State of the Art Energy Submetering at Texas Department of Criminal Justice Industries

John A. Bryant, Ph.D., P.E.
Assistant Professor
Texas A&M University
College Station, Texas

John McBride
President
New Horizons Technologies, Inc.
Butte, Montana

Tom Merka
Director of Utilities & Energy
Texas Department of Criminal Justice
Huntsville, Texas

ABSTRACT

The Texas Department of Criminal Justice Utilities and Energy Department (TDCJ-U&E) has completed the first phase of a detailed energy use submetering system that will be one of the largest such installations in the United States at the second largest state prison system in the nation. Through responsibility accounting, TDCJ unit wardens and other staff needed to be able to monitor and justify the utility and energy use and expenses for the various prison industries and agricultural operations. These facilities are scattered at many locations around the state and cover a diversity of prison industries and agricultural operations from meat packing operations to metal fabrication, furniture restoration, garment and shoe factories, vehicle restoration, soap and detergent plants, mattress making and graphics that include sign and license plate manufacturing. The Energy Systems Laboratory (ESL) with New Horizon Technologies, Inc. (NHT) proposed to install a state-of-the-art submetering system that would meet the needs of the TDCJ system well into the future. Upon award of the contract, TDCJ-U&E assisted the ESL and NHT in conducting numerous surveys of the proposed metering locations, coordinated installations of the equipment with local unit wardens and staff, then installed the system hardware and software. The system uses a web-based user interface and is capable of real-time data acquisition and display. SquareD supplied the components for the field metering installation and local plumbing contractors either retrofitted existing gas meters or installed new meters as required. Preliminary testing began in late summer of 2000 and the system is collecting 15 minute interval utility and energy consumption data. This paper will describe the issues involved in implementing a project covering such a large geographic area, tight security issues and using inmate labor. .

INTRODUCTION

In 1995, the Texas Department of Criminal Justice (TDCJ) began an energy metering and monitoring program and implemented the initial metering phases at 24 TDCJ prison units across the state. The metering program included installing metering at both the whole unit level and submetering of functions within the unit. TDCJ was in the midst of a large system expansion with new construction and units were coming on-line at a rapid rate. TDCJ administrators saw that energy use and resulting utility bills were going to be a large portion of the overall budget for the system. The TDCJ Utilities and Energy Department (U&E) contracted with the Energy Systems Laboratory at Texas A&M University (ESL) to design and install an energy submetering system at 24 selected TDCJ units. Through responsibility accounting, TDCJ unit wardens and other staff needed to be able to monitor and justify the utility and energy use and expenses for the various prison industries and agricultural operations. Manually recording this data was not feasible because of the lack of existing submetering equipment on the units. It was clear to unit managers and to the U&E that an expanded submetering program would be needed to address these needs and provide energy use information back to the unit managers.

These systems used a combination of input signals from utility revenue meters (electric and gas) and where utility meters were not available, current transformers were used. These transformers were either direct wired to the data logger or were connected to watt transducers that then sent a digital pulse to the data logger. Data were collected on an hourly averaged basis and typically included electrical and natural gas usage. These data were downloaded weekly and stored on TDCJ servers for post processing and review.

Now called the Phase I Metering Program, this data collection process was performed at the U&E offices. U&E managers and analysts were able to provide energy use information to unit managers in a much more timely and accurate way than had been possible to that point. TDCJ had previously installed some stand-alone metering systems in a few units, but these had failed in addition to the manufacturer going out of business. Instead of allocating costs on a square foot basis, unit managers now had firm energy consumption data and could make budget decisions with much higher confidence. The success of this first phase of energy use submetering

established the importance and role for energy use information within TDCJ.

Rationale for Expanded Submetering Project

Unit wardens were now being asked to provide a better accounting of energy use (energy expenditures) for their facility and the Phase I metering program was allowing some of them to do just that. This data was needed because TDCJ prison industries are contained within many of the prison units. These facilities are scattered at many locations around the state and cover a diversity of prison industries and agricultural operations from meat packing operations to metal fabrication, furniture restoration, garment and shoe factories, vehicle restoration, soap and detergent plants, mattress making and graphics that include sign and license plate manufacturing. The Phase I metering effort had only covered a few of these secondary functions within the TDCJ system.

During the time that the Phase I metering system was being installed, TDCJ was also implementing a Computerized Maintenance Management System (CMMS). This system utilized a bar-coding system to allow for better management of the inventory throughout the TDCJ system units. The CMMS allowed the facilities management function at TDCJ to schedule and track maintenance on mechanical systems. It became evident to the analysts at the U&E that energy use data could also be used to help identify potential equipment and/or operator problems with equipment in TDCJ facilities. This "heads-up" for facility managers allowed some problems to be addressed before they became a crisis or a fix-after-failure event.

Another benefit of the Phase I project was the ability for different unit wardens to be able to compare consumption profiles on an equal basis (apples vs. apples). Trends, base lines, and use patterns were all now available for use in managing these facilities and unit wardens continued to find additional uses for the information. Another important use of the data was for predicting energy use for prototypical units then under construction. This was used to help develop the biennial energy budget for TDCJ.

The U&E division was also involved with implementing new and managing existing energy efficiency projects throughout the TDCJ system. Metering and submetering allowed accurate measurement and verification (M&V) of these projects. Savings could be calculated, funding for capital improvements could be justified, and the potential for future additional energy savings could be established as a long-term goal for resource allocation decisions.

For the above reasons, Texas Correctional Industries (TCI), a number of large agricultural operations and five High Security Bed (HSB) additions became the core of the Phase II metering effort within TDCJ. Additionally, there was the need to better allocate utility and energy costs to TCI produced goods and services as well as the other unit costs for the finished industry product. The TDCJ Agribusiness Department also needed to better identify the "true costs" of production, storing, and marketing food and fiber to the TDCJ system. The HSBs required M&V to meet commissioning standards for each of the $36M additions.

The Energy Systems Laboratory (ESL) with New Horizon Technologies, Inc. (NHT) proposed to install a state-of-the-art submetering system that would meet the needs of the TDCJ system well into the future. Upon award of the inter-agency contract, the TDCJ-U&E assisted the ESL and NHT in conducting numerous surveys of the proposed metering locations, and coordinated installation of the equipment with local unit wardens and staff.

SYSTEM ENGINEERING

System design and implementation began with an initial site inspection visit to every TDCJ unit that contained a TCI function in the state of Texas. These visits took place in the fall and winter of 1997. The purpose this initial site inspection visit was to develop a preliminary metering system design and develop a budget estimate for each site.

It became very clear during these site visits that geography was going to be an issue for the duration of the project. The TDCJ system literally covers the state of Texas. With an area of 267,339 square miles, travel around the state to visit the unit industries had to be carefully planned and coordinated. Visits to each site were scheduled at least two weeks in advance because of the travel requirements and, as importantly, to ensure that unit escorts would be available for the ESL and NHT engineers. Since these are prison units, access into and out of each unit was difficult at best. As "free-world" contractors the ESL and NHT engineers had to be escorted at all times while on the unit. Typically, the unit warden would arrange for the unit facility manager and an inmate assistant to escort the engineers during the visit and to permit access to the industry buildings.

During the visit, information was gathered on type of energy feeds (electrical and gas) into the industry facilities and the extent of any existing metering equipment. Most industries had gas meters (some non-working) but very few were submetered on the electrical feeds. A total of 34 unit industries were visited during this time period.

System Architecture

An enterprise-level system was then designed, based on the results of all of the initial site inspection visits. The overall project scope and budget was then developed through an iterative design process in which cost and system features were negotiated with TDCJ U&E. This iterative process continued through1998 and early 1999. The project commenced in May 1999.

The first step in project implementation involved a second visit to each prison industry site for the purpose of finalizing the monitoring system design at each site. Engineering drawings for each installation were then reviewed and approved by TDCJ Facility Engineering personnel. A generic schematic drawing of the monitoring system is shown in Figure 1. The design has several novel communication and data acquisition features. The central element of the monitoring system was a "Thin Server," The Thin Server, in essence, is a single-board computer with an embedded Linux operating system, pulse counting channels and several communications ports. These communications ports support 10baseT Ethernet as well as RS-232 and 485 communications. The system, as designed, included telephone-based modem communications and supports TCP/IP Internet protocol.

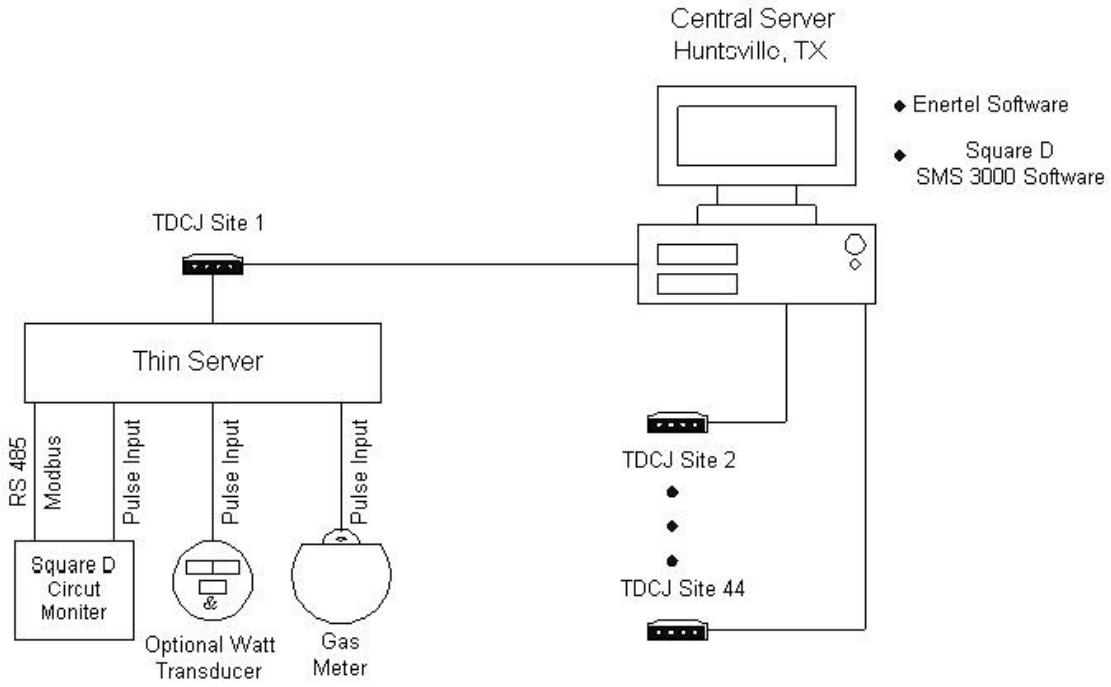


Figure 1. Schematic of Texas Department of Criminal Justice Energy Metering System.

The Thin Server-based monitoring system is extraordinarily flexible and expandable. The current base monitoring system includes service entrance level electricity and natural gas metering, with at most five data points being collected at each site. However, the Thin Server monitoring system can support up to 67 channels of data collection. Three data collection channels are on-board pulse counting channels. The remaining 64 data collection channels are provided through a digital expansion module with RS-232 or RS-485 communications. Both pulse accumulation and various analog devices such as temperature and relative humidity sensors are supported. The Thin Sever, with custom software developed for NHT by Fishbaugher & Associates, supports traditional interval-based data acquisition. It also has real-time data display and alarming capability. The Thin Server also supports digital outputs for metering-based control capability. All of the pulse accumulating channels can display quasi-real-time data as well as accumulated pulses. The real-time pulse data display is accomplished through a pulse frequency timing algorithm developed by NHT.

Existing natural gas meters at the TCI sites were equipped with retrofit pulse initiators. At sites where natural gas metering was not present, new pulse initiating natural gas meters were installed. Pulse

output from the natural gas meters was routed to the Thin Server via communications cable. Since these were prison industry sites and security specifications were used for all metering installations which required that all cable was installed using rigid conduit.

The principal electric meter in the TDCJ industries monitoring system is a Square D Circuit Monitor 2250. This is a sophisticated electronic meter that measures over 100 different electric variables including several power quality measurements. It has waveform capture capability. The meter supports Modbus RS-485 communications and multiple meters can be networked using Square D's SMS 3000 client-server software. All of the Circuit Monitors in the TDCJ Industries monitoring project are networked and real-time data from all meters is accessible at TDCJ's headquarters in Huntsville, Texas. The network connection was made through the Thin Server and SMS Software communication takes place through the Thin Server in a "pass-through" mode. The Thin Server also records a kWh Pulse output from each Circuit Monitor.

In situations where multiple electric loads were monitored, pulse-output Watt transducers were installed on the subsidiary electric loads. The kWh pulse output from the Watt Transducers is recorded by the Thin Server. Again, all signal and communications cable was routed to the Thin Server in rigid conduit.

The TDCJ TCI Monitoring System is operated through a central server located at the TDCJ U&E offices at the system headquarters in Huntsville, Texas. The server operates Square D SMS 3000 and EnerTel® software. EnerTel, developed by eComponent Technologies and NHT, is a client-server based integrated data acquisition, data visualization and data base management software package. The EnerTel software system can operate in a dial-up mode, as is the case in the TDCJ Industries project for security reasons. It can also provide internet-based data delivery using File Transfer Protocol (FTP) in a dial-out modem mode or Ethernet-based communications over Local or Wide Area Networks. The EnerTel software system can provide data updates on a last-interval basis, but in the TDCJ Industries project daily polling meets program requirements. The EnerTel software package also provides real-time data display for all pulse output data collected, alarming capability based on threshold meter measurement levels, and sophisticated energy cost allocation and rate structure modeling capability. Examples of EnerTel data display are shown in Figures 2 - 6.

Future capabilities of the Thin Server-based TDCJ-TCI Monitoring System include the provision of control output signals. The basic software of the Thin Server supports a digital output module that can supply control outputs for applications such as load shedding and motor and lighting control. When certain threshold electricity or natural gas consumption levels are reached, EnerTel software can active an alarm signal. A digital output control signal can also be activated. This particular capability will be useful under peak load or time-of-day utility rate structures. In this case, control technology can be implemented at very low incremental cost and without the expense of a separate energy management and control system.

Current communication capabilities of the TDCJ-TCI Energy Monitoring System are relatively basic, but significant expansion capability exists. Currently, the individual Thin Servers are polled from a central station server in Huntsville. This central server can provide Internet-based data display to individual industry facilities as needed. The EnerTel software can also generate monthly utility cost allocations for the various industries. However, the Thin Servers at the individual industries are all Ethernet compatible so that an individual workstation can be installed at each industry to access historic energy consumption data as well as real-time data from EnerTel and SMS 3000.

FIELD INSTALLATIONS

The installation of energy metering systems in a prison environment presents a number of challenges. All of the work was conducted in a secure environment and installation personnel needed to be escorted at all times. Stringent security requirements were associated with the use of tools and security issues also limited access to parts and equipment. There was no electrician's truck loaded with parts and pieces accessible to provide supplies to address normal design and installation. NHT field engineers and the U&E escort had to physically carry all tools, hardware, and associated equipment onto each facility. If a single fitting was needed and had not been carried in, the engineer and the escort had to secure the installation area, exit the unit, get the part, re-enter the unit and resume the installation. Each pass through security involved a substantial amount of time and access to the job site was thus limited. Security at all TDCJ system units was further heightened after the escape of the "Connally Seven" during December, 2001. Fortunately the unit where the escape took place was not part of the Prison Industries Monitoring Project.

Figure 2. Screen Shot of Main Electrical Service kWh for Jester III Unit at TDCJ.

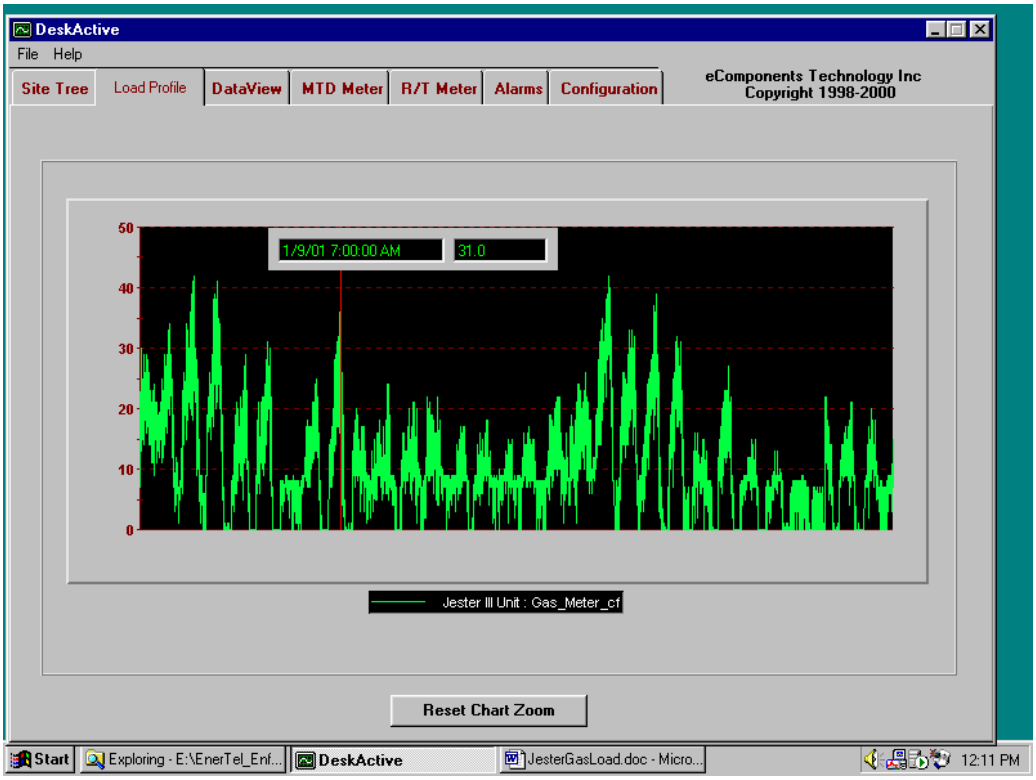


Figure 3. Screen Shot of Natural Gas Load Profile Data for Jester III Unit at TDCJ.

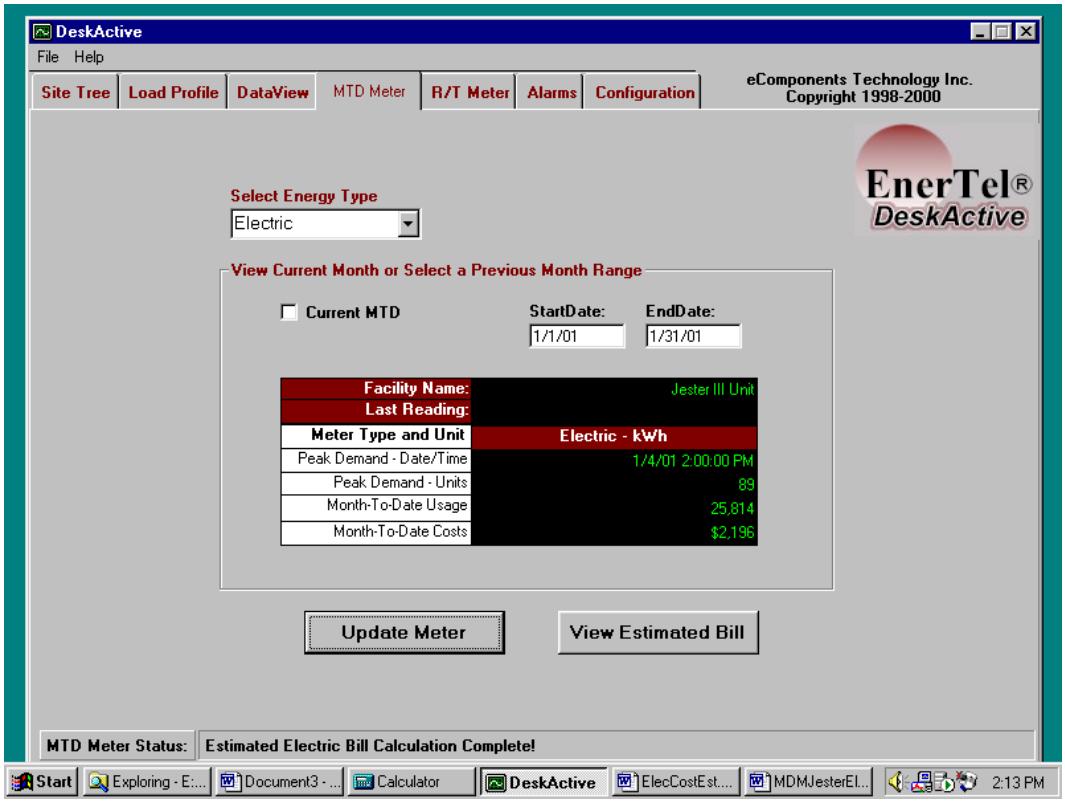


Figure 4. Screen Shot of Primary Electric Service Demand and Costs for Jester III Unit at TDCJ.

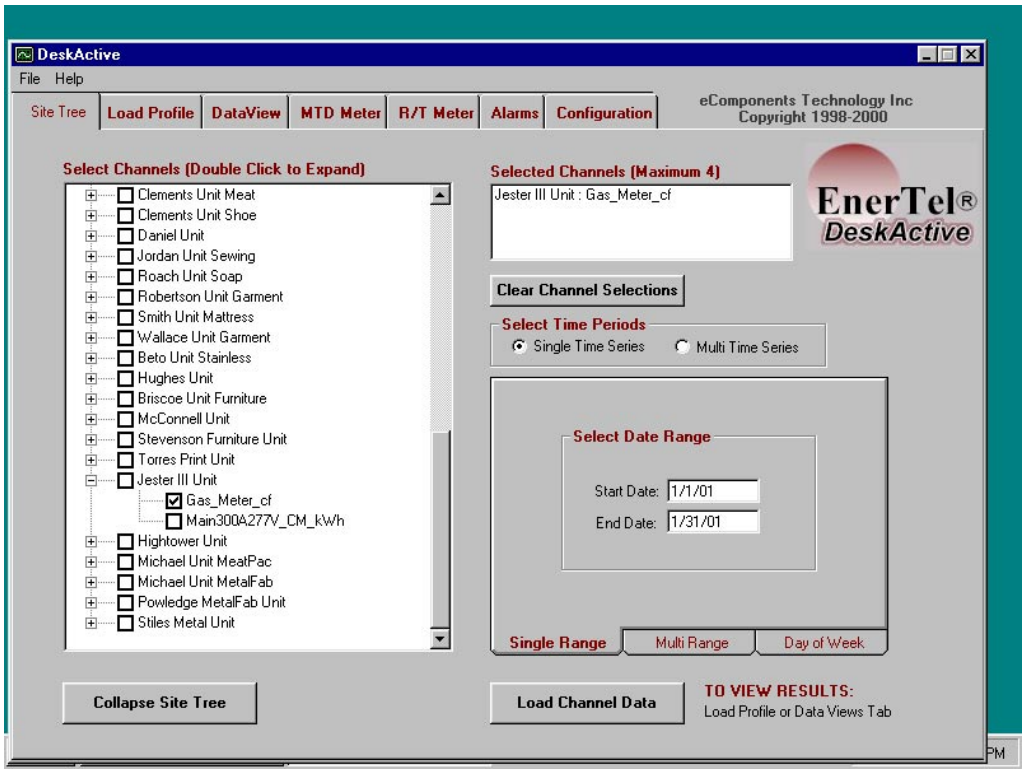
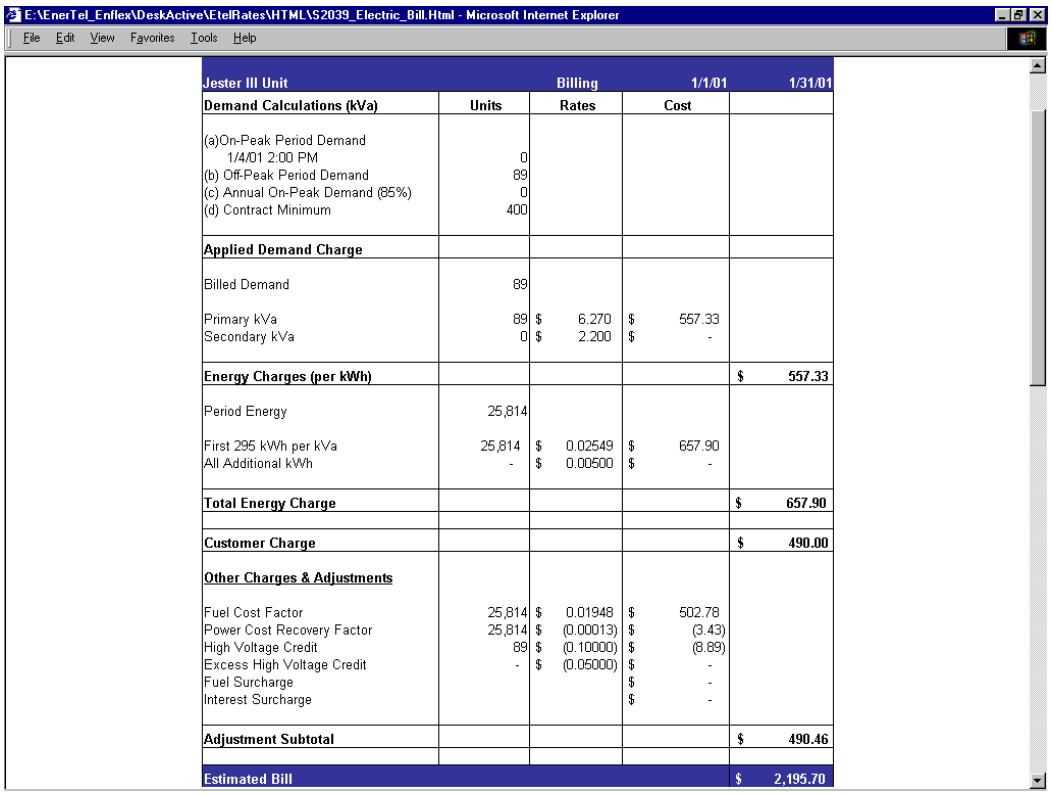


Figure 5. Screen Shot of TCI Metering Directory Structure.


E:\EnerTel_Enflex\DeskActive\EtelRates\HTML\S2039_Electric_Bill.Html - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Jester III Unit		Billing	1/1/01	1/31/01
Demand Calculations (kVa)	**Units**	**Rates**	**Cost**	
(a)On-Peak Period Demand				
1/4/01 2:00 PM	0			
(b) Off-Peak Period Demand	89			
(c) Annual On-Peak Demand (85%)	0			
(d) Contract Minimum	400			
Applied Demand Charge				
Billed Demand	89			
Primary kVa	89	$ 6.270	$ 557.33	
Secondary kVa	0	$ 2.200	$ -	
Energy Charges (per kWh)				$ 557.33
Period Energy	25,814			
First 295 kWh per kVa	25,814	$ 0.02549	$ 657.90	
All Additional kWh	-	$ 0.00500	$ -	
Total Energy Charge				$ 657.90
Customer Charge				$ 490.00
Other Charges & Adjustments				
Fuel Cost Factor	25,814	$ 0.01948	$ 502.78	
Power Cost Recovery Factor	25,814	$ (0.00013)	$ (3.43)	
High Voltage Credit	89	$ (0.10000)	$ (8.89)	
Excess High Voltage Credit	-	$ (0.05000)	$ -	
Fuel Surcharge			$ -	
Interest Surcharge			$ -	
Adjustment Subtotal				$ 490.46
Estimated Bill				$ 2,195.70

Figure 6. Screen Shot of Estimated Electric Bill for Jester III Unit at TDCJ.

The prison units themselves are typically located in remote areas so that mechanical subcontractor availability was limited. Associated travel costs for both subcontractors and installation personnel were high and many hours were consumed traveling to and from the job site. Substantial coordination was required to facilitate the delivery of materials and equipment to the job sites. The installation of conduit and wire runs were typically accomplished using prison labor so that equipment deliveries had to be made and materials totally inventoried before any installation work could be accomplished. Detailed installation instructions had to be provided in many cases. There were labor savings to the project through the use of inmate labor, but the complexity of the metering equipment required close supervision and oversight by the NHT field engineers and the U&E staff.

In general, the installation of the energy monitoring equipment was more time consuming than anticipated and the overall complexity of the job was underestimated. Coordination between TDCJ Unit wardens, TDCJ U&E, subcontractors, and NHT proved to be a fundamental problem. This was probably exacerbated, at times, by communications problems among these same groups. These problems are not unique to these groups or to this project. They merely highlight the challenges faced by any large, complex project.. Communication, especially, is key. As the project progressed, these and other management problems were identified and corrective measures implemented.

START-UP AND COMMISSIONING

System start-up and commissioning also proved to be very challenging. The project was initially plagued by unanticipated hardware failures relating to a third-party equipment manufacturer. These problems required multiple visits, to install upgrades and perform troubleshooting on the affected equipment. As described above, geography played a role as related to travel issues and access to TDCJ units also delayed rapid solution to the problem. Further, modem-based telephone communications at remote TDCJ units was sometimes unreliable.

Initial data acquisition at the first sites began in May 2000 and commissioning continued through the remainder of the year. Initial software training was provided in November 2000. Continuous data collection from all channels at all sites was ultimately achieved in March 2001.

FUTURE SYSTEM APPLICATIONS

The TDCJ Prison Industries Energy Monitoring System will initially be used to allocate energy costs for all of the prison industry facilities. In that way, TCI production costs can be more accurately isolated and presented. The system will also be used for power quality monitoring at the industries and to generate load profile information at the individual sites.

Ultimately, as deregulation of the utility industry in Texas is accomplished, the data from the Industry Monitoring System could be used for load aggregation purposes and to provide potential energy suppliers with detailed load characteristics.

CONCLUSIONS

The current energy metering system at the TCI of TDCJ is the most advanced and sophisticated system to be found in any state agency facility in the state of Texas. The software allows for flexibility and ease of use. This is important as the U&E staff is small and cannot afford to “baby sit” a metering system. Though simple for the user to manipulate, the system is robust and has considerable room for expansion and added functions.

Probably the single largest problem encountered during the project was the discovery of a manufacturing defect in a key component of the field installations. This unit had to be replaced as many as three times at some Units before all of the bugs were worked out. With the enormous travel requirements of this project, return visits to far-flung units was not a trivial time or cost venture

It is anticipated that this system will serve TDCJ Industries far into its metering future. The system can be upgraded to true Internet capabilities and software is under continuous development It is truly a flexible and expandable system.