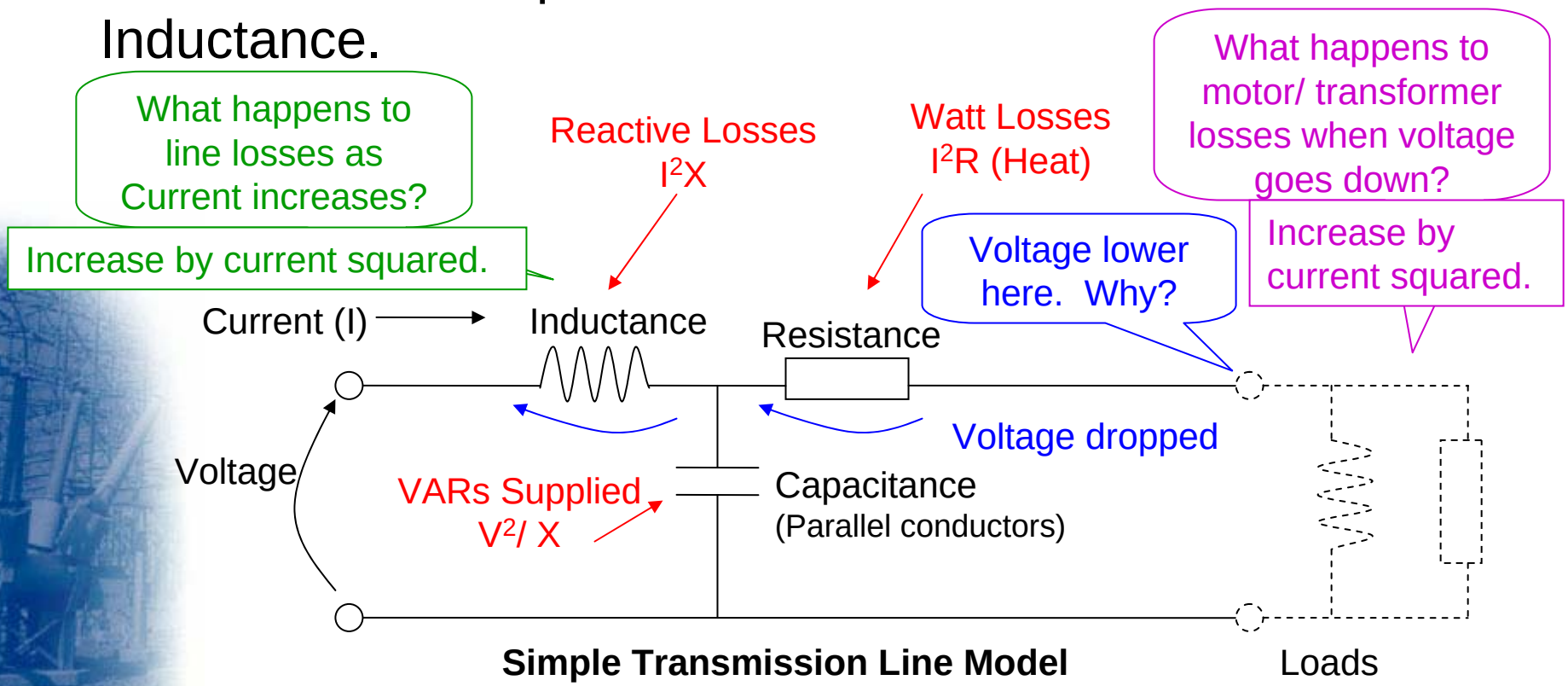
AC Machines are the work horses of our society:
Nikola Tesla was the Father of the AC Power System. He invented a way to configure an AC motor such that the alternating current created a "reversing" magnetic field in a non-moving Stator. The Rotor, which spins the shaft, requires no electrical connection since its currents are supplied by induction. *Low Voltage reduces the strength of the magnetic fields and the mechanical power (torque) of the motor.*


Rotor


Stator

Reactive Losses

- Most AC devices including Transmission Lines can be modeled as partly resistive and partly reactive.
- Capacitance cancels out inductance. For example, 100 MVARs of Capacitance cancels out 100 MVARs of Inductance.



Surge Impedance
Capacitance = Reactance

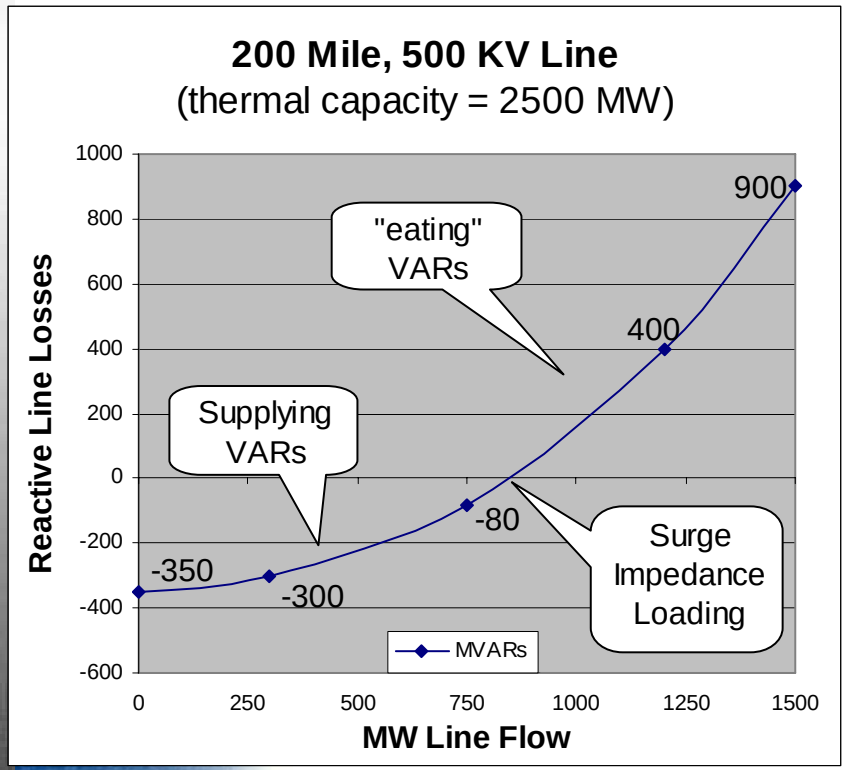
Sources of Reactive Reserves (VARS)

•**Generators** and other **Dynamic Sources** can respond to system disturbances. Typical Plant: .33 MVar/MW

600 MW Plant
~200 MVARs max

•**Static Capacitors** help keep **Dynamic Reserves** in machines to respond to **Contingencies** (Line outages).

•**Transmission Lines** Lightly loaded lines supply Vars. Heavily loaded lines consume Vars.



200 Mile, 500 KV Line

400 MVAR Losses
= full VAR output of
2 plants

VARs In → A — B ← VARs In

1200 MW Flow →

200 Mile, 500 KV Line

(Contingency increases flow by 300 MW)

900 MVAR Losses

VARs In → A — B ← VARs In

1200 MW Flow
+ 300 MW Contingency flow

Operator techniques to boost Reactive Reserves

Contingencies can dramatically lower reactive reserves.
How can we insure a high level of dynamic reserves?

- Voltage Schedule
- Capacitor Switching
- System Configuration
- Redispatch Generation

Optimizes power flow to reduce losses and keeps VARs in machines.

Boosts voltage which reduces losses. Also keeps VARs in machines

Lines in service generally reduce current flows and lower losses.

Long distance flows tend to increase losses. Can we supply the load from a closer resource to reduce line flows?

How are dynamic VARs better than static?

Timely response to contingencies

Determining Dynamic Reserves in Real-Time

Generator Dynamic Reserves = Capability – Output – Losses

- Generator Capability is represented by a family of curves that are a function of the machine's cooling system (typically Hydrogen). Constraints include:
  - Higher Hydrogen pressure = Higher Costs (H_2 losses, maintenance costs).
  - 30 minutes to move to higher H_2 pressure.
  - Station Service Voltage
    - Range limited by high/low voltage on SS electrical loads.
    - VAR Consumption by SS loads.
  - Generator Step-up (GSU) Transformer reactive losses

Curves at max H_2 pressure may overstate actual capability.

- **GenVARR™** is a computer program designed to calculate real-time generator capability based on actual generating unit and system conditions.
  - GenVARR™ also has the ability to estimate reactive capability in the near future (approximately 30 minutes) to assess adjustments to H_2 pressure.

GenVARR™ System

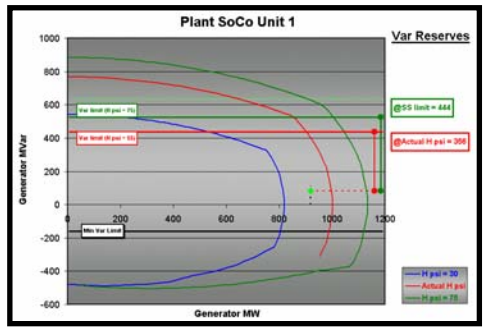
Real-time data
Generator
• MW, MVAR, Terminal Voltage, & Amps
•Hydrogen Pressure (if applicable)
Station Service
•MW, MVAR, Voltage & incoming Amps

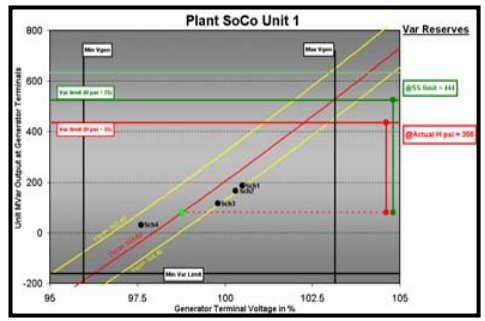
Plant electrical system model & GSU

Real-time data
Transmission
• Voltage
•Voltage schedule

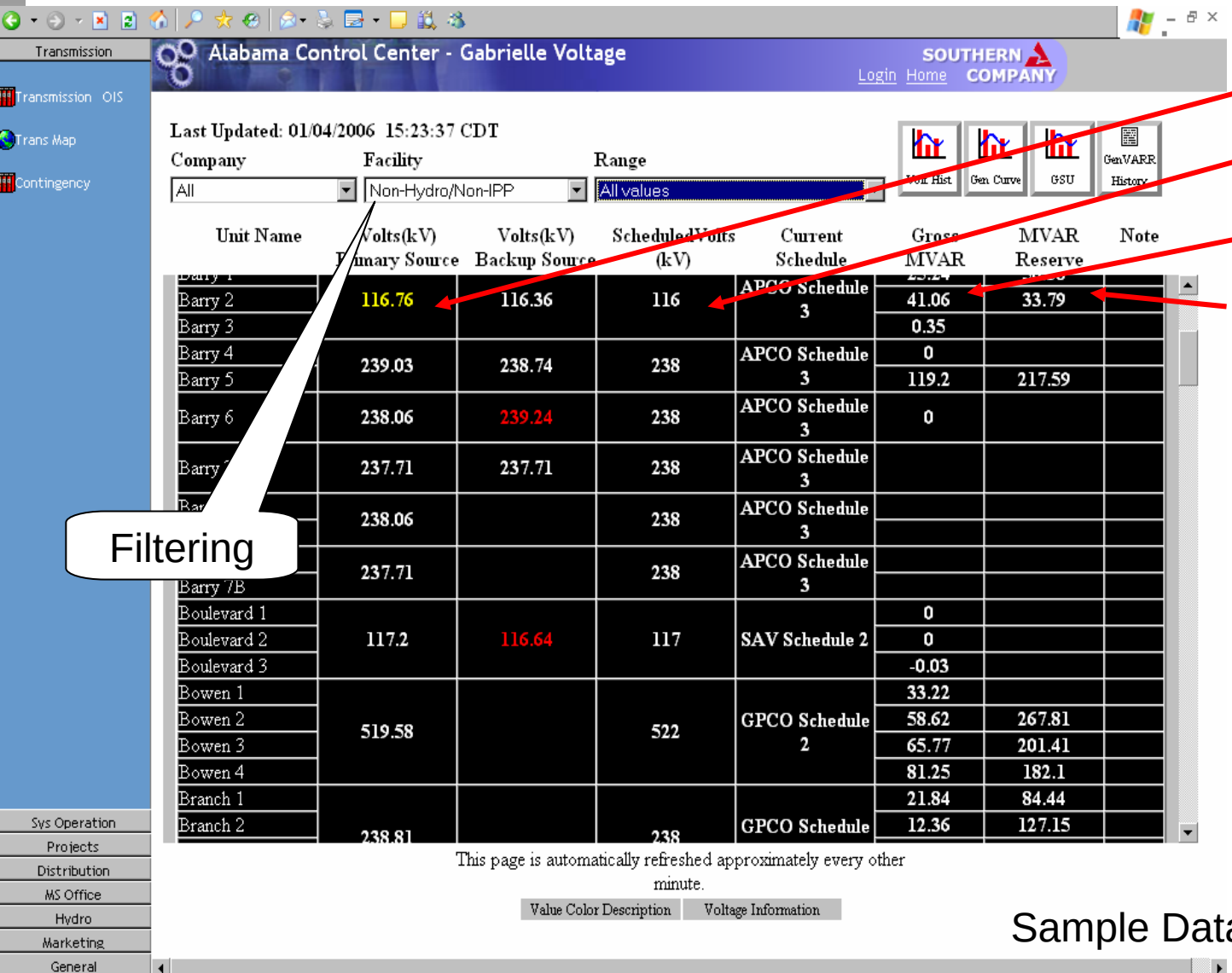
Data Base

GenVARR™ system calculates and displays summary and graphical results





GenVARR™ Operator Screen (Voltage)



Filtering

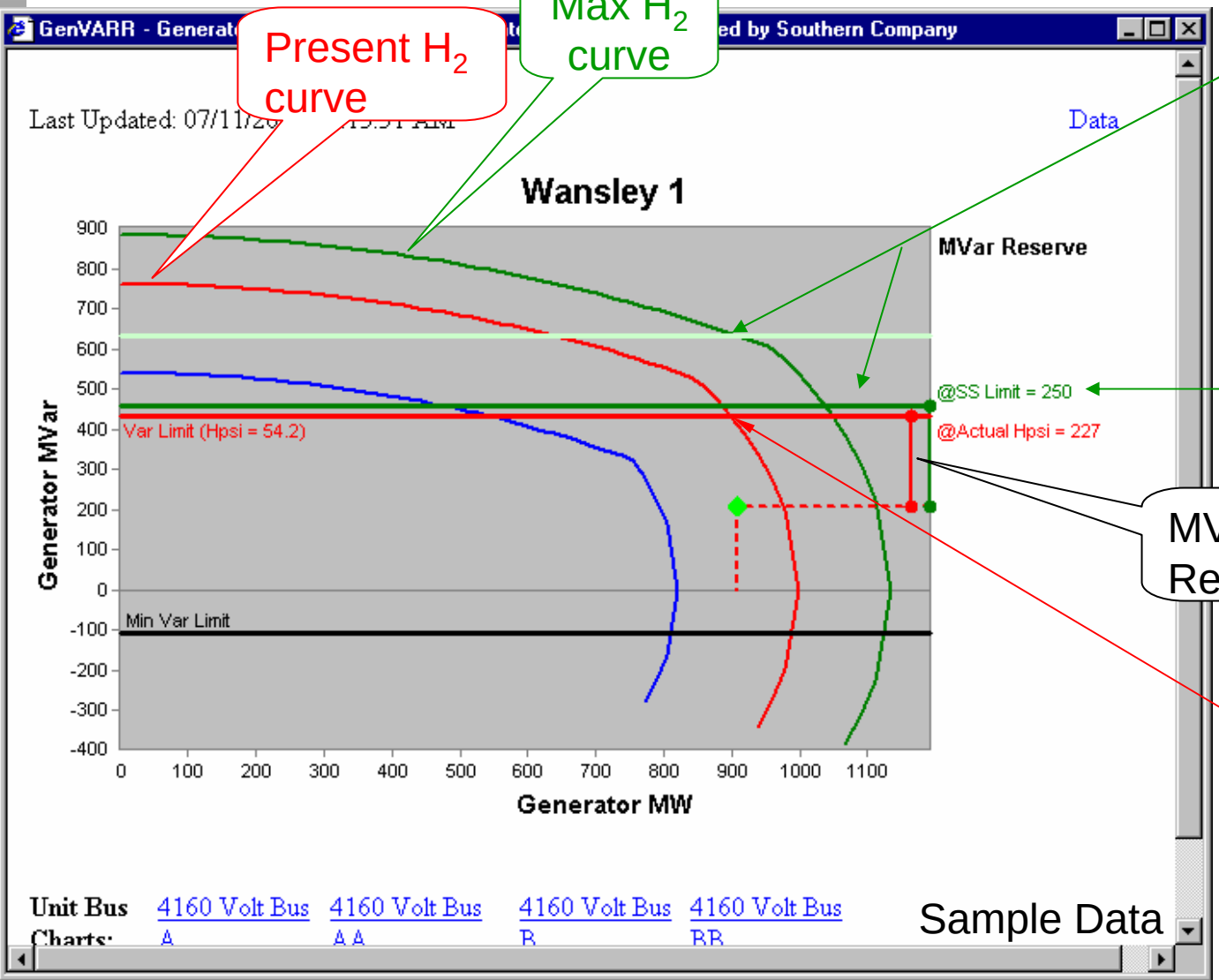
Operators see:

- Actual Voltage
- Scheduled Voltage
- MVAR Output
- MVAR Reserve

- Colors indicate voltages that are outside of the scheduled voltage band.

Sample Data

GenVARR™ Operator Screen - Gen Curve



Present H_2 curve

Max H_2 curve

Light green - indicates the max H2 pressure capability can't be reached due to station service bus voltage limit.

SS limit at 250 additional MVARs.

MVAR Reserves

At present H2 pressure, Unit is limited to 227 additional MVAR.

Sample Data

GenVARR™ Project with DOE Underway

- Convert to a .NET Platform
  - Open coding to enable broader industry use.
  - Enhanced screens and ability to aggregate groups of Generators.
  - Export to other applications such as a State Estimator program or wide-are view applications.

- Scheduled for November 2006

Questions?