Voltage Stabilization Using Synchronous Condensers

Western Mine Electrical Association

November 15,2001

The Players

- Jim VanEmmerik – visionary
  - TBCC -> Grand Eagle -> Kennecott Energy
- Rick Scherer - designer
  - TBCC -> DCS -> Grand Eagle -> Kennecott Energy (abbreviated to save space)
- Gary Sorenson – trying to take the credit
  - Kennecott Energy -> DCS

Background & History

Black Thunder Mine 1999

- Large surface mine in powder river basin
- 3 draglines
- 6 shovels
- Overland conveyor
- Acquired by arch minerals who intended to grow the operation

Black Thunder Mine- Growth Plans

- Thundercloud lease
  - Additional 8750 dragline
  - Two BE 495 shovels
  - Overland conveyor and crusher
- Concern about growth at neighboring mines.
  - North Rochelle - new mine
  - Jacobs Ranch Mine – proposed dragline
  - North Antelope / Rochelle – dragline and shovels

Black Thunder Mine- Problems

- Experiencing 8% voltage drops.
  - Due to VAR deficiency on 2570 dragline.
  - Heavy load on 69kv line shared by 4 mines and a large gas plant.
  - Under voltage trips on 2570 swing inverter.
  - Over voltage problems with static drive shovels.

Model Results With Projected Additional Loads

- Power system modeling predicted problems with projected loads.
  - Voltage dips in excess of 17%.
  - Under voltage trips at utility substation.
  - Voltage flicker outside of new utility standards.
  - Problems at neighboring mines.

Options Considered / Design

Solutions Investigated

- Static VAR compensator.
- Dedicated substation and power line from utility.
- Synchronous condenser.

Static VAR Compensation

- Advantages
  - Very fast
  - Industry standard on arc furnace applications
  - Slightly more energy efficient than synchronous condenser
- Disadvantages
  - Expensive
  - Harmonics issues
  - Maintenance learning curve with unfamiliar equipment

Utility Upgrades

- Advantages
  - Isolates mine from other customers
  - Allows for more growth
  - Easy to maintain
- Disadvantages
  - Utility was initially reluctant
  - Cost is high
  - “Band-aid” approach for underlying VAR deficiency

Synchronous Condenser

- Advantages
  - Customer had 7 synchronous motors available
  - No harmonics
  - Cost
  - Scaleable
  - Short-circuit capacity
- Disadvantages
  - Operating cost
  - Rotating machinery maintenance
  - Reaction speed

Synchronous Condensers Were Selected

- System was modeled with proposed condensers.
  - Model indicated that voltage control was most effective control method over power factor or demand level.
  - Up to 20 MVAR would be required for proper regulation.
- An equipment specification was developed for the mine.

Synchronous Condensers Solution

- 3 units planned
  - Unit #1: three 3500 HP- 900 RPM sync motors
  - Units #2 & #3: two 3000 HP-1200 RPM sync motor each. (Unit 3 was never built)
- Total capacity 23.5 MVAR (17.5 MVAR installed)
- Utilized 15MVA pit substations to save money
- Controlled by radio link from main meter or under local voltage regulator control
- Semi-portable design

Control Hardware

- Allen-Bradley SLC 5/05 Ethernet PLC
- PanelView user interface
- Power meters networked to PLC through Ethernet
- Remote Ethernet link to mine network
- Firing-Circuits static field exciter
- Vacuum contactors
- Pilot ground monitor

Safety Considerations

- Safety
  - MSHA checks
  - Start console
  - Ground check
  - Hardwired pilot wire from substation to start console for emergency stop
  - Communications watchdog

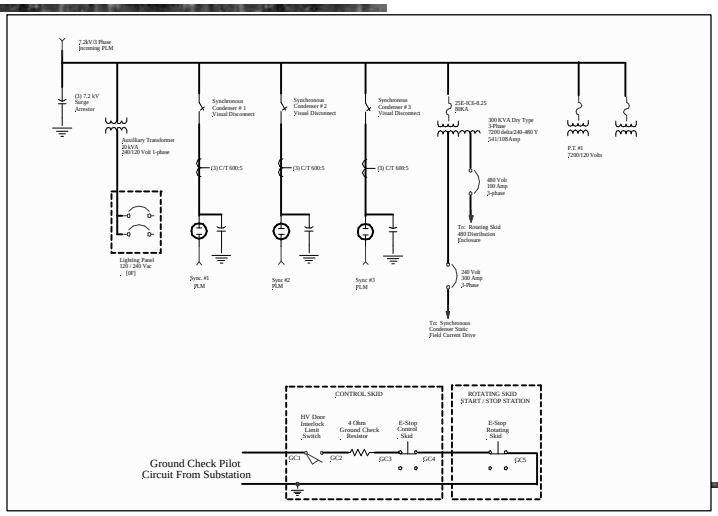
Machinery Protection

- RTD's on every bearing
- Rotor over current- RMS and instantaneous
- Stator over current- RMS and instantaneous
- Multiple start lockout
- Cooling fan control
- Vibration transducers

The Final Result

Gary Sorenson

System One Line Diagram



Synchronous Condenser #1

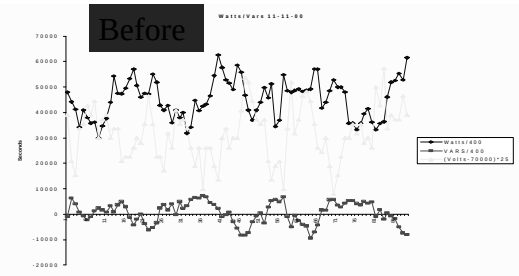
Control Skid

Rotating Skid

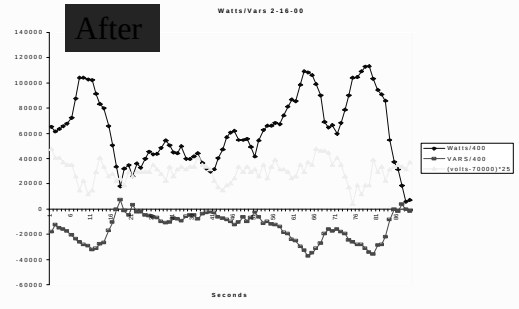
Results

- Voltage dips reduced from 9% to 4% before utility upgrade occurred
- Reduced fuse loss on 2570 dragline substantially

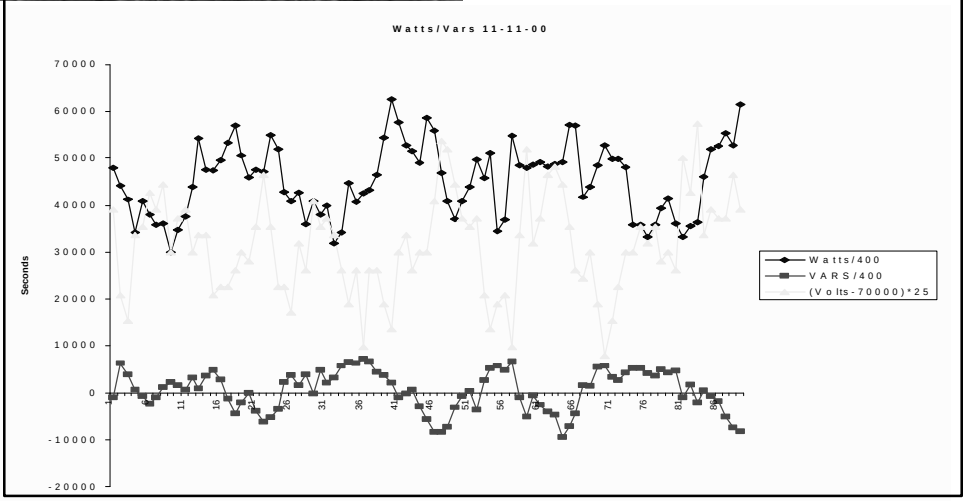
Before



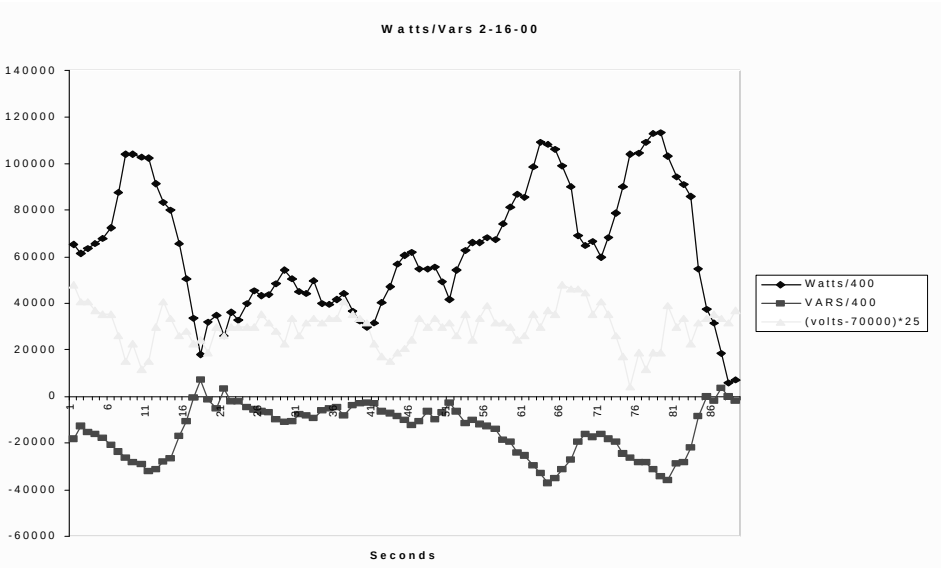
After



Watts/VARS/volts Before Upgrade



Watts/VARS/volts After Upgrade



Black Thunder 2001

- Overland conveyor and plant upgrades did not occur.
- Only 2 of the 3 planned condensers were commissioned.
- Operating 4 draglines and 8 shovels.
- Utility eventually provided dedicated substation and power line to mine due to growth in area.

Problems Encountered

- Regulating from main metering point created unacceptable voltage swings on secondary of pit substation due to transformer impedance. This caused problems for shovels sharing the substation.
  - Operating on local voltage regulation mode.
- System response on unit #1.
  - Complemented well with unit #2.

Additional Credits

- Tony Strgar- TBCC Electrical Superintendent during project.
- Tom Walker/Dale Wilgers- TBCC -helped with wireless network
- Donald Jean- DCS Panel Shop