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IT USE IN THE UTILITIES OF UKRAINE, ARMENIA, AND GEORGIA

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ABSTRACT

This paper examines the use of information technology in the electric and gas utilities of Ukraine, Armenia, and Georgia. Data was gathered through the performance of Year 2000 risk assessments, small business visits, document research, and academic visits between 1999 and 2001. Data was analyzed by comparing IT usage in Ukraine, Armenia, and Georgia to that in the United States. Overall IT usage was found to be low, at about the level of the United States in the 1970s. Financial difficulties and managerial issues prevent the acquisition and implementation of IT. The electrical supply itself is insufficient to support a digital economy because of poor power quality and unreliable power sources and will require large investments to correct.

Keywords: telecommunications, infrastructure, information technology, digital divide

I. INTRODUCTION

Dr. Philip Ein-Dor, President of the Association for Information Systems, AIS, in his letter to the membership on AIS as a global community and the digital divide [Ein-Dor, 2002] discusses the very low number of AIS members from the former Soviet bloc countries, a total of 33 of whom 19 are in Slovenia. He cites the digital divide (lack of technical infrastructure, information technology know how, and use) and language as the causes. This paper agrees with this assessment and explores this digital divide by comparing the use of information technology (IT) in the utilities of Ukraine, Armenia, and Georgia to that in the United States.

The study originated out of the perceived risk from the Year 2000 (Y2K) computer date problem to nuclear reactors built by the former Soviet Union, specifically those at Chernobyl and other reactors of the same design. To assess this risk, the United States sent teams of electrical utility experts to several republics of the former Soviet Union to assess actual risk to those countries' electrical systems. The author led the team assigned to assess the risk to Ukraine, Armenia, and Georgia. The scope of the assessment included the control, communication, engineering support, and business systems found in the electrical transmission and distribution systems, the gas transmission and distribution systems, central heating systems, and nuclear, fossil and hydroelectric generation stations. The author also conducted follow up visits in 2000 and 2001 to verify the accuracy of the assessment, to discuss IS education, to research and assist a small startup energy company, and to look at the energy infrastructure in homes and small businesses.

While the purpose of the assessment was to determine risk, the process used to determine this risk resulted in the comparison of IT usage in the three countries to IT usage in the electric utility industry of the United States. This paper presents the results of this comparison. The conclusion is that the infrastructure of these countries cannot support a digital economy where a digital economy is defined as the economy that is based primarily on digital technologies, including digital communication networks, computers, software, and other related IT [Turban, et. al., 2002]. The infrastructure in Ukraine, Armenia, and Georgia is inadequate because of poor power quality (lack of stable voltage and frequency and unreliable power sources [CEIDS, 2002]) and inadequate telecommunications and electrical infrastructure. Recommendations are made on how IT can be used to improve power quality to where it can support a digital economy, as well as improve cost performance of the utility industry.

II. BACKGROUND

IT IN THE UNITED STATES UTILITY INDUSTRY

The computer generated massive changes in the way North America and Western Europe generate, transmit, and distribute electricity and gas. Digital controllers and SCADA systems (Supervisory, Control, And Data Acquisition) regulate, monitor, and collect data on energy systems. For the most part they replaced the electro-mechanical devices previously used. Computers replaced many older manual office systems such as those for billing, payroll, document management, and accounting. Communications are also becoming dependent upon microprocessors. Y2K found that the energy sectors of North America are dependent upon microprocessors [Jennex, 1999, NERC, 1998].

Use of computers and microprocessors in the energy industry has greatly improved system reliability and power quality and lowered the cost of power generation, transmission, and distribution. Integrated work and plant systems are lowering maintenance costs and improving equipment reliability. Real time networks for managing power are controlling power quality to the tolerances necessary for a digital economy. The extent to which digital systems pervade the U.S. utility system can be seen from Table 1 that lists the types of digital systems used. A description of each of these systems is presented in Appendix I.

In addition to the systems listed in Table 1, personal productivity systems are used extensively in the United States. In many cases management is not even aware they exist. These are the systems workers create for themselves to help them do their jobs. They are particularly prevalent in organizations that use large numbers of personal computers. They are usually built using off-the-shelf software such as spreadsheets and personal databases. These systems are the key to the trend of empowering workers to make more decisions. To illustrate how prevalent these systems can be, Jennex [2002] examined an engineering organization at a nuclear plant in the United States and found approximately 160 previously documented systems and 267 undocumented applications in an organization of approximately 400 engineers. All 267 undocumented applications were personal productivity or small groups support systems.

BACKGROUND ON UTILITIES IN UKRAINE, ARMENIA, AND GEORGIA

Ukraine, Armenia, and Georgia, as republics in the Soviet Union, developed their utilities as part of the overall Soviet energy system. This system was developed starting in 1969 [Voitenko, 1995] and used standard equipment and designs to create a uniform and integrated system spanning the Soviet Union. Figure 1 shows the transmission system developed for this system and reflects the integration of Ukraine, Armenia, and Georgia into the overall power system. These interconnections, dispatch centers, and energy monitoring systems still exist and serve to tie and perpetuate the dependence of former republics to Russia. These ties and standard systems also continue into Eastern Europe and former Warsaw Pact nations [Jennex, et. al., 1999b]. This relationship proved useful for validating observations with utility personnel from outside Ukraine, Armenia, and Georgia.

Table 1. Digital Systems in Use in United States Utilities

System	United States
Power Production Fossil/ Thermal	Digital Control Systems, Turbine/ Generator Control and Supervisory Systems, Plant Computers, Emission Monitoring and Control, and Feed water/Boiler Controls.
Power Production Hydro	See above plus networks used to operate multiple units/equipment, and to facilitate the flow of plant status information.
Power Production Nuclear	Plant computers, steam plant supervisory and controls, radiation monitoring.
Energy Management	SCADA and Metering to monitor/regulate electrical transmission and generation.
Gas Transmission	SCADA and Metering to monitor/regulate transmission.
Telecom	Microwave, telephone, and VHF radio communications, Local and Wide Area Networks.
Protection	Digital relays, circuit protection devices.
Work Process	Large, networked databases supporting procurement, maintenance, and operations.
Engineering Support	CAD/CAM, modeling, statistical, geographical systems and specialized databases.
Business Systems	Accounting, Human Resources, Budgeting, Email, and Metering systems.
Facilities/Transportation	Air conditioning, lighting, fire protection, and access control/ security systems all facilities.

Standardization was reflected in a variety of ways. Nuclear plants are standardized on the RBMK, VVER-440, or VVER-1000 designs [Jennex, et. al., 1999b and Voitenko, 1999]. Plant computers were all of the same designations (SM-2 and SM-1420), appearance, and design and used to perform the functions of data acquisition and display. Communication switches, turbines, electrical protection devices, and other equipment were all the same [Jennex, et. al., 1999a and b, Furumasu, et. al., 1999, and Voitenko, 1999]. Long-term employees and managers disclosed in interviews that they were all trained within the Soviet system and served in other Republics prior to being shipped home after the breakup. The result is relatively common organizational cultures, procedures, and practices across Ukraine, Armenia, and Georgia. Interviews found that differences appeared primarily in equipment and employees added since the breakup because of differences in aid and foreign investment levels. The following sections provide additional background specific to the utilities, energy usage, and economy of each country.

Ukraine

Ukraine was a net electricity producer in 2000, 163.6 billion kilowatt hours (bkwh) produced versus 151.7 bkwh used. However, deteriorating power lines and equipment prevents them from having much excess energy [EIA, 2002b]. Ukraine's oil (395 million barrels), natural gas (39.6 trillion cubic feet, Tcf), and coal (37.6 billion short tons) reserves are significant, but it still imports the bulk of its natural gas needs while being an exporter of coal [EIA, 2002b]. Given the cost of fuel and the slow pace of economic activity, energy (of all types including electricity and gasoline) consumption steadily decreased since independence (from a high of 8.89 quadrillion BTUs in 1992 to a low of 6.26 quadrillion BTUs in 1998) but rose in recent years (6.41 and 6.46 quadrillion BTUs in 1999 and 2000) [EIA, 2002c].

Figure 1. Transmission System, United Power System of Russia [Voitenko, 1995]

Ukraine's installed generation capacity of 53.9 gigawatts (GW) is nearly double what it needs but due to the inefficient and antiquated transmission and distribution network significant amounts of power are lost due to line losses (estimated at 21% of the total generated electricity in 2000) [EIA, 2002b]. Generation is distributed with approximately 50% provided by thermal plants burning coal, natural gas, or fuel oil, 40% provided by nuclear plants, and 10% provided by hydroelectric stations on the Dnieper river. Generation is concentrated in four thermal stations (Dobrotvirska, Kyiv, Tripolye, and Zaporizhia), four nuclear stations (Khmelnitski, Rivne, South Ukraine, and Zaporizhia; a fifth site, Chornobyl, has been shut down); and six hydroelectric stations (Dnieprodzerzhinsk, Dnirovskaya, Kakhovka, Kanev, Kremenchug, and Kyiv [EIA, 2002b and Jennex, et. al., 1999b]. Pacific Northwest National Laboratories (PNNL) and Ukraine's Ministry of Energy report that a significant percentage of the thermal generation facilities are reaching the end of useful operating life [EIA, 2002b; Jennex, et. al., 1999b].

Ukraine's nuclear generation segment is large. Khmelniatski operates one VVER-1000 pressurized water reactor (PWR)¹ with one more under construction and two with construction cancelled. Rivne operates two VVER-440/213² and one VVER-1000 PWRs, with an additional VVER-1000 under construction. Three VVER-1000 PWRs are in operation at South Ukraine and six at Zaporizhia. The four RBMK reactors at Chornobyl are now shut down (the last, Unit 3, was

¹ The VVER-1000 is a 1000 megawatt (MW) reactor that is very similar to those used in the United States

² The VVER 440/213 is a 440 MW PWR similar to those used in the United States but does not have a containment structure

shut down on December 15, 2000 [EIA, 2002b]) for safety reasons following the disastrous accident at Chernobyl Unit 4 in 1986³. The two units under construction, Khmelnytsky-2 and Rivne-4, were begun under the Soviets and were over 80% complete at the time of independence. Ukraine obtained a loan from the European Bank for Reconstruction and Development (EBRD) but the loan was put on hold in December 2001. Russia offered \$500 million to complete construction but this funding is not considered sufficient. Ukraine is still negotiating with the EBRD to secure additional funding [EIA, 2002b].

Bulk electrical energy on the Ukrainian system is transported primarily on 750 kV and 330 kV transmission lines for long distances and on 110 kV lines for shorter distances. Twenty-seven distribution companies deliver energy to the end use customers over 0.5 kV to 20 kV distribution lines. The system includes a number of electrical connections with neighboring countries, with the strongest connection being with Russia. The electrical grid operates on day ahead generating schedules determined by the National Dispatch Center (NDC), with the electrical frequency allowed to float within maximum and minimum frequency limits. The NDC sends out the schedule to the eight Regional Dispatch Centers (RDCs), which in turn implement the schedule. The nuclear power plants provide base generation, with generation schedules at the thermal power plants used to balance the system with load demand and Hydro stations adjusted manually for load following to maintain frequency.

The Natural Gas System in Ukraine was built by Russia. This system enters the country from the southeast near Zaporizhia and capillaries out to all major communities and use locations. The basic components of the system are pneumatic and "self contained" pressure regulators and compressors. These devices are not reliant on microprocessors for control, very similar to the gas distribution and transmission systems in the United States.

Ukraine began the process of restructuring its electrical system by privatizing seven of 27 regional distribution companies. Stakes in six more distribution companies were sold in April 2001. However, further privatization was halted in May 2001 for a presidential review and further legislative reform. Privatization was restarted in December 2001 with the hope that all the remaining distribution companies will be sold by the end of 2003 [EIA, 2002b]. However, it is recognized that the excessive energy sector debt, \$10 billion as of 2002, will need to be restructured, reduced, or canceled before privatization will succeed [EIA, 2002d].

Ukraine's population is approximately 48.4 million (July 2002 estimate) but has been declining in population since independence [CIA, 2002a]. Ukraine's economy started to grow, 9.1% in 2001, following several years of decline [World Bank, 2002d]. However, IMF and World Bank fund disbursements were suspended in September 1999 as a result of allegations of improprieties in the handling of IMF funds [World Bank, 2002d]. Disbursements were resumed in September 2001 [EIA, 2002e].

Armenia

Armenia was a net electricity producer in 1999, 6.7 bkwh produced versus 6.2 bkwh used [EIA, 2002a] and when possible, exports electricity to Georgia. Armenia, with no oil, coal, or natural gas reserves/production, imports all the fuel it uses to produce electricity [EIA, 2002a]. Given the cost of fuel and the slow pace of economic activity, energy (of all types including electricity and gasoline) consumption decreased steadily since independence (from a high of 0.21 quadrillion BTUs in 1992 to a low of 0.09 quadrillion BTUs in 1998) but steadied in recent years (0.10 quadrillion BTUs in 1999 and 2000) [EIA, 2002c].

Generation is concentrated at six major generation sites: Hrasdan Thermal (1,100 MW), Yerevan Thermal (550 MW), Vanadzor Thermal (96 MW), Sevan-Hrazdan Hydro Cascade (532 MW), Vorotan Hydro Cascade (456 MW), Metsamor Nuclear (450 MW), and a number of small generating facilities. While the installed capacity of the major facilities is nearly 3,200 MW, the actual operating capability is limited to approximately 1,700 MW. In addition, the Metsamor

³ All the previous designations and status come from [PRIS, 2003].

nuclear plant is planned for shutdown in 2004 (provided sufficient alternate energy sources are available)⁴, leaving a generation capacity of around 1,500 MW and the possibility that the system will be in an energy deficit situation. Supplying the current system load is already difficult since much of the generating capacity is unreliable. Fuel and water constraints observed in 1999 limited generation capacity to about 1,000 MW on any given day.

Metsamor nuclear plant consists of two VVER 440/230 reactors modified with seismic upgrades and sometimes called model V270. Unit 1 is permanently shutdown and Unit 2 operates when fuel is available (and, as noted above, is tentatively scheduled for permanent shutdown in 2004). The VVER 440/230 is a pressurized water reactor similar to those used in the United States but does not have a containment structure and virtually no emergency core cooling system. Armenia's chronic energy shortages of recent years were largely offset by the energy supplied by Metsamor Unit 2 although this supply was interrupted during portions of 1999 and 2001 due to a lack of fuel [Jennex, et. al., 1999a and Energy Information Administration, 2002]).

Bulk electrical energy on the Armenian system is transported on 330-kV and 110-kV transmission lines. The electrical system is connected with Azerbaijan, Georgia, Iran, and Turkey. The interconnection with Iran, which has approximately 20 times the load as Armenia, is the most significant tie to the Armenian System. Also, due to regional conflicts, the Azerbaijan and Georgia interconnections were not active in 1999 [Jennex, et. al., 1999a]. The World Bank is currently funding efforts to this area through its Electricity Transmission and Distribution Project, started in 1999 and scheduled to be complete in 2004 [World Bank, 2003a].

The Natural Gas System in Armenia was built by Russia. This system enters the country from the north through Georgia and capillaries out to all major communities and use locations. The basic components of the system are pneumatic and "self contained" pressure regulators and compressors. These devices are not reliant on microprocessors for control, very similar to the gas distribution and transmission systems in the United States. There is no SCADA on the current system but there are plans to build a modern SCADA system to monitor potential leaks/problems and flow locations, and for remote metering. Many of these devices will be digital, but none have been purchased or installed. The only digital device in the current system is the super meter used to measure gas usage. This super meter is located at the Georgia - Armenia border.

In 1996, Armenia began the process of restructuring its electrical system to unbundle generation, transmission, and distribution into commercial enterprises designed to operate in a market-based electricity industry. The Energy Regulatory Law of 1997 provided the vehicle to privatize the vertically integrated state monopoly Halergero (Armenergo). The EBRD agreed to take a 20% equity stake in each of Armenia's four distribution companies on December 5, 2000 to support restructuring [EIA, 2002a]. However, the process stalled when no bids were received for privatization tenders in March and April of 2001 [EIA, 2002a].

The Armenian Government in 1994 launched an ambitious IMF-sponsored economic program that resulted in positive growth rates in 1995-2000. Armenia also managed to slash inflation and to privatize most small- and medium-sized enterprises. Armenia's severe trade imbalance, importing three times its exports, are offset somewhat by international aid, domestic restructuring of the economy, and foreign direct investment. Armenia's population is approximately 3.3 million but has been declining since independence [CIA 2002b]. Human capital, in terms of skilled workers, deteriorated through the 1990s due to high poverty levels, 49.1%, and poor employment opportunities, resulting in a deleterious effect on the quality of life and on the economy [World Bank, 2002a].

Georgia

Georgia was technically a net electricity producer in 1999, 8.0 bkwh produced versus 7.1 bkwh consumed but deteriorating power lines and equipment makes them an energy importer [EIA,

⁴ Armenia is backing off the 2004 commitment [Danielyan, 2000].

2002a]. Georgia's oil (35 million barrels) and natural gas (300 billion cubic feet, Bcf) reserves are limited. It still imports the bulk of its energy needs, including oil and natural gas [EIA, 2002a]. Given the cost of fuel and the slow pace of economic activity, energy (of all types including electricity and gasoline) consumption decreased steadily since independence (from a high of 0.33 quadrillion BTUs in 1992 to a low of 0.14 quadrillion BTUs in 1994) but became stable since (0.16 and 0.17 quadrillion BTUs in 1999 and 2000) [EIA, 2002c].

Georgia's electrical generating plants are operated and maintained by Sakenergo-Generazia. The only sizable internal energy resource is hydroelectric. The installed generating capacity is 2590 MW of hydroelectric (mostly at the Inguri hydropower plant, 1270 MW) and 1818 MW of thermal generation (most at the Gardabani thermal power plant), with an operating capacity of approximately 1200 MW hydroelectric and 416 MW thermal. This decreased capacity is attributable to lack of funds for fuel, spare parts and repair services, and inadequate maintenance or maintenance personnel with the proper expertise. Approximately 430 MW of hydroelectric and 230 MW of thermal capacity is not available because of lack of water or fuel [Furumasu, et. al., 1999 and EIA, 2002a]. Additional electricity is lost during transmission due to deteriorated transmission and distribution lines. As a result, Georgia is not able to produce enough electricity to supply itself and experiences frequent power interruptions [Furumasu, et. al., 1999 and EIA, 2002].

The Natural Gas System in Georgia was built by Russia. The basic components of Georgia's Saktransgasmrevi Natural Gas Transmission system are pneumatic and "self contained" pressure regulators and compressors. These devices are not reliant on microprocessors for control, very similar to the gas distribution and transmission systems in the United States. Data collection systems are not real time. Dispatchers transfer all data and communications over the telephone. The data is then manually posted on a map board displaying the gas transmission system valves and outage status, by the dispatchers. The only devices that used computers were the super flow meters. There were seven of these meters in Georgia, five at international borders and two located at large customer facilities. For all other locations where gas is delivered, data is acquired over the telephone and entered manually in an Excel spreadsheet to calculate gas consumption.

Georgia suffers from energy shortages, outages, and disruptions; it privatized the distribution network in 1998, with AES of the United States purchasing 75% of the Telasi distribution company. Deliveries are improving although there are still issues with generation [EIA, 2002a]. In a meeting with the IMF during January 2002, Georgia blamed problems in privatization on rampant corruption and said it was taking steps to correct those problems [EIA, 2002a]. The country is pinning its hopes for long-term recovery on the development of an international transportation corridor, primarily for oil and gas, through the key Black Sea ports of P'ot'i and Bat'umi. Georgia, with the help of the IMF and World Bank, made substantial economic gains since 1995, increasing GDP growth and slashing inflation. The Georgian economy continues to experience large budget deficits because of a failure to collect tax revenues. Georgia has a population of approximately 5 million [CIA 2002c].

III. METHODOLOGY

This paper is based on action research. The author served as the team leader for a project team of eight utility engineers. Data was collected and analyzed to support decision-making by the client, the United States State Department, which wanted to determine if United States citizens should be evacuated from former Soviet countries as a result of Y2K concerns. It was the job of the team leader to provide a recommendation with respect to evacuation and to provide information about what to expect from Y2K to the United States State Department and the western expatriate communities in Ukraine, Armenia, and Georgia⁵.

⁵ There was great concern by the United States government and western expatriates living in the former Soviet Union that Y2K would disrupt communications, transportation, and basic services such as electricity

The methodology developed for the project was based on identifying each country's Y2K processes and comparing them to the best-practices-based processes:

- NEI/NUSMG 97-07 [NEI, 1997] and NEI/NUSMG 98-07 [NEI, 1998] published by North America's Nuclear Energy Institute (NEI) and endorsed by the Electric Power Research Institute (EPRI), and
- IAEA-TECDOC-1072 [IAEA, 1999] published by the International Atomic Energy Agency (IAEA).

The differences in the programs were then analyzed for risk significance based on risk and risk mitigation factors identified in the data collection process. The data collection process involved document review, visits with Y2K officials and organizations in the three countries, and visits/tours of selected facilities within the countries. The purpose of these visits and tours was to collect information on the amounts and types of digital controls and systems used in the energy sector. It is the results of these visits and tours that are the source of data for this paper.

Approximately two months were spent in the three countries gathering data: five weeks in Ukraine and two weeks each in Georgia and Armenia. Not all energy sector sites could be visited in a country. Sites selected for visits/tours were those sites that were known to use digital controls or information systems and those that were the newest and available. Sites that were visited/toured were not necessarily visited/toured by all team members. In order to visit more sites the overall team was broken into smaller teams. Appendix II provides a listing of sites visited by members of the project team. The author did not visit/tour all the sites discussed in this paper; however, the author, as the project manager for the team, was responsible for collecting and analyzing the data and generating the risk analysis and report. The team also visited government and organizational offices associated with the energy sectors (Appendix II). Due to the nature and sensitivity of the study, the team had access to many senior energy officials as well as engineers and technicians working at the sites.

During the study, the author also had the opportunity to corroborate the findings at two contingency planning conferences (Prague, Czech Republic and Vienna, Austria) attended by other former Soviet bloc nations. Through informal discussions the author was able to confirm with senior technical people from Lithuania, Czech Republic, Slovenia, Bulgaria, and Hungary observations with respect to general design and use of digital components in nuclear and transmission and distribution systems. It was found that Soviet power systems were of the same design across the entire former Soviet bloc [Voitenko, 1995].

The author made two additional visits to Ukraine in the summers of 2000 and 2001. These visits were for visiting contacts made during the risk assessment and for meeting with Energy Solutions LLC, the Ukraine Ministry of Education, Odessa State Polytechnic University, Chornobyl Union (a charitable institution assisting survivors of the Chornobyl nuclear disaster), and businesses in Kyiv. Interviews were conducted in which the energy sector of Ukraine, IT infrastructure, IT education, and the application of IT in business, government, and education were discussed. In addition, inspections were performed on several typical office and residential structures to assess their basic electrical and telecommunication infrastructure.

IV. FINDINGS

DISCUSSION

It was assumed that the energy sectors of Ukraine, Georgia, and Armenia would use digital systems to some extent. This was not found to be the case. In general, the energy sectors in these countries were at the technological level of North America and Western Europe during the 1960s or 70s. Few digital controls and information systems were found. Relatively few personal

and heat. This concern and whether westerners should evacuate former Soviet countries was the primary driver for this project.

computers (PCs) were observed, usually no more than a dozen at a hydro or conventional power plant and only a couple dozen for each nuclear reactor (most all of which were 286, 386, and 486 models) [Furumasu, et. al., 1999, Jennex, et. al., 1999a and b, and NPP-OSI, 1999]. By contrast, approximately 2000 PCs were used at the San Onofre Nuclear Generating Station (two operating and one shut down reactor) and 19,000 PCs at Southern California Edison in 1999 [Y2KPMO, 1999]. Additionally, only two types of Soviet designed computers, the SM-2 (similar to the HP-1000 [NPP-OSI (1999)]) and SM-1420 (a PDP-11 clone [NPP-OSI, 1999]) and two DEC Alphas and one DEC RX-11 (all three found in Ukraine's power monitoring and dispatch system), were observed [Furumasu, et. al., 1999 and Jennex, et. al., 1999a and b].

This is not to imply that information and digital systems are not in use or wanted in these countries. Many interviewees indicated a desire to innovate the utilities. Plans were in place at many sites for updating to digital controls and information systems. Several instances were found where digital controls and information systems were in use. From the interviews of plant officials at each of the power plants visited, it was learned that the single limiting factor to widespread adoption of Information Technology was a lack of funding. While the lack of funding was observed, it was also observed that there were no real economic drivers pushing plants to purchase and install digital controls and information systems. Wages of approximately \$150 to \$300 per month for engineers in Ukraine [Jennex, et. al., 1999b] and approximately \$65 to \$150 per month in Armenia [Jennex et. al 1999a] and Georgia [Furumasu, et. al., 1999] are so low as to provide no incentive for inducing IT investments that replace employees. Ukraine in particular is hesitant to do any modifications that would reduce the number of jobs [EIA, 2002b].

SIDEBAR 1. USE OF DIGITAL CONTROLS IN THE UNITED STATES NUCLEAR INDUSTRY

The move to digital controls in the United States nuclear industry began with the issuance of IEEE Standard 7-4.3.2-1993, Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations. However, widespread adoption of digital safety controls was slow due to regulated single failure evaluation criteria that made it difficult for power plant operators to verify that software defects would not affect all trains/channels of a safety related control system (while redundant hardware can be verified not to have common defects, running multiple copies of the same software is not considered redundant). Issuance of IEEE Standard 379-2000, Application of the Single Failure Criterion to Nuclear Power Generating Station Safety Systems, and its pending endorsement by the NRC through the issuance of Draft Regulatory Guide DG-1118 (May 2002), Application of the Single-Failure Criterion to Safety Systems, is expected to clarify and resolve these issues. Finally, North American nuclear plants long used digital and information systems for monitoring, supervising, and acquiring data; and for controlling non-safety related systems such as water processing, equipment electrical protection, and steam plant side support systems. North American fossil power plants embraced digital controls starting in the early 1980s.

A very surprising finding was that design principles during Soviet times precluded the use of digital controls. This opinion was heard in all three countries and at several different sites with no real reason for this preclusion being provided. A possible explanation comes from Clements [1999] who found that in the 1950s Soviet authorities did not regard digital computers as worthy of investment with many Soviet scientists believing that digital computers would never prove reliable and analog computing was the better choice. Also, this finding, while surprising, is consistent with pre-1990s nuclear design principles in North America that also precluded use of digital controls for safety systems. However, since 1990 the United States Nuclear Regulatory Commission (NRC) and the Institute of Electrical and Electronic Engineers (IEEE) published a series of standards and regulatory changes authorizing and promoting the use of digital controls in nuclear safety systems.

Fifteen nuclear reactors were examined, 14 in Ukraine and one in Armenia. Several digital systems are used in these plants. The digital systems that are present are used primarily for data acquisition and display and secondary plant control and include:

- turbine and steam generator control (ACYT-1000),
- plant process computer (SKALA, TITAN, Uran),
- safety parameter display (Vulcan),
- reactor monitoring (Khortitsa),
- performance monitoring (Regina),
- personnel dose control (ASPDC),
- access control, and fire protection [NPP-OSI, 1999].

Most of these systems are based on the SM-2 or SM-1420 computers but several use PCs for interface and display or as the base computer. A few digital instruments such as liquid scintillation analyzers, ion chromatographs, and atomic adsorption spectrometers were also found [NPP-OSI, 1999]. These systems are consistent with what would be found in the United States and are reflective of the safety concerns and upgrades generated by the Chernobyl-4 meltdown in 1986. What was different from the United States was the general lack of PC use by the technical staff. The Data Information System (DIIS) with 25 workstations and a few small networks (six to eight workstations) and several PCs were all that was observed to be available for personal productivity use. Standard practice in the United States is for each engineer to have his or her own PC networked to the United States DIIS equivalent (this name varies between United States sites). This sector is the closest to matching what is found in the United States and it would be closer were more funds available.

Another finding that was somewhat surprising was the poor reliability and power quality observed in Ukraine and Georgia. These countries have routine frequency oscillations of 0.5 hertz or more and power outages are quite common. An average of one outage per day varying in length from a few seconds to several hours was observed in Tblisi [Furumasu, et. al., 1999] and are reported to occur daily in most parts of the country [Energy Information Administration, 2002]. Most critical building and hotels, as well as many residences, in all three countries kept and maintained backup generators. North American standards specify frequency oscillations controlled to 0.05 hertz or less. Figure 2 shows the frequency of the Ukrainian electric power grid as monitored by Pacific Northwest National Laboratory (PNNL) in its Kyiv office. This figure shows the instability of frequency over an approximate 10-month period. Note that there is an approximate one Hz range of oscillation, from approximately 49.15 to 50.15 Hz.

Observations found that frequency not only varied widely during the approximate two week intervals as shown, but also varied widely throughout the day [Jennex, et. al. 1999b]. Digital equipment does not function well nor last as long with the large observed frequency swings due to increased heat generation within the devices. Digital clocks brought by the team routinely lost approximately twenty minutes a day.

The most surprising aspect of this finding was that Armenia's frequency control is very good. Armenia uses a digital SCADA to monitor frequency but uses analog controls and instruments to maintain frequency within 0.1 hertz. This stability shows that digital controls are not absolutely necessary for good power quality, as Armenia had no other digital control systems in their electrical transmission and distribution system [Jennex, et. al., 1999a]. However, Armenia also had a very low load, an average of 800 MW with an approximate winter peak of 1200 MW, that is mostly resistive residential loads that do not cause power oscillations [Jennex, et. al., 1999a]. Ukraine recognized the need for more stable frequency control and in February of 2001 struck a deal with Russia to reconnect their transmission grids although reconnection did not occur until August 2001 [EIA, 2002b]. This agreement also gave Russia the ability to sell its excess electricity to countries such as Moldova, Romania, Bulgaria, and the Balkans by providing Russia a link to those electricity markets.

Figure 2. Ukraine Frequency Plot 12/25/98 - 10/2/99 [Jennex et. al., 1999]

The fuse box of the average house or small office in Ukraine is 45-amp while the average house or small office in Southern California is 150-200 amps. Also, Ukrainian fuses generally are one shot fusible links and not modern, re-settable trip breakers⁶. Coupled with the previously discussed poor power quality and unreliable power sources it is concluded that the electrical infrastructure in Kyiv and Ukraine does not readily support a modern office's IT electrical needs. Observations in Armenia and Georgia support this same conclusion for those countries. Large companies compensate by installing their own power equipment. Small companies make do with what they have with the result that they have less reliable IT. Private homes find it difficult to support running computers as outlets are few, existing appliances, lighting, heating, and cooling use almost all of the available load, and second phone lines or broadband access (ADSL or cable modems) are not available.

Power quality to support digital economies is an increasing concern, even in North America and Western Europe, primarily due to decreasing capital and maintenance expenditures worldwide [EPRI, 1999]. Current electric infrastructure (worldwide) was not designed to provide the near-perfect power quality required for digital economies [CEIDS, 2002]. The implication is that while observed conditions were poor, they are not uncommon and may be reflective of a worldwide degradation trend.

⁶ This difference is important as blowing a fuse requires the replacement of the fuse, making owners very hesitant to load their power systems heavily; they usually leave a 10-15% safety margin

An interesting observation is the comparison of per capita energy consumption between Armenia, Georgia, Ukraine, and the United States for the years 1999 and 2000 shown in Table 2.

Table 2. Per Capita Energy Consumption in 1999 and 2000 (millions of BTU)

Country	2000	2001
Armenia	26.1	25.5
Georgia	30.7	32.3
Ukraine	127.9	130.3
United States	354.9	351.0

Source: [EIA, 2002c]

Starr (1997) categorized social conditions/wealth as a function of energy generation and use. Starr defined four levels: survival, basic quality of life, amenities, and international collaboration. The levels of usage for Armenia and Georgia place them in the basic quality of life category, Ukraine in the amenities category, and the United States is well placed in the international collaboration, or top category. This result shows that since the breakup, electrical generation and use indicates a drop in social status and wealth for the former Soviet Republics; prior to the breakup the Soviet Union electrical generation and usage [Voitenko, 1995] would rate placement in the top international collaboration category.

The use of IT for performance monitoring is low. All three countries use some kind of performance monitoring system. Ukraine's performance monitoring systems are used on the larger generation units that were based on Soviet SM-2 computers. However, while these systems collected real time data, little to nothing was being done with it in the thermal generation plants (nuclear sites used the data much like it is used in the United States). Several displays were observed indicating degrading conditions but they were being ignored with the explanation given that, while there was no money for spare parts, there was much excess capacity. When one unit broke down another was started. In all three countries it was observed that the average combined thermal unit sites were operated at approximately 20-25% capacity. Hydro sites were all operated at the maximum capacity available. Nuclear sites were also operated at full capacity if fuel was available⁷

Georgia used PCs to do performance monitoring. These systems were not real time and required the user to type in data from operator logs for trending. However, these systems were not being used for maintenance purposes due to lack of funds for parts. Armenia had the same type systems as Georgia but used their systems to track performance and schedule maintenance. The result was that well maintained, efficiently operating plants were observed in Armenia while poorly maintained and operated plants were observed in Ukraine and Georgia. While a lack of IT cannot be blamed for this difference, the overall lack of resources can be. Ukraine and Georgia's excess capacity allows them to run plants until they fail, doing little or no maintenance. Armenia, with little excess capacity and thermal plants that exceeded their design life [EIA, 2002a] were doing their best to keep what they had running.

A finding detrimental to future IT development is the very poor condition of the telecommunications used for energy management and plant communications. Analog switches/equipment were common in all three countries. Telecommunication service between dispatch centers and plants or other dispatch centers were unreliable. Ukraine uses a Wide Area Network for monitoring the power system that is based on SM-1420 and SM-2 computers⁸ This system was observed to be out of service frequently, requiring system operators to rely on voice communications, which were also frequently out of service, for dispatch functions. The result

⁷ As indicated in Section III, Armenia's Metsamor did not have fuel and could not afford to purchase it for several months in 1999 [Jennex, et. al. 1999a] and again in 2001 [Energy Information Administration, 2002]).

⁸ Two DEC Alphas and a DEC RX-11 were installed as Y2K replacements in Ukraine.

was that plant operators used analog radios or simply load followed⁹. It was observed that commercial communications systems, particularly cell phone systems, are well developed in all three countries and Ukraine installed some fiber, although these systems are concentrated around the capitals and major cities [ITA, 2002].

A pleasant surprise finding was the level of IT expertise found in 1999. Given the modest to no use of digital controls and IT, it was expected that little intellectual capital would be found that could support an IT-based energy sector. Discussions with plant personnel, engineers, and students found a sufficient, if underutilized IT knowledge base. However, Olearchyk [2001] reports that this talent is leaving. He states that approximately 2500 IT specialists leave Ukraine each year. In addition, the schools are not producing usable IT professionals due to their focus on theory and not on practical education. This problem does not exist for the energy sector because school training is sufficient for the existing legacy systems. This trend contributes to the digital divide and is not encouraging for the Ukraine's future ability to close the divide.

SUMMARY OF COMPARISON TO U.S. SYSTEMS

This section compares IT systems found in Ukraine, Armenia, and Georgia to those discussed in Section II. The following paragraphs and Table 2, at the end of this section, discuss these findings.

Very few digital controls were found in the thermal and Hydro plants. Dedicated turbine, generator, boiler, and feed water controls were found but very few digital components are used and no DCS's were found. Those digital controls that were observed were all produced in the United States and Western Europe and installed since the breakup of the former Soviet Union. In Ukraine, digital controls were found in Hydro installations where the economics of free fuel made investment in these plants possible and nuclear plants where western investment as a result of Chernobyl occurred. Georgia has two units at its Gardabani site that were installed in 1990 and which utilize microprocessor controls for fuel, boiler, and turbine control. However, the Energy Information Administration [2002] reported that one of these units exploded on December 22, 2001. The reported cause of the explosion was incompatibility between the computer control system and the plant's mechanical components. No digital controls were observed in Armenia.

No digital control components or systems were observed in the Gas Transmission system. Digital super meters were found where pipelines crossed national borders and at a few large customer sites. Some passive SCADA systems were in place to monitor flows and pressures.

No digital control devices were found in the nuclear control systems but digital control systems for steam generators and turbines were found in the secondary plant. However, digital data acquisition systems and monitors are found for use in displaying plant data and supervising turbine/generators. These systems were based on Soviet SM-1420 computers. Digital radiation monitoring systems exist at Chernobyl and are being procured for the other Ukrainian nuclear sites [Ukraine Embassy Page, 2002]. Digital access control and fire protection systems were also found.

Energy Management Systems are not used. Power Monitoring Systems, used to assist in generation dispatch, utilize SM-1420 based digital technology and were found in all three countries. These systems provide passive SCADA functions and are used to collect data on power usage and frequency stability.

No digital telecommunication systems or devices were observed. Routine communications are on copper wires using analog switches. Analog radio provides backup communications. No fiber systems were observed. The only observed use of the Internet for plant data purposes was in Armenia where it is used to transmit daily batch data on equipment conditions. When the Internet is not available data is transferred using hand-carried diskettes. This way of working is also common for the Plain Old Telephone System (POTS).

⁹ In load following operators adjust plant output in reaction to frequency and load. It results in poor power quality with little frequency stability.

Another negative is the poor condition of the telecommunications infrastructure. Observations of phone lines in hotels catering to westerners found that dial up connections, when available, of greater than 9800 bps were difficult to impossible to sustain for more than a few minutes due to line noise and errors. Commercial cell phone systems are well developed but not used by utilities. Additional analysis of the telephone system from the Central Intelligence Agency's World Fact Page confirms the antiquated state of the system:

"Ukraine's telecommunication development plan, running through 2005, emphasizes improving domestic trunk lines, international connections, and the mobile cellular system. At independence in December 1991, Ukraine inherited a telephone system that was antiquated, inefficient, and in disrepair; more than 3.5 million applications for telephones could not be satisfied; telephone density is now rising slowly and the domestic trunk system is being improved; the mobile cellular telephone system is expanding at a high rate. Two new domestic trunk lines are a part of the fiber-optic Trans-Asia-Europe (TAE) system and three Ukrainian links have been installed in the fiber-optic Trans-European Lines (TEL) project which connects 18 countries; additional international service is provided by the Italy-Turkey-Ukraine-Russia (ITUR) fiber-optic submarine cable and by earth stations in the Intelsat, Inmarsat, and Intersputnik satellite systems."

No digital protection devices or system were found in any of the countries. Digital unit protection devices were being prepared for installation at some Ukrainian Hydro units but none were installed.

No work process control systems were observed nor was there any indication that these types of systems were considered necessary.

PC-based performance monitoring systems are used. Their primary purpose appears to be to support plant operators in making real time plant decisions. Use of these systems to support engineers performing functions such as maintenance and operations planning was not observed nor mentioned by engineers as a use for these systems. Engineering support systems, where they exist, are all stand-alone systems that do not receive plant data automatically. Observed examples include a failure analysis system and performance trending systems found in Armenia.

Accounting/Billing/Business systems were observed on stand-alone desktop personal computers at several sites in all three countries. Use of spreadsheets and other financial/business software was prevalent. Some small business LANs were observed in all three countries. Use of e-mail for communications was also observed but was not consistent across the energy sector. Commercial metering systems for supporting customer billing do not exist. Apartment buildings generally have a single meter rather than a meter for each apartment.

Facilities systems were observed for access control, seismic monitoring, and fire protection in the nuclear industry. No other digital systems were observed.

Personal productivity systems were not observed but probably exist on PCs observed at the various sites. Desktop PCs were not observed in great numbers, only a few (less than 12) were seen at each site with not all sites having PCs (Nuclear sites had several dozen PCs).

V. CONCLUSIONS

The digital divide in utilities in Ukraine, Armenia, and Georgia is real and may not be overcome for several years. The use of digital controls and IT systems in the utilities of Ukraine, Georgia, and Armenia is limited. Also, the physical infrastructure for building these systems does not exist and the technical knowledge infrastructure, while currently available, is leaving. This state of affairs means that the telecommunications and electrical infrastructures are inadequate for supporting a digital economy or infrastructure.

Table 3. IT Comparison between the United States and Ukraine, Armenia, and Georgia

System	United States	Ukraine, Armenia, Georgia
Power Production Fossil/ Thermal	Digital control systems, turbine/ generator control and supervisory systems, plant computers, emission monitoring and control, and feed water/boiler controls,	Ukraine and Armenia have no digital controls. Ukraine has some monitoring. Georgia's Gardabani site utilizes microprocessor controls for fuel, boiler, and turbine control.
Power Production Hydro	See above plus networks used to operate multiple units/equipment, and to facilitate the flow of plant status information	Some digital in Ukraine Hydro, vibration monitor and generator protection. None observed in Armenia or Georgia
Power Production Nuclear	Plant computers, steam plant supervisory and controls, radiation monitoring	Essentially the same systems found. However data was less available to technical staff.
Energy Management	SCADA and Metering to monitor/regulate electrical transmission and generation	EMSs not used. Power Monitoring Systems with SM1420 are used for dispatch/use/frequency monitoring.
Gas Transmission	SCADA and Metering to monitor/regulate transmission	No digital controls. Some Digital super meters. Some passive SCADA.
Telecom	Microwave, telephone, and VHF radio communications, Local and Wide Area Networks	No digital telecommunication systems or devices. Analog phone switches. Analog radio. Some Internet use.
Protection	Digital relays, circuit protection devices	No digital protection devices or systems
Work Process	Large, networked databases supporting procurement, maintenance, and operations	No work process systems
Engineering Support	CAD/CAM, modeling, statistical, geographical systems and specialized databases	Performance monitoring systems in Ukraine. Armenia has PC based systems for failure analysis and performance trending.
Business Systems	Accounting, Human Resources, Budgeting, Email, and Metering systems	Spread sheets other SW prevalent. Some small business LANs. Some Email use. No metering for billing
Facilities/	Air conditioning, lighting, fire protection, and access control/ security systems all facilities	Access control, seismic monitoring, and fire protection in nuclear only

The main barrier to developing digital and IT systems is financial. Little money is available for investment or salaries and IMF or World Bank funds tend to be contingent on privatization. It was observed that no automation that results in reduced personnel was being done. It was less costly to have employees than it was to purchase equipment and develop systems. However, because salaries are quite low, those with technical skills are leaving [Olearchyk, 2001]. While IT is slowly being developed, as money permits, it is expected that large-scale investment in IT will not occur until the economies of these countries improve or until private, outside investment occurs. The major barrier to outside investment is the lack of return on investment. It was observed that there is not a consistent practice on the part of consumers to pay regular bills. Also, the necessary metering system that would allow energy companies to generate consumer billing does not exist. Finally, the utilities' debt loads are high, which would suggest a low likelihood for private investment.

Exacerbating the digital divide are language issues. Technical terms do not necessarily have Russian equivalents and in some cases have different meanings. Also, because the Cyrillic character set is used in Russian, files are not readily exchanged between the United States and the former Soviet countries. Few technicians or academics read and/or speak English. Although a country can avoid a digital divide without English, a lack of English does impact knowledge transfer. Nonaka [1994] describes four modes of knowledge creation and transfer:

- Socialization, the process of sharing experiences,
- Externalization, the process of articulating knowledge,
- Combination, the process of systemizing concepts into a knowledge system by combining different bodies explicit knowledge, and
- Internalization, the process of converting knowledge to understanding.

These methods show that the transfer of knowledge depends on the transfer of a common context of understanding from the knower to the user of the knowledge. The transfer of a common context of understanding requires that the knower and user must be able to communicate. The language and character set issues described created barriers to the team in its attempt to transfer Y2K knowledge to their Ukrainian, Armenian, and Georgian counterparts. Discussions with USAID and PNNL personnel found that these issues were also common barriers to knowledge transfer for them.

A final conclusion is that while there is a good, but eroding, technical knowledge base, there is not a good business knowledge base. The lack of work process systems and the low use of performance monitoring systems suggest a lack of understanding of how to use IT to improve business processes. This study did not look at business systems in detail so a firm conclusion cannot be supported, but it is expected that this area that will need to be addressed by these countries.

RECOMMENDATIONS

The financial problems in Ukraine, Georgia, and Armenia are the limiting factor in the acquisition and implementation of IT. There is little doubt that implementing IT would improve effectiveness and power quality while reducing costs. Experience in North America supports this finding. However, experience in North America also shows that these benefits are realized only marginally until integration of systems controlling generation, transmission, and distribution occurs. The "Productivity Paradox" was a real event in North American IT implementation. Given the existing weak communications, the lack of customer metering, and the absence of a MIS knowledge base, the need to address infrastructure issues first is necessary. Concurrently, the rapidly degrading physical condition of generation plants in Ukraine and Georgia, and to a much lesser extent in Armenia, suggests that plant replacements will need to occur. New plants should include modern digital controls.

The following recommendations are made for Ukraine, Armenia, and Georgia:

- Continue building a telecommunications infrastructure using wireless technology and extend its use to utility data transfer. Add fiber as time and funding permit.
- Raise power quality standards to that of the United States and Western Europe.
- Raise building standards to include better wiring and increased electrical capacity in homes and small offices.
- Add MIS curriculum to technical education.
- Install sufficient metering to enable customer billing.
- As plants are replaced, purchase turnkey units with modern digital controls.

- As economies improve and underemployment decreases, improve productivity through automation of work processes.
- Build Internet based wide area networks for data transmission between sites and dispatch centers.
- As control systems and equipment age and need to be replaced, replace with modern digital control systems or equipment.

LIMITATIONS

The main limitation of this study comes from cultural differences and language. Because none of the members of the project team spoke Russian and few of the people interviewed spoke English, interpreters were used. On at least one occasion a difference in word meanings occurred. The interpreters translated "contingency planning" as meaning emergency planning when the United States meaning is just-in-case planning. While no other instances of miscommunication are known, they may have occurred.

The second limitation is timeliness. This study was done in the fall of 1999 so there is a potential that the information is out of date. The author mitigated this problem by returning to Ukraine during the summers of 2000 and 2001 and reconfirmed the general data. Also, one member of the research team remained in Ukraine and started an energy related company. Communications with this individual confirmed that the data collected is still valid for Ukraine. Review of news reports from Georgia and Armenia suggest that financial conditions did not improve significantly enough to allow for many recent purchases of digital equipment or information systems.

The final limitation is a selection threat based on the selection of sites and personnel visited/toured and/or interviewed. It is possible that the sites and personnel selected are not representative. This threat is not considered viable because new sites or sites known to have computers or digital controls were specifically selected. Since these sites were the ones the study was looking for, if a selection threat exists it is a positive. The issue would exist if significant sites were missed that had digital controls or information systems. Since the majority of sites were visited/toured in Georgia and Armenia it is not expected that significant digital controls or information systems were missed. The threat may be possible in Ukraine, though, given the size of the country. However, the majority of the major thermal and hydro sites were visited and contractors working in the Ukraine nuclear industry were members of the team. It is not expected that significant digital controls or information systems were missed.

In summary, while there are potential threats to the validity of this study, none are considered viable and the findings are considered acceptable and consistent with the data gathered.

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EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers who have the ability to access the Web directly from their computer or are reading the paper on the Web, can gain direct access to these references. Readers are warned, however, that

1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
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APPENDIX I. DETAILS ON IT IN THE UNITED STATES UTILITY INDUSTRY

The computer generated massive changes in the way North America and Western Europe generate, transmit, and distribute electricity and gas. Digital controllers and SCADA systems (Supervisory, Control, and Data Acquisition) regulate, monitor, and collect data on energy systems. For the most part, these systems replaced the electro-mechanical devices used previously. In addition, computers replaced many older manual office systems such as those for billing, payroll, document management, and accounting. Communications are also becoming dependent upon microprocessors. Y2K found that the energy sectors of North America are dependent upon microprocessors [Jennex, 1999; NERC, 1998].

Use of computers and microprocessors in the energy industry greatly improved system reliability and power quality and lowered the cost of power generation, transmission, and distribution. Integrated work and plant systems are lowering maintenance costs and improving equipment reliability. Real time networks for managing power are controlling power quality to the tolerances necessary for a digital economy. The types of digital systems used are summarized below.

POWER PRODUCTION SYSTEMS

The state of the art for controlling the power production cycle in electrical generation units is the digital control system (DCS). This integrated system controls fuel and water flows, turbine/generator speeds, valve positions, and pump operations. Other systems include Turbine/Generator Supervisory and Control, Plant Computers, Emission Monitoring and Control, and Feedwater/Boiler Controls. Telecommunication networks are used to operate and/or monitor multiple units/equipment from single locations, and to facilitate the flow of plant status information. The net effect is a general reduction in the number of personnel needed to operate units, improvement in equipment condition, and improvement in plant efficiency and performance. To illustrate this gain, the author, in his role as a Y2K manager assessing risk to a major utility's control systems, found that the hydroelectric generating stations were mostly un-staffed with groups of stations being controlled from a central station.

ENERGY MANAGEMENT SYSTEMS

Computer systems within the electric control centers across North America use complex algorithms to operate transmission facilities, to control generating stations to balance electrical generation to load demand, and to deliver electricity to where it is needed. These systems monitor transmission and generation status in real time to maintain a tight control on power quality. The result is a stable and reliable power source that supports a digital economy.

TELECOMMUNICATIONS

Electric supply and delivery systems are highly dependent on local area networks (LAN) and wide area networks (WAN) using microwave, telephone, fiber, satellite, and wireless communication technologies. These systems provide in-plant communications; recall and data transfer capability; and energy management. The electric supply depends on facilities leased from telephone companies and commercial communications network service providers. Furthermore, reliance on LAN capability is crucial for work management and site equipment control.

PROTECTION SYSTEMS

Protection systems are designed to protect equipment and the transmission and distribution grid by isolating fault conditions before they can propagate through the grid system. Although many relay protection devices are still electromagnetic, newer systems are digital. Digital protection device usage is increasing as system operators can monitor and control these devices as well as diagnose problems remotely. These digital devices speed the detection, isolation, and correction of system problems resulting in a more reliable system that uses fewer people. For example, Southern California Edison through its substation automation program, went from over 900 staffed substations to just one [Southern California Edison, 1999]¹⁰

WORK PROCESS CONTROL SYSTEMS

Work Process Control systems are used to track, monitor, and control work activities associated with generating plants or the distribution and transmission systems. They usually include large databases listing plant equipment, equipment data, and history data. Their use improved work efficiencies by decreasing redundant problem reporting and work plan review and approval times. Improved planning capability results in a better-utilized work force with less inactive time. These systems are also instrumental in improved control of spare parts inventories and decreased procurement times and costs.

ENGINEERING SUPPORT SYSTEMS

Engineering Support systems are used to aid engineering staffs in the design and maintenance of the generating plants and distribution and transmission systems. Systems vary from drawing and document control to performance monitoring of equipment and systems to computer aided design (CAD/CAM) to systems designed to aid in performing design calculations for the building and maintaining of transformers, heat exchangers, turbines, and other equipment. Technologies for these systems include digital imaging, smart instruments, special networks, geographical systems, databases, statistical analysis, and document management. These systems are key to improving equipment performance and reducing costs.

ACCOUNTING/BILLING/BUSINESS SYSTEMS

Accounting/Billing/Business systems are used to track, monitor, and control costs and budgets, to plan activities, generate payroll, generate customer-billing statements, maintain personnel

¹⁰ Several substations are still staffed but staffing is for administrative purposes such as auxiliary facilities being located at the substation and for central trouble crew dispatch areas.

records, and monitor personnel performance. Email is included in this category. These systems were instrumental in flattening the management structures of energy sector organizations by improving the flow of organizational performance data to lower levels of decision makers. The systems generally include large customer databases. Billing systems are interconnected to digital metering systems or to systems that allow for the input of meter information.

FACILITIES/TRANSPORTATION SYSTEMS

Facility systems handle the air conditioning, lighting, fire protection, access control/security, and elevators of office and operational facilities. With the increased reliance on information systems these systems are required for maintaining the environment for digital devices. They are also essential for personnel protection and comfort in workspaces and under harsh weather conditions. Transportation systems are necessary for the transportation of fuel, parts, and other supplies. They improve the tracking of components and materials enabling just in time delivery as well as automate the paperwork for high-risk and/or hazardous shipments. Additionally, vehicle maintenance and operation is becoming more automated as manufacturers increase the numbers of digital devices in their vehicles.

APPENDIX II. LOCATIONS/PEOPLE VISITED

GOVERNMENT/ENERGY MANAGEMENT OFFICES

- Chief Mayors Office, Kyiv, Ukraine.
 - Chief Mayor and staff.
- Hagler - Bailey, USAid contractor specializing in assisting in the privatization of energy sectors, Kyiv, Ukraine, Tblisi, Georgia, and Yerevan, Armenia.
 - Hagler Bailey Engineers/Program Managers, Armenia, Georgia, and Ukraine.
- International Atomic Energy Agency, IAEA, in Vienna, Austria.
 - Y2K Manager and cost free Y2K expert.
- Ministry of Communications/IT, Kyiv, Ukraine.
 - Director of Ukraine Y2K, and Information Systems.
- Ministry of Education, Kyiv, Ukraine.
 - Director of Exchange Programs.
- Ministry of Energy, Kyiv, Ukraine and Yerevan, Armenia.
 - First Deputy Ministry of Energy, Ukraine.
 - International Activities Department Head Ministry of Energy, Ukraine
 - Head of Technical Procurement, High Voltage Electrical Network, Ministry of Energy, Armenia.
- National Academy of Sciences of Armenia.
 - Vice President responsible for Y2K.
- National Dispatch Centers, NDC, in Kyiv, Ukraine, Tblisi, Georgia, and Yerevan, Armenia.
 - Head Engineer and Deputy Chief Engineer, National Dispatch Center, Yerevan, Armenia.
 - Deputy Director for Hardware and Control Systems, Head of Service of Relay Safeguard and Automatic Protection, and Telecommunications Group Manager, National Dispatch Center, Kyiv, Ukraine.

- Director, Head Engineer, and staff, National Dispatch Center, Tblisi, Georgia.
- Nuclear Power Plant - Operations Support Institute, NPP-OSI, Kyiv, Ukraine.
 - Head of Emergency Response Department and staff.
- Odessa State Polytechnic University, Odessa, Ukraine.
 - Dean and faculty of the computational science department.
- Pacific Northwest National Laboratories, PNNL, office in Kyiv and participation in Contingency Planning Workshops in Prague, Czech Republic, and Moscow, Russia.
 - Program Representative, International Nuclear Safety Program, Kyiv, Ukraine.
 - Staff Engineer, Decision, Safety and Risk Management Group.
- Science and Technology Center of the Ukraine, STCU, Kyiv, Ukraine.
 - Deputy Executive Director.
- United States Embassies, Kyiv, Ukraine, Tbilisi, Georgia, Yerevan, Armenia.
 - Ambassadors and staff.
- USAID Kyiv, Ukraine Tbilisi, Georgia, Yerevan, Armenia, and Washington DC.
 - Energy sector and Economics specialists.

POWER PLANTS

- Centerenergo's Kyiv Hydro Power Plant and pump storage facilities, Kyiv, Ukraine.
 - Plant Manager and staff.
- Centerenergo's Kyiv Combined Heating Plant, Kyiv, Ukraine.
 - Chief of Producing Technical Department for Centrenergo and staff.
- Chornobyl Nuclear Power Plant, Ukraine.
 - NPP-OSI Staff, PNNL Staff, Chornobyl project consultants.
- Dniproenergo's Zaporizhya Hydro Power Plant, Zaporizhya, Ukraine.
 - Chief Engineer and staff.
- Dniproenergo's Zaporizhya Combined Thermal Plant, Zaporizhya, Ukraine.
 - Plant Manager and staff.
- Dobrotvirska Thermal Power Plant, L'viv, Ukraine.
 - Head of Production and Technical, Head of Electrical, and staff.
- Gardabani Thermal Power Plant, Tbilisi, Georgia.
 - Chief of Department of Analog and Digital Control Systems, Chief of Department of Automatization Gardabani, and staff.
- Hrasdan Thermal Power Plant, Armenia.
 - Executive Director, Plant Manager, Controls Manager and staff.
- L'viv Combined Thermal Plant, L'viv, Ukraine.
 - Plant Manager and staff.
- Metsamor Nuclear Power Plant, Armenia.

- Head of Department of Atomic Energy, Ministry of Energy, Armenia.
- Tatev Hydro Power Plant, Armenia.
 - Plant Manager and staff.
- Tripolyi Combined Cycle Power Plant, Kyiv, Ukraine.
 - Head of Production and Technical Department, Chief Engineer and staff.
- Vorotan Cascade Hydro Power Plant, Armenia.
 - Plant Manager and staff.
- Zaporizhshe Nuclear Power Plant, Ukraine.
 - Director, Head and Deputy Head, Head of Technical Automation Center, and Chief of Laboratory (Control Systems).
- Zhinvali Hydro Power Plant, Georgia.
 - General Director, Technical Director, New Equipment Main Specialist, and Computer Operator.

DISPATCH/TRANSMISSION-DISTRIBUTION/COMMUNICATION CENTERS

- Centerenergo's communications center, Kyiv, Ukraine.
 - Site Manager and staff.
- Dniproenergo's office center, regional dispatch center, and 750/330 KV substation, Zaporizhya, Ukraine.
 - Site Manager, Chief Engineer, and staff.
- Hrasdan dispatch center, Armenia
 - Deputy Chief Engineer, National Dispatch Center, Yerevan, Armenia.
- Kievenergo's dispatch facility, Kyiv, Ukraine.
 - Deputy General Director of Kievenergo, Site Manager, and staff
- L'viv Western Electric dispatch center, central office, and distribution center, L'viv, Ukraine.
 - Director, Deputy Director, Head of the Service Relay Safeguard and Automatic, and staff.
- Pontoel, International Dispatch Center in Management Technology & Coordination and Parallel Energy Network & System, Tbilisi, Georgia.
 - General Director, Deputy General Director, Manager, and staff.
- Sakenergo, National Control Center, Tbilisi, Georgia.
 - Chief Of Main Dispatch Department, Lead Software Engineer of Technical Department, Chief of Service "SCADA", Chief of Telemechanical Department, and staff.
- Shahumyan 2 High Voltage Substation, Yerevan, Armenia.
 - Deputy Chief Engineer, High Voltage Electrical Network.
- Vorotan Hydro Cascade dispatch center, Armenia.
 - Site Manager, Head Engineer, and staff.

GAS TRANSMISSION/DISTRIBUTION FACILITIES

- Armrusgasprom Gas Company facilities, Yerevan, Armenia.

- Chairman of Board, Manager, and staff.
- Saktransgasmrevi, Gas Facility, Tbilisi, Georgia.
 - Deputy Chief, Technical Director of Technical Department, and staff.
- Ukgazaproekt Gas Company facilities, Kyiv, Ukraine.
 - Deputy Technical Director and staff.

ABOUT THE AUTHOR

Murray E. Jennex joined San Diego State University in the spring of 2001 following 20 years as a consultant, project manager, and manager for Southern California Edison. His research interests include knowledge management, system analysis and design, security, e-commerce, outsourcing, IS in developing countries, and organizational effectiveness. Dr. Jennex primarily teaches system analysis and design, e-commerce strategy, and decision support systems. He is the Knowledge Management Cluster co-chair at the Hawaii International Conference on Systems Sciences as well as a mini-track chair and reviewer for several other IS conferences and Journals. Dr. Jennex is on the editorial advisory board for "In Thought & Practice: The Journal of KMPro" and is President and Chief Information Officer of the Foundation for Knowledge Management (LLC).

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