



MAJOR UNDERGROUND DEPARTMENT CONTROL & MONITORING SYSTEM

SWEDE CONFERENCE, MAY 2007

SAN ANTONIO, TEXAS

DAVID GOMES, P.E.

The presentation is about a project to monitor and control 3Ø underground distribution facilities.

It covers:

- A brief overview of the Major Underground Department's (MUD) responsibilities to establish the need for the project
- A brief overview of low voltage network systems
- The architecture of the project
 - The hardware
 - The software
- Highlights of some of the results achieved so far

- MUD designs, installs, operates, and maintains 3ø, underground electric distribution facilities serving industrial and large commercial customers throughout CNP's electric service territory.
- Today we are responsible for the operation and maintenance of almost 5,000 locations. This number keeps growing. Our challenge is to maintain a highly reliable system while controlling our cost.
- Some areas are designated as dedicated underground service areas. These include:
 - Downtown Houston
 - Texas Medical Center
 - UT Medical Branch – Galveston
 - And other locations

- Most of the buildings in the dedicated underground areas are served from vaults (electrical rooms) in the buildings
- In these vaults are transformers



- Circuit Breakers, Network Protectors, and Switches



- Relay panels



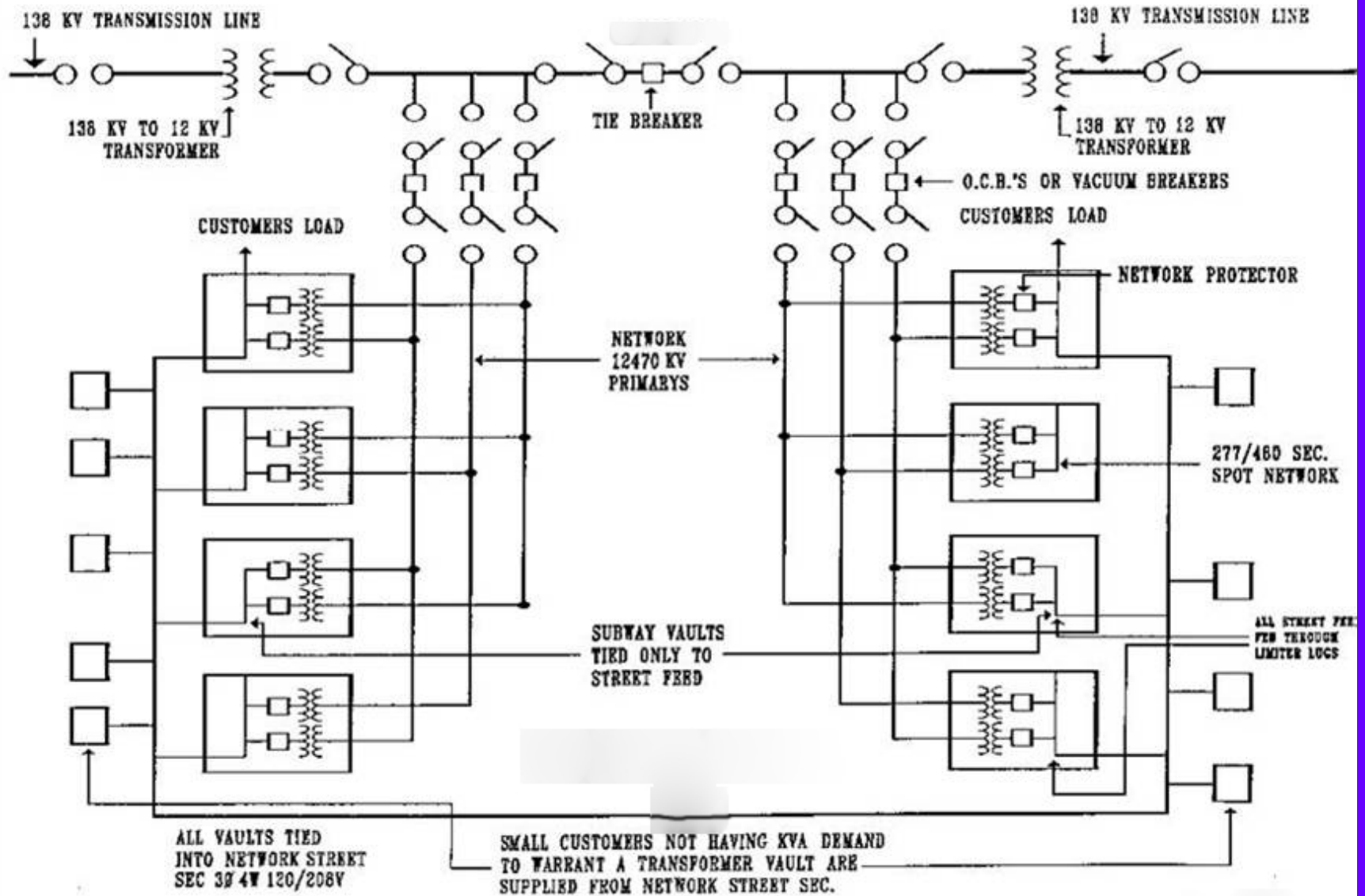
- There are expensive equipment serving large customers in these rooms. Once the door was closed we didn't know if a problem was developing.



- The need to remotely monitor these facilities was always there.

- We use 4 basic service arrangements to serve customers in the Dedicated Underground areas:
 - Manual Transfer Service
 - Automatic Transfer Service
 - Spot Networks
 - Service from the Secondary Network Grid
- We started our monitoring system with the Network Systems.
- Network systems are the most reliable but their operation is the most complex.

A NETWORK SYSTEM

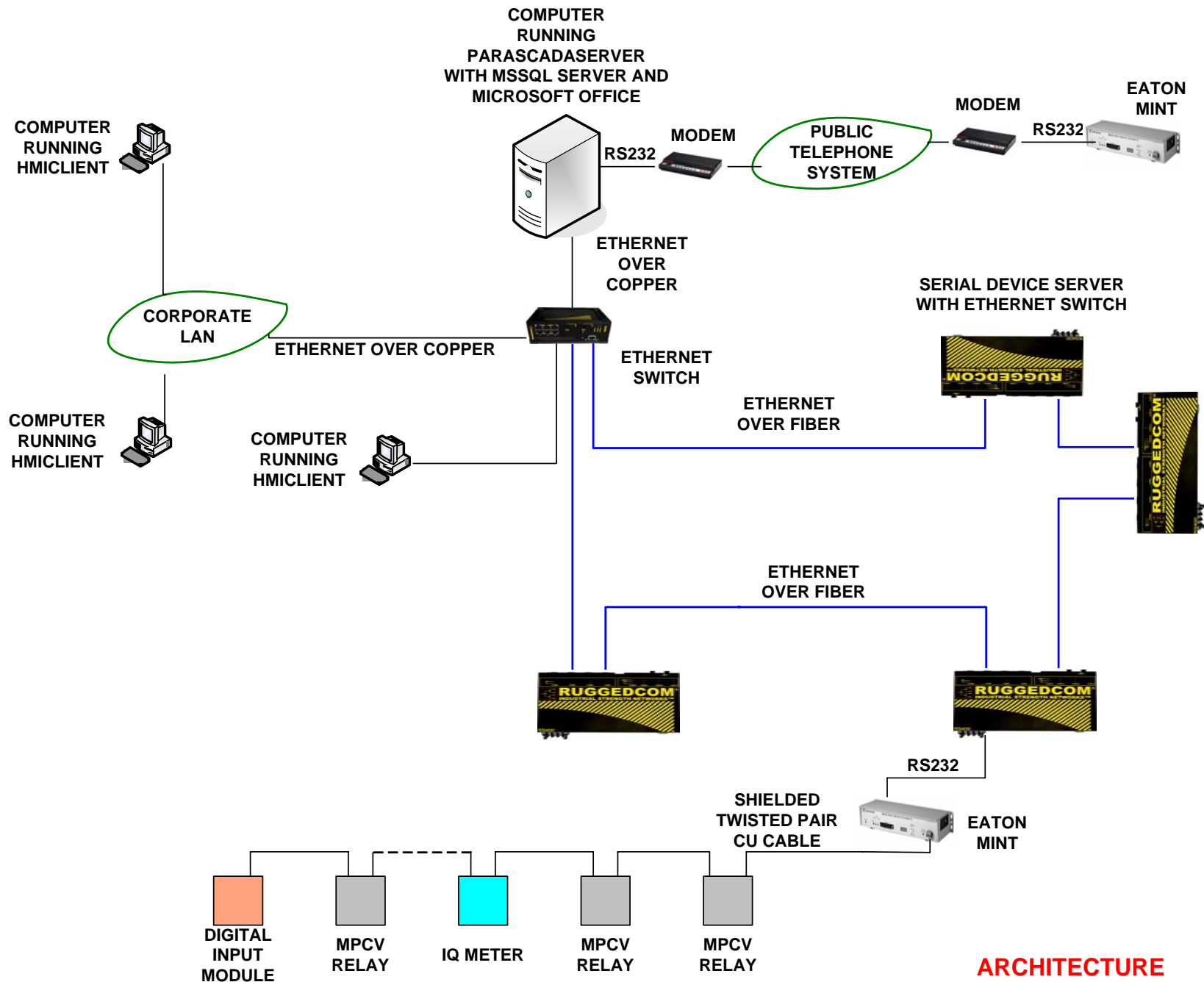


- All CNP's Networks share certain characteristics:
 - Network systems are designed based on a single contingency criterion. Any single equipment failure will not result in service outage on the network.
 - Each network is served by several primary feeders.
 - A primary feeder serves many network units, and in most cases, also serves radial distribution loads.
 - The transformer connection is delta primary-wye grounded secondary.
 - Network protectors have no published overload rating.

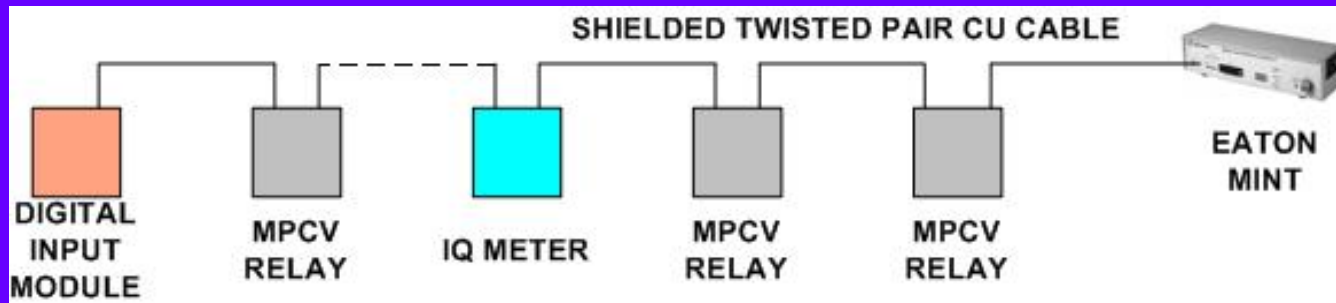
- This redundant power delivery system is very reliable but when things go wrong the impact can be widespread.
- The key to the successful operation of this complex system is the network protector with its integrated relaying.
- Network protectors are designed to:
 - Provide automatic isolation of faults in the primary feeder or network transformer.
 - Trip on reverse power.
 - Automatically close when the feeder is energized if power will flow into the network when the network protector is reclosed.

- These functions were originally done with three electro-mechanical relays. Later these functions were combined in one solid-state device.
- Around 1997 Eaton (then Cutler-Hammer) introduced a microprocessor network relay with communication capabilities, the MPCV relay.
- From 1999 to 2002 MUD replaced most of its old network protectors.
- The replacement network protectors were purchased with MPCV relays.

- We had relays that could talk. We just had to build a communication link to hear them.
- We began with small steps. We installed a phone line at one location and used demo software from Eaton to communicate with a few relays. Our user interface was Excel. Management was impressed enough to give us the go ahead to continue our evaluation.
- We continued field trials and eventually decided on the following architecture.



ARCHITECTURE

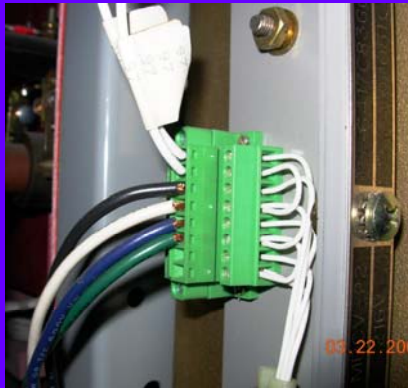


- The MPCV relay is the backbone of the monitoring system.
- This relay permits monitoring of voltages, current, network protector status, setpoints, and other useful operational data.
- The relay uses the Incom protocol. An Incom device can be connected to an adjacent device using shielded twisted pair. According to the relay's manufacturer, up to 1000 Incom devices can be connected together.

- The MPCV relay installed in a network protector



- A Water Sensor and a Thermostat are connected to spare contacts on the MPCV Relay.



Spare Contacts
On MPCV Relay



Water Sensor



Thermostat

- Other Incom Devices are connected to the system.



IQ200 Meter to Monitor Street Feed Load



CT's For IQ200 Meter



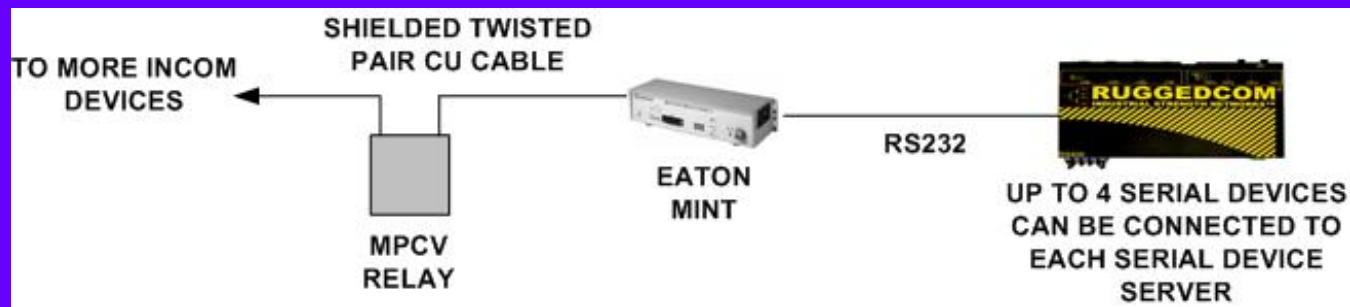
Float Switch Connected to Digital Input Module

Digital Input Module to Monitor Water Level, Temperature, and Station Service in Non-network Vaults



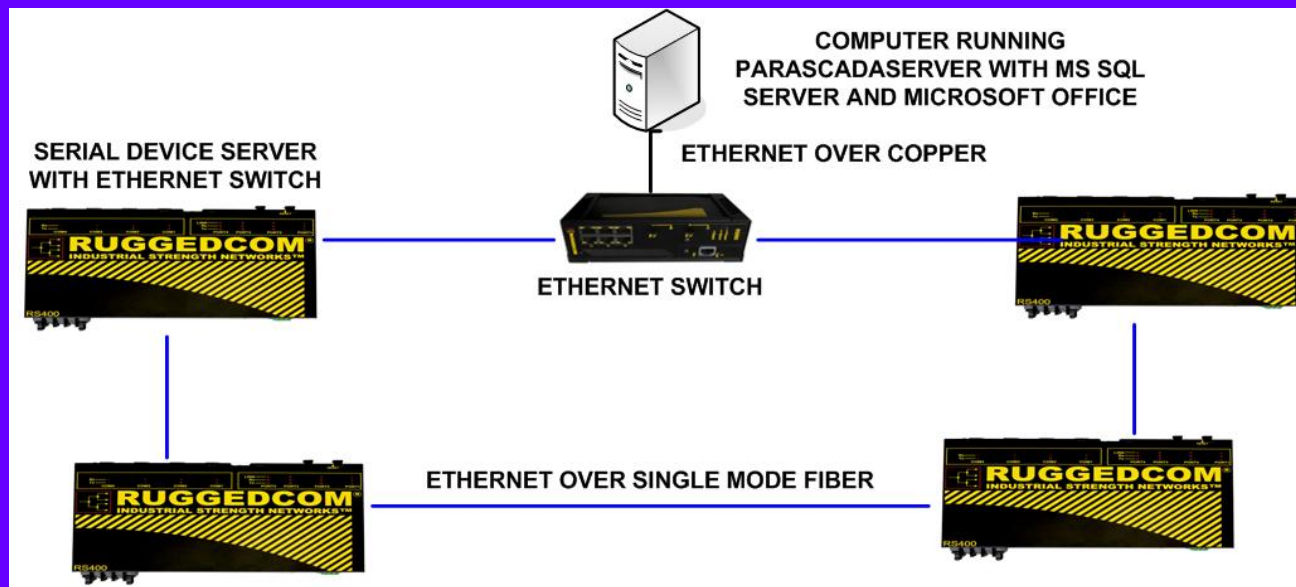
- The devices use a frequency shift keying (FSK) signaling method to bring the data back to a Master Incom Network Translator (MINT). This signaling method is less prone to interference from power frequency signals.
- The MINT converts the FSK signal to a RS232 signal.
- The MINT can be connected to modem and use the public telephone system as we have in Galveston.





- The MINT can also be connected to a serial device server. This device encapsulates the serial data into IP packets for transmission over an Ethernet network.
- This is MUD's long term solution. The device we selected is a Ruggedcom serial device server with an integrated managed Ethernet switch.
- This device has 4 serial ports.

- Devices used in vaults must be able to withstand hot and electrically noisy conditions. The device meets IEEE 1613-2003 "IEEE standard environmental and testing requirements for communications networking devices in electric power substations".
- The Ruggedcom devices are connected in a ring using single-mode fiber. The loss of a switch or fiber link only interrupts communication for a few milliseconds.



The Serial Device Server with 4 Mints connected to it.



- We use an Ethernet switch to connect to the computer running the software that enables communication to the field devices.
- The IT department helped us establish a link to the Corporate LAN from this switch. Another PC running the user interface software is connected to this switch.
- There are plans to add a backup server to this switch.
- All the hardware was configured, installed, and is maintained by MUD staff.

- As stated before, the MPCV relay is the backbone of the first phase of this project. Eaton has software to communicate with the Incom devices but to display the data requires a third-party visualization software such as Rockwell's RSView or Wonderware.
- MUD chose not to go this route as we intend to communicate with non-Incom devices later.
- The non-Incom devices include:
 - Allen-Bradley plc's using the DF1 protocol
 - Schweitzer relays using native SEL protocol or DNP 3.0 protocol
 - Electronic fuse emulators using Modbus RTU

- A local company, Parijat Controlware, helped us develop this system.
- They had software that communicated with the Allen Bradley and Modbus devices. They developed a driver for the Incom devices and are developing a driver for the SEL relays.
- The software is based on the Microsoft platform and written in Visual Basic.Net and uses MS SQL Server for data manipulation.

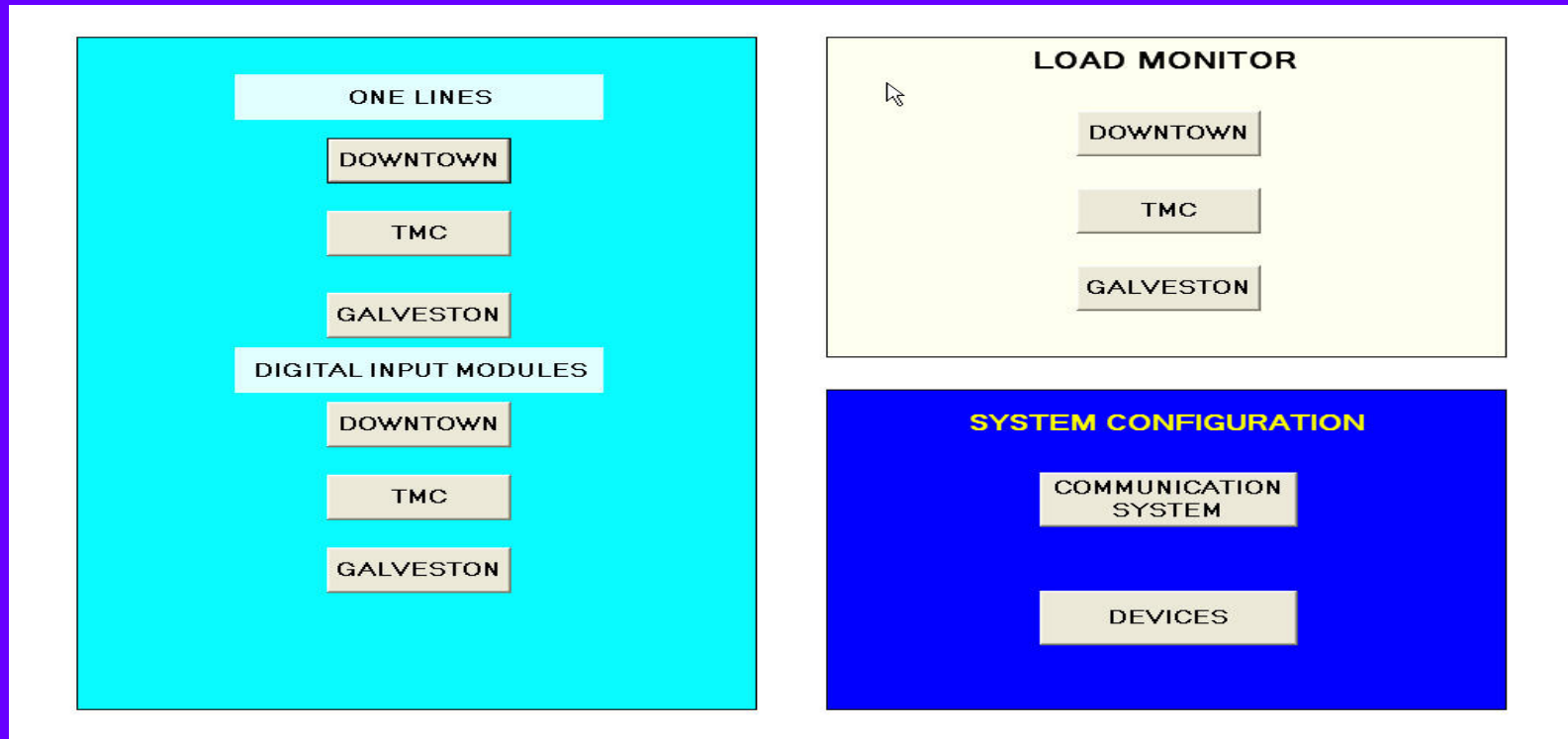
- The software system has three main components.
- The **Server application** responsible for gathering data from field devices, processing this data, and notifying clients about data changes.
- A **Configuration application** that allows the configuration of the database of devices, users, etc..
- A **Client application** for data display and sending commands to the field devices.
- This section of the presentation will focus on the client application, the User Interface.



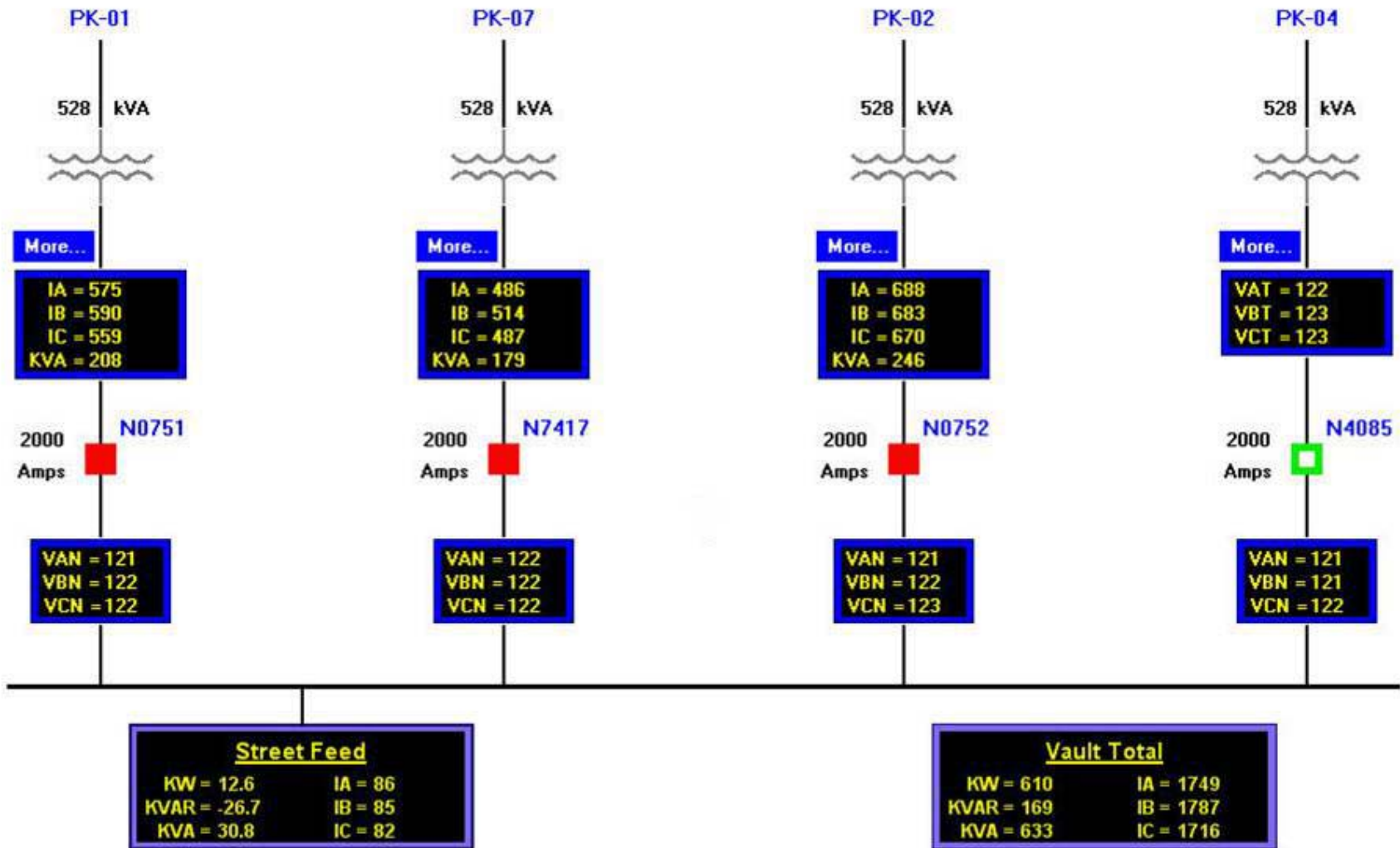
UNDERGROUND CONTROL & MONITORING SYSTEM

User Name:	<input type="text" value="user"/>
Password:	<input type="password" value="AAAAAAAA"/>
Server:	<input type="text" value="2UA64007T6"/>
<input type="button" value="Log Out"/>	<input type="button" value="Log In"/>

- The Login Screen. The Configuration Application is used to assign security levels to users.



- The Overview Screen. The entry point of the User's Interface.



- One-Line Display of a Location.

More Data From MPCV Relay

Print Settings Waveform Phasors Flags TripBuffers

MP0171 PK-01 N0751

RELAY VOLTAGES	CURRENTS & POWER
Vat = 122.4	kW = 162.1 Ia = 455.5
Vbt = 122.6	kVAr = 42.2 Ib = 471.1
Vct = 122.5	pf = 1.0 Ic = 451.5
Vap = 0.0	kVA = 167.5
Vbp = 0.0	
Vcp = 0.0	
Van = 122.4	
Vbn = 122.5	
Vcn = 122.5	

AUX. CONTACTS	
High Water in Vault	No
High Temp in Vault	No
Aux 4	No

Relay Temp = 39 deg C 102.2 deg F

Operate Protector **Close Display**

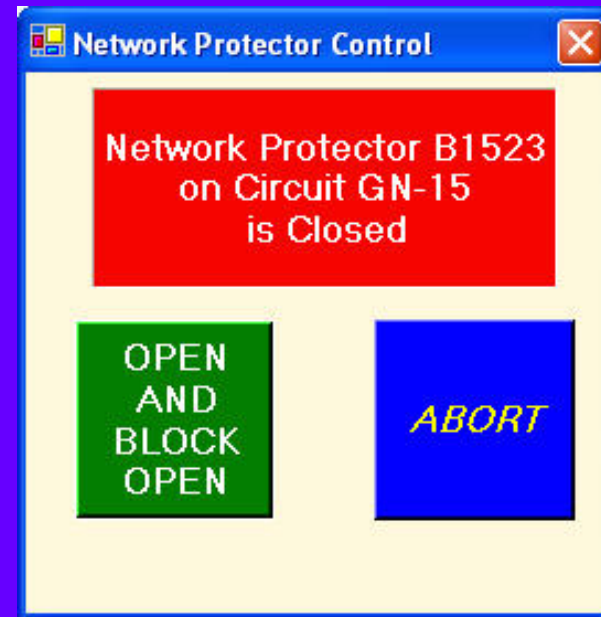
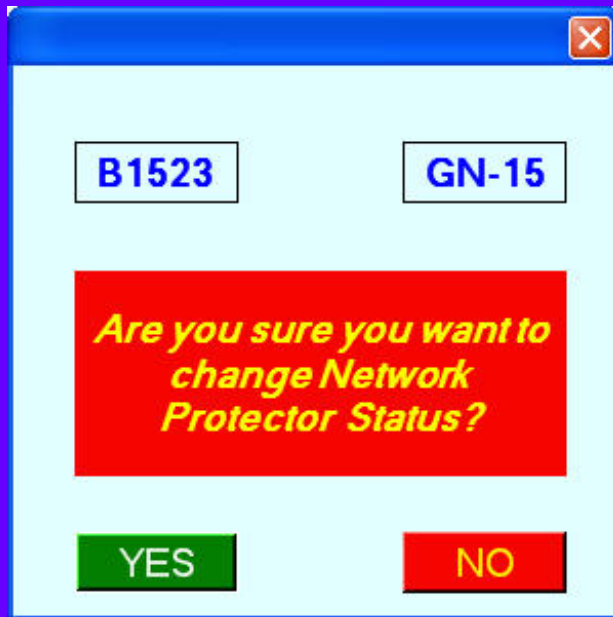
- Additional data available from the MPCV relay

GS- NETWORK LOCATIONS CIRCUIT BREAKER STATUS

Double-Click Status to View One Line Diagram

Work Center	Status
MP0229:	CLOSED
MP0231:	CLOSED
MP0235:	CLOSED
MP0237:	CLOSED
MP0244:	CLOSED
MP0250:	CLOSED
MP0258:	CLOSED
MP0262:	CLOSED
MP0292:	CLOSED
MP0302:	OPEN

- Clicking on the Circuit Label on the One-Line display shows the status of the network protectors on that circuit



- Clicking the Network Protector symbol or the "Operate Protector " button allows an authorized user to operate the network protector.

SET DATES AND TIMES

Start Date

End Date

SELECT LOAD INTERVAL

SELECT DATA REQUIRED

POWER AMPS VOLTS TEMP

SELECT DATA TYPE

Average Maximum Minimum

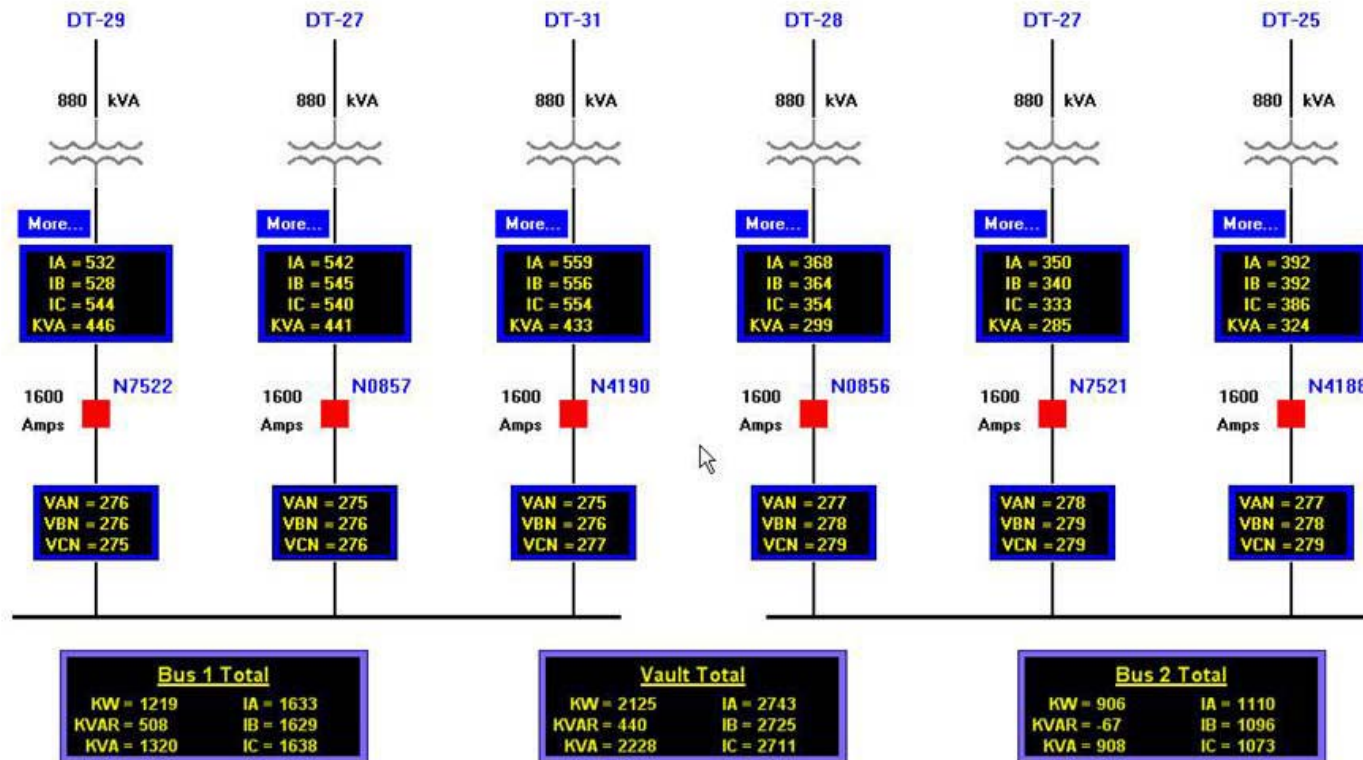
- A user is able to select historical load data to view on screen or export to Excel.

	A	B	C	D	E	F	G	H	I
1	BUILDING								
2	15 MIN STREET FEED DATA								
3									
4									
5	Timestamp	IA	IB	IC	KW	KVAR	KVA		
6	8/1/2006 0:15	45	64	55	11	17	21		
7	8/1/2006 0:30	45	64	55	11	17	21		
8	8/1/2006 0:45	48	64	55	11	17	21		
9	8/1/2006 1:00	53	60	54	10	17	20		
10	8/1/2006 1:15	53	64	64	10	20	22		
11	8/1/2006 1:30	53	64	64	8	20	22		
12	8/1/2006 1:45	45	63	55	8	18	20		
13	8/1/2006 2:00	44	58	53	5	18	19		
14	8/1/2006 2:15	47	62	63	10	19	21		
15	8/1/2006 2:30	47	62	63	10	19	21		
16	8/1/2006 2:45	47	62	63	11	19	21		
17	8/1/2006 3:00	47	62	58	11	18	21		
18	8/1/2006 3:15	47	58	58	8	18	20		
19	8/1/2006 3:30	47	64	60	12	18	21		
20	8/1/2006 3:45	46	64	60	12	17	21		
21	8/1/2006 4:00	46	56	57	9	17	20		
22	8/1/2006 4:15	48	60	57	9	18	20		
23	8/1/2006 4:30	48	60	57	8	18	20		
24	8/1/2006 4:45	46	56	57	8	18	20		

- Example of load data available.

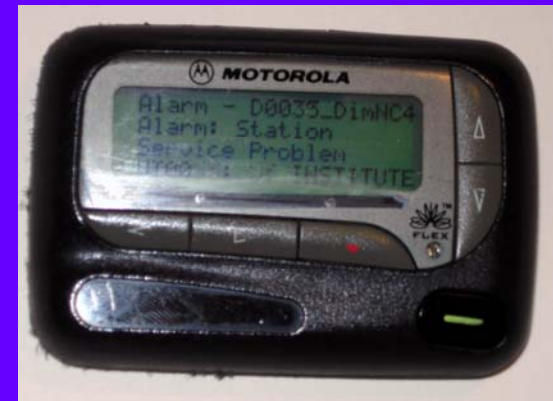
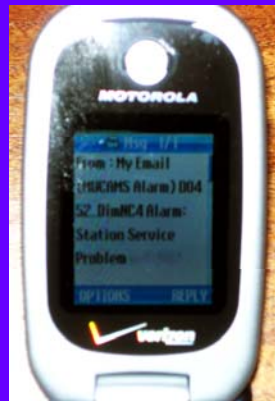
- Other benefits from the system:
- In February, 2006 there was a fire in a manhole just outside the Gable St. substation. We lost 4 of the 6 circuits feeding the Gable St. North Network.
- Normally we would have shutdown that network to prevent further damage to equipment.
- Two factors helped us keep that network in service. The incident happened around 2 am in February. Loads were very light and we were able to monitor load with our monitoring system.

- At one location all three circuits were out of service. The customer's load was being served from the secondary network grid. We contacted the customer and asked him not to increase his load. He agreed and we were able to keep this important data processing center in service.
- At another location we had 3-100 kVA transformers being loaded to 388 kVA. We dispatched a crew to physically monitor that location while we continued to monitor other potential trouble spots remotely.
- This system allowed us to deploy our workforce more effectively during this critical situation.



- The above location has a two service points. The combined load as indicated by the revenue meter never exceeds the firm capacity of the vault. From monitoring the individual circuits, we observed that if we loose one circuit feeding service 1, at times the remaining two circuits may be overloaded.

- One solution was to electrically connect the two services. This was not viable as the available fault current would be about twice as much and the customer's switchgear was not rated for this current.
- Another solution was to add a fourth transformer to service 1. Expensive and underrated switchgear.
- In discussing this situation with the customer, we found out that he had some flexibility in running his large chillers. We now have an agreement that if we need a load reduction on service 1 he will do so.
- We did not realize we had a problem at this location until we started monitoring load.



- This is a display from an automatic transfer location with a Digital Input Module. Loss of voltage on one circuit causes the load to be transferred to the alternate circuit. Station service transformers are used to sense voltage on the two circuits.
- The system paged us about the station service problem. A crew found a blown fuse that would have prevented the transfer of the load.

- Recently the system alerted us that there was water in a vault. We were on site before the customer reported the problem to us and were able to prevent the water from reaching our equipment. The equipment included two network protectors.
- In conclusion, the system has provided real benefits to us.
- We plan to gradually connect the other underground locations to the system.

Questions?