DCS

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Thunder Basin Coal Company
Synchronous Condenser Project

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Introduction:
In December 1998, Arch minerals made the decision to move a Marion 8750 dragline to the Black Thunder Mine. The mine had experienced many power quality issues in the past and it was a concern that the additional load would create additional stresses to the 69 kV distribution system.

The mine commissioned a power study by Electrical Systems Consultants of Ft. Collins, CO. This study determined that an under voltage trip would occur at the utility substation if the four draglines ever peaked at the same time. It is more likely that under voltage devices on the mine site would occur before this ever happened.

Black Thunder then hired Drives and Control Services to develop a feasibility study of utilizing some surplus synchronous motors as synchronous capacitors to regulate the mine voltage.

At present, the mine is operating with two synchronous skids. Skid #1 utilizes three 3500 HP synchronous motors and develops a peak of 11,000 KVAR of reactance. Skid #2 utilizes two 3000 HP synchronous motors and develops a peak of 6000 KVAR of reactance. The system voltage regulation has improved by approximately 45%, from +3%, -8% to +2%, -4% despite adding a large dragline and a large electric shovel.

System Design:
The system is designed to actively control the synchronous rotor field utilizing a Firing Circuits DC drive and an Allen-Bradley SLC 5/05 programmable controller and Allen-Bradley Power Monitor II meters providing feedback and control for the system. A Power Monitor II is installed at the main metering point and the data is transmitted via Ethernet/radio modem to each condenser skid. Each skid can regulate from the radio transmitted voltage feedback from the mine meter or from the local 7200 volt bus on the skid. Each synchronous motor is mounted on M-G set pedestals and has its own thrust bearing. Vibration, temperature, and RMS rotor and stator current are monitored by the PLC to protect the system. The skids are powered from 7200 Volt feeders from existing portable substations at the mine.

System Performance:
With a cyclical load such as a large dragline, reactive power must be injected into the line to compensate for the real power being consumed by the machine. At Black Thunder Mine, the X/R ratio at the power delivery point is approximately 3. Therefore, in order to correctly regulate voltage, one VAR (negative) must be injected into the system for three Watts (positive) drawn from the system. Prior to installation of the voltage regulation system, Black Thunder Mine did not provide adequate VARS to compensate for its large cyclic load (see Figure 1).

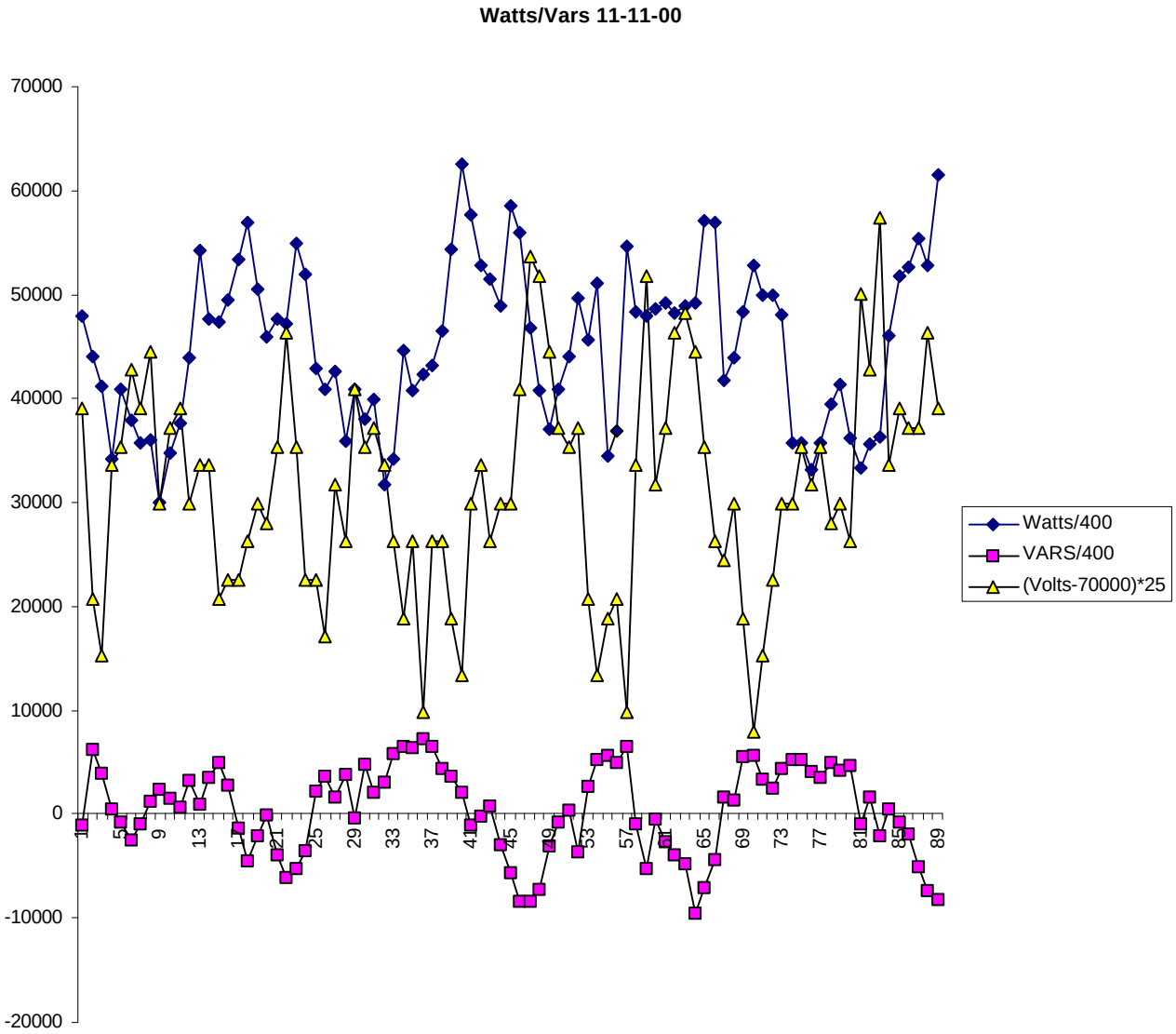


Figure 1: Black Thunder Mine before Voltage Stabilization Project.
Note that the positive peak of VARS corresponds to the largest voltage dips. Negative VARs are required to stabilize the voltage at an acceptable level. On November 11, 1999 the mine experienced a 9.8% voltage swing during the 24 hour period these recordings were taken. Typical voltage swings in November, 1999 were +3% to –9% from the nominal 71.7 kV system. Occasional events created voltage drops of –18% resulting in under voltage trips on the 2570 dragline at the mine.

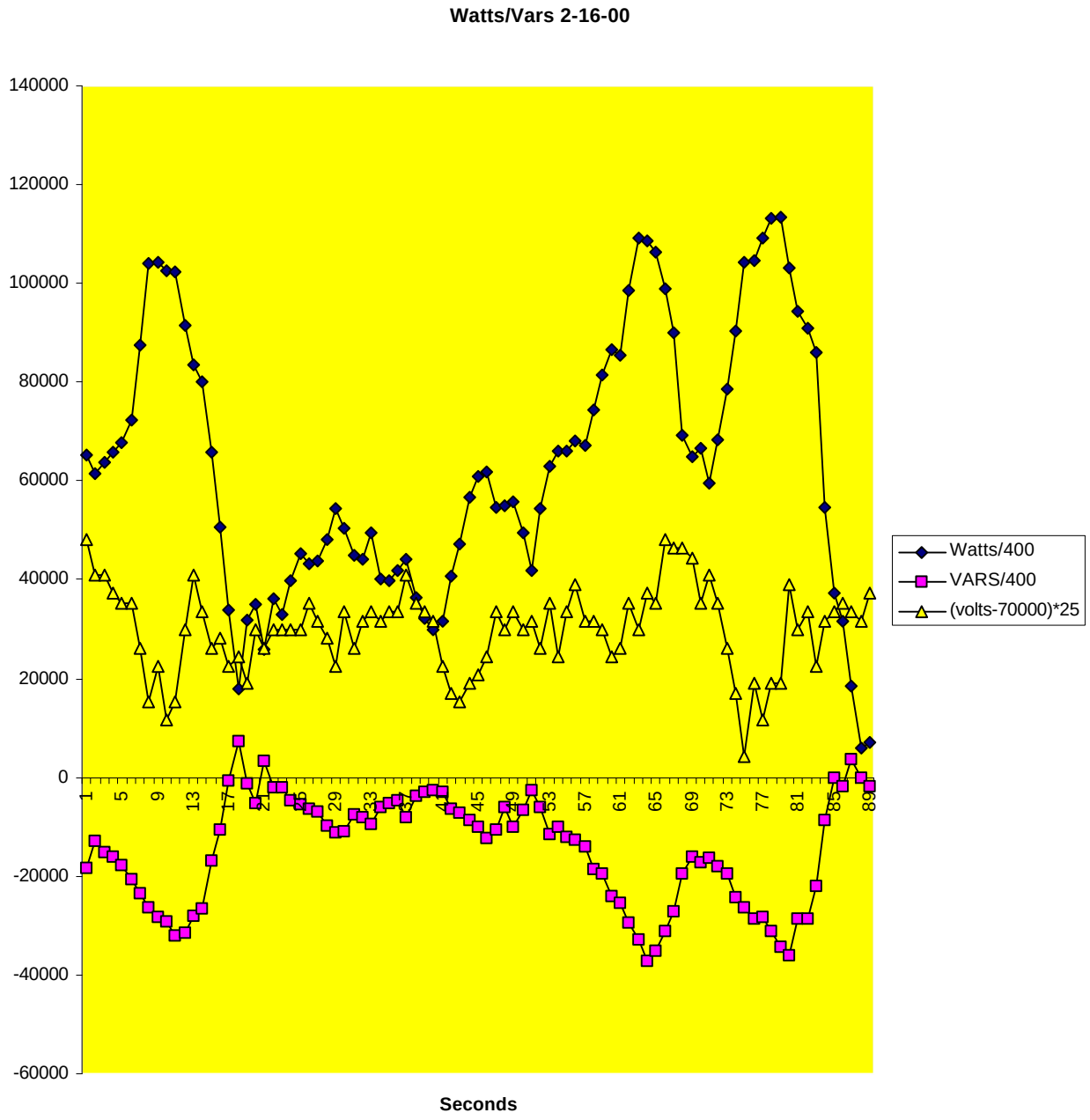


Figure 2: Black Thunder Mine following commissioning the second voltage stabilizing skid.

Note how the VARS now closely mirror the watts about the zero axis with about a 3:1 ratio. Voltage dips are now a function of regulator response which is approximately one half second and the fact that the regulators are regulating their 7200 V bus voltage locally rather than the actual 69 kV line voltage. Voltage swings are regulated at 6% peak to peak and +2% to –4%.

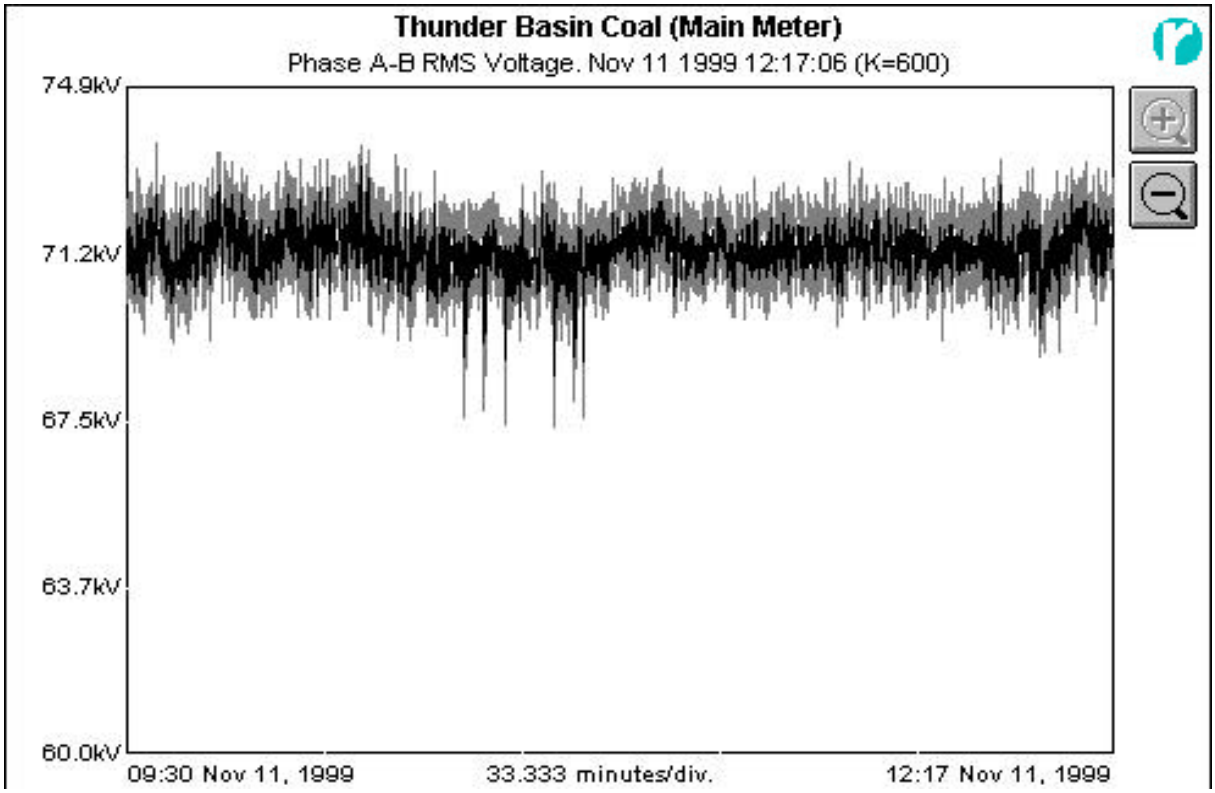
Advantages of Synchronous Condensers:
Utilizing synchronous condensers provide several advantages over static regulators. Primarily the motors are linear devices and provide no harmonic noise to the power system. In addition, the cost will be lower than a static system if used motors are utilized for the condensers. Additional cost benefits can be realized if the condensers will also provide double duty as a running spare for a dragline synchronous motor where warehouse inventory overhead can be reduced if a spare motor is kept in stock and utilized in the system or compatible motors are purchased for the system and the mine would have a spare that it did not have previously.

Once tuned to the mine voltage system, the unit is very low maintenance relative to a static reactive power compensator where fuses, capacitors, shunts, reactors, and SCR's are routinely causing problems. The system is very similar to a M-G set regulator on a dragline and therefore easy to maintain and troubleshoot without additional training for technicians familiar with dragline control systems.

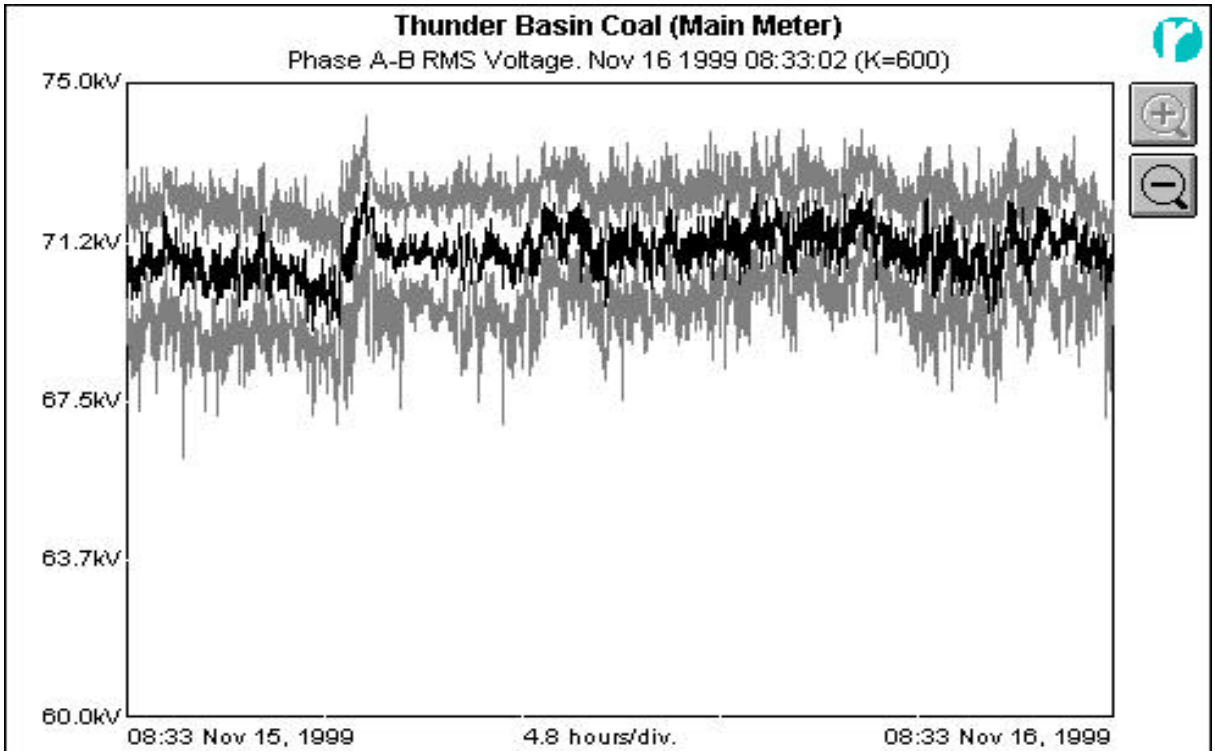
Problems Encountered:
The system was designed to regulate the 69kV system remotely. This method of regulation works better for the 69kV line than regulating the local 7200 V bus. However, the local voltage will swing quite dramatically due to transformer impedance when the synchronous condenser was directly regulating the 69kV line. Because the mine utilized existing substations and other shovels were using the same substation bus, operating in remote 69kV regulation caused more problems for equipment sharing the substation with the regulator than running locally and tolerating the 6% regulation at the 69kV bus. A permanently mounted system with a dedicated transformer would be able to regulate the system voltage to tighter tolerances although 6% peak to peak is well within industry standards.

Conclusions:
The voltage stabilization project at Black Thunder mine has met its objective. The mine has been able to add additional equipment and improve the system voltage regulation by 45 percent without adversely affecting system harmonics.

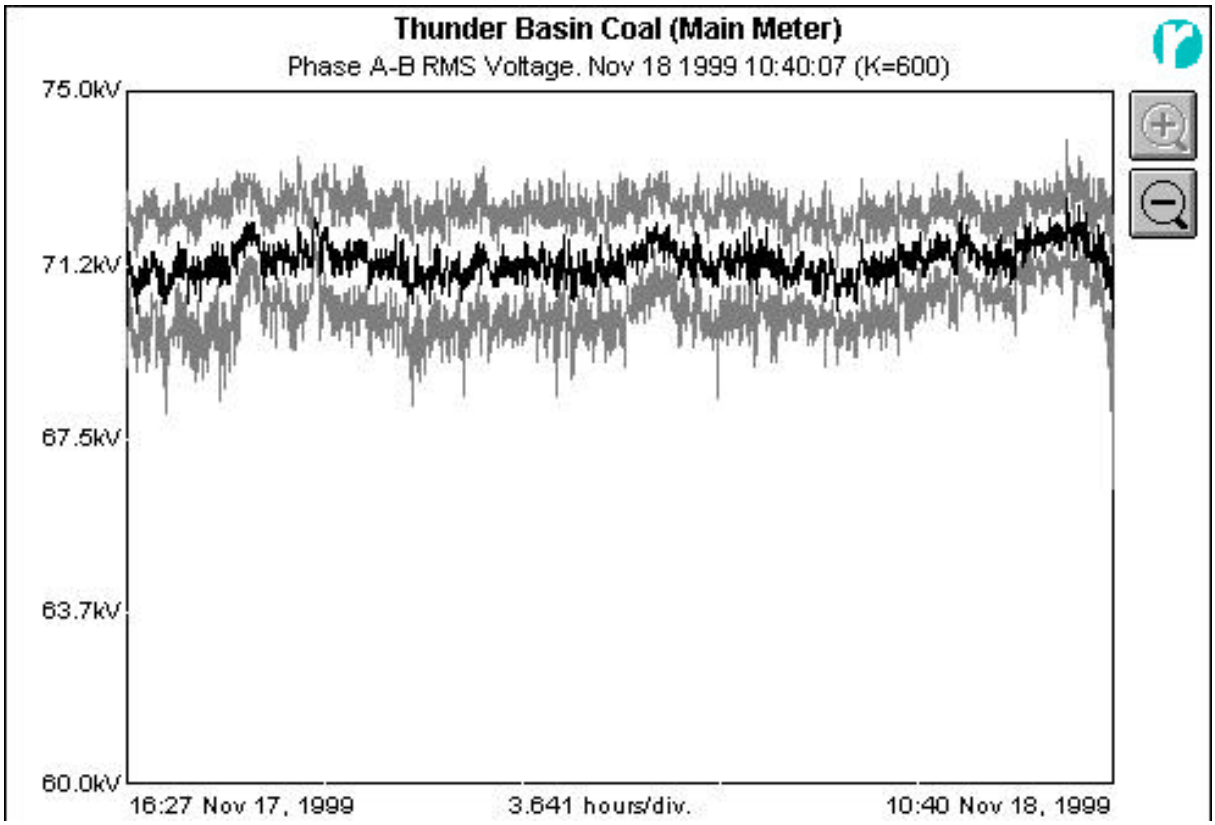
Appendix A: Reliable Power Meter Charts of System Voltage:



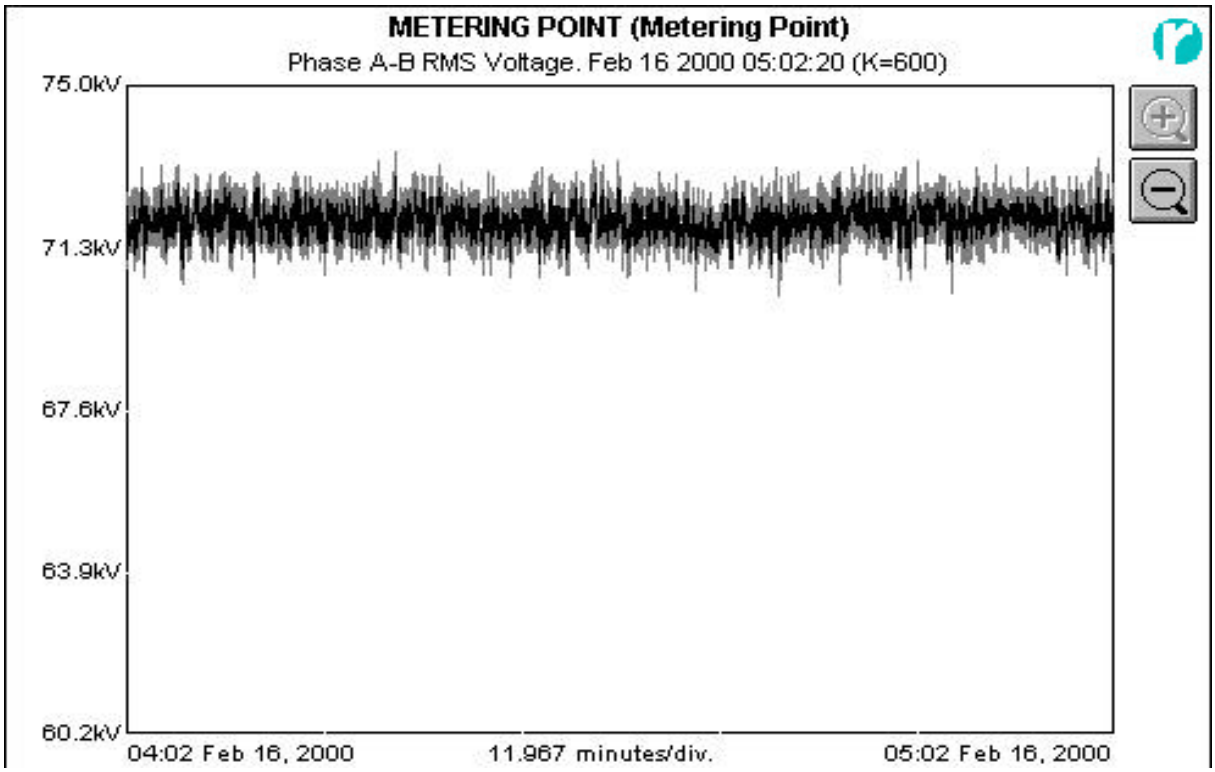
11-11-99: 1 hour recording without regulation.



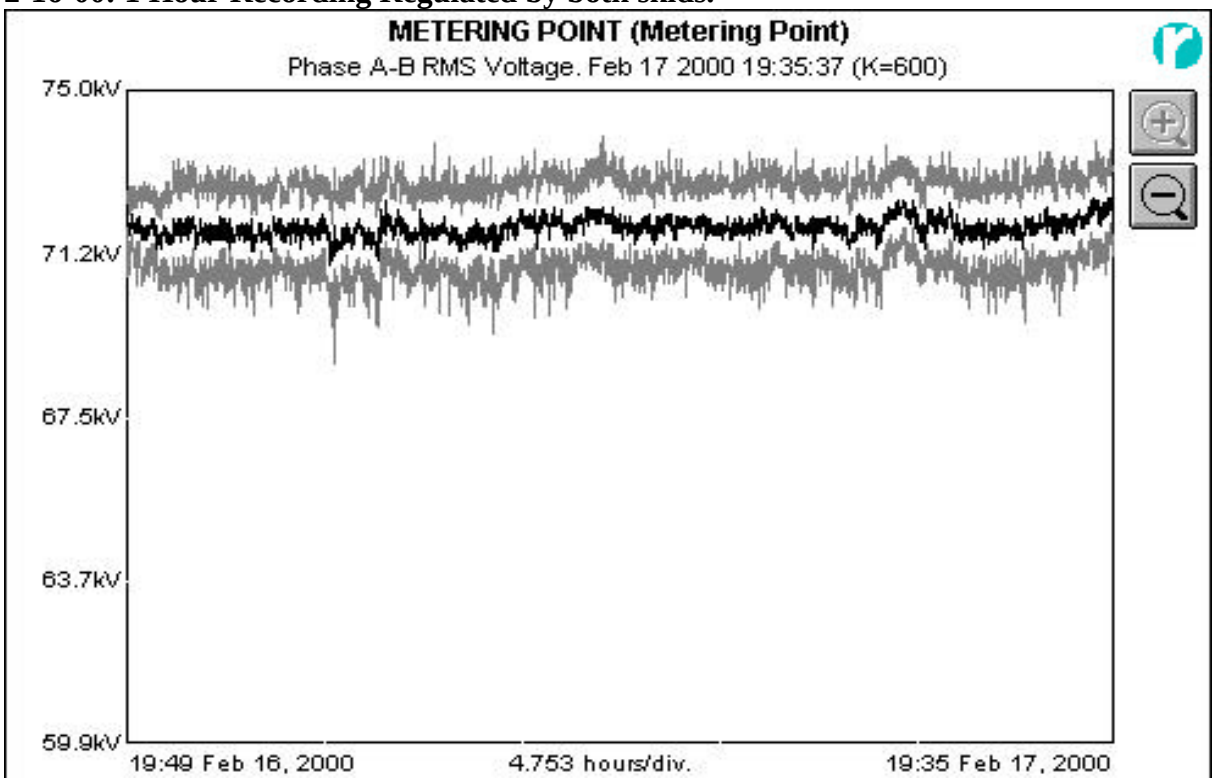
11-16-00: 24 Hour recording 10 hours without regulator, 14 hours with skid 1.



11-18-99: 24 Hour Recording Regulated by Skid #1



2-16-00: 1 Hour Recording Regulated by both skids.



2-17-00: 24 Hour monitoring with both regulators running. Largest dip was due to a condenser restart on Skid 2.