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A Study on the Development of Nuclear Safety Parameter Display System for Korean Nuclear Power Plants

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한국원전의 SPDS 개발에 관한 연구

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Abstract

Through a project "Development of Nuclear Safety Parameter Monitoring System", a nuclear data link system was established between Kori nuclear unit 2 and Nuclear Safety Center. We present in this paper the selected parameter sets, a description of the developed pseudo-network software and the functional descriptions of the equipments involved. We also include the conceptual design of the Kori four unit ERF/SPDS system, along with the localization direction for the related software and hardware.

요 약

고리 2호기와 원자력 안전센터 상황실을 연결하는 Nuclear Data Link System에 대하여 기술하였다. 특히 선정된 원자력 안전변수, Data Link용 Pseudo-Network 소프트웨어, 관련장비들의 입출력 기능 및 전송된 자료의 영상화 등의 내용을 포함하였다. 아울러 현재까지 수행해온 고리 1,2,5,6호기에 대한 비상대응 설비의 설계 내용과 ERF/SPDS 하드웨어 및 소프트웨어 국산화 연구 방향을 제시하였다.

1. Introduction

In Jan. 1982, Korean Ministry Of Science and Technology(MOST) established Nuclear Nuclear Safety Center(NSC) under Korea Advanced Energy Research Institute. Late 1982, the authors proposed a project 'Development of Nuclear Safety Monitoring System' to MOST in an attempt to establish a Nuclear Data Link System betweeen NSC and the nuclear power plant under commercial operation, and to develop some graphic displays necessary for monitoring the critical safety functions.

Through this project, a data link between NSC and Korea Nunclear Unit 2(KNU2) was established in 1983, a data link between NSC and the Environmental Radiation Monitoring System(ERMS) in 1984, followed by a data link between NSC and Nuclear Unit 3 (Wolsung unit 1) in 1985. For Unit 2, 108 parameters are being sent to NSC at 15 minute intervals along with 11 post ERMS data, while for unit 3, 140 parameters at the same intervals. The long time interval is due to the limit of plant process computer performance. Meteorological data are included in the unit 2 parameters. Graphic displays are designed and implemented for the Westinghouse PWR plant KNU 2.

Korea Electric Power Company (KEPCO), meanwhile, had started to study a conceptual design of the Emergency Response Facility for Nuclear Unit 1 & 2, 5 & 6 by awarding a contract to Korea Power Engineering Company (KOPEC) in 1984. As a result of this project, a conceptual design followed by a procurement specification[1] for the ERF system for the four unit nuclear power plants at Kori site was produced early 1985.

KEPCO fell into a problem, however, that purchasing a turnkey ERF/SPDS system from a foreign country is not the best interest of the Korean government, and yet there is no experienced local agent which can supply this system. In Aug. 1986, KEPCO finally determined to award this project to KAERI so that some technology transfer can be achieved. In section 4 the ERF project overview is included as studied by KAERI.

2. System Design for SPMS

Design of the system started with defining the requirements. Requirement definition includes the selection of safety parameters, defining display formats, and the way to display, etc. Then the adequate hardware configuration along with the functional specification of the software were studied.

2.1. Requirement Definition

The principal objective of this project was to supply brief information about the operating status of nuclear power plants for the officials in the Nuclear Emergency Response Center at NSC. For those in the conference room of the NERC, a safety parameter panel was designed for LED display of 39 parameters. For expertees in the work room, a larger set of parameters is necessary. We selected 108 parameters for the Westinghouse 600MW KNU2 as shown in table 1, and 140 for AECL's CANDU reactor plant KNU 3 from their I/O lists.

To display these parameters on a graphic terminal, we used a set of five top level displays for the critical safety functions as suggested in NUREG-0696.[2] They are reactor power control, reactor core heat removal, steam generator heat removal, primary coolant inventory, containment integrity and radioactivity control. The frequency of data collection is set to 15 minute intervals during normal operation and thereby rough pictures of the trends of the each parameter can also be displayed on graphic terminal.

2.2. Hardware Configuration

The basic components of the hardware are Data Acquisition Subsystem(DAS), Data Communications Subsystem(DCS), and Operations Center Subsystem(OCS). A schematic diagram

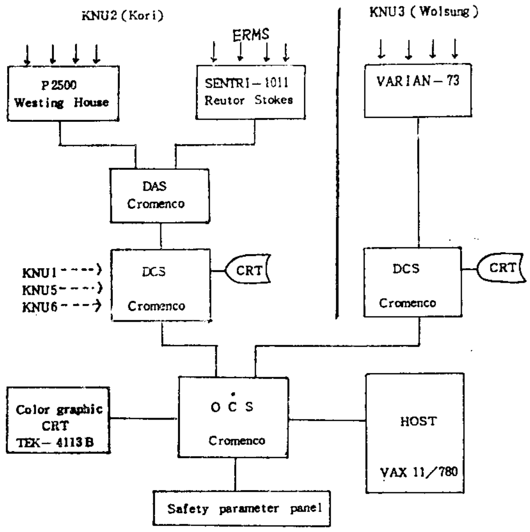

Fig. 1. Shematic Diagram for H/W Configuration

Table 1. Parameter Selection for KNU 2

PARAMETER	No.	sub-total
1. Reactor Power Control		49
A) Neutron Power		
1. Power Range Channel 1, 2, 3, 4	12	
2. Intermediate Channel 1, 2	2	
3. Source Range Channel 1, 2	2	
B) Thermal Power		
—Reactor core status (Temperature)	26	
C) Reactivity Control		
1. Control Rod Position A, B, C, D (Bank)	4	
2. Boron Concentration in Coolant	1	
3. Shutdown Rod Average Position	2	
2. Reactor Core Heat Removal (2 loops)		11
1. Pressurizer Water Level 1, 2, 3	3*	
2. Reactor Coolant Line T average	1×2L	
3. Hot Leg Temperature (Narrow Range)	1×2L	
4. Cold Leg Temperature (Narrow Range)	1×2L	
5. Reactor Coolant Line Pressure (Wide Range)	1×2L*	
3. Steam Generator Heat Removal (2 loops)		22
1. Steam Generator Water Level 1, 2, 3 (Narrow R)	3×2L	
2. Steam Generator Water Level (Wide R)	1×2L	
3. Steam Generator Steam Out Pressure 1, 2, 3	3×2L	
4. Steam Generator Steam Out Flow	2×2L	
5. Steam Generator Feedwater Flow	2×2L	
4. Reactor Coolant System Integrity		1+(5)
1. Presssurizer Water Level 1, 2, 3	(3)	
2. Reactor Coolant Line 1 Pressure (Wide R)	(1)	
Reactor Coolant Line 2 Pressure (Wide R)	(1)	
3. Containment Sump Water Level	1	
5. Containment Integrity & Radioactivity Control		12
1. Containment Pressure 1, 2, 3	3	
2. Containment Air Elevation Temperature 1, 2, 3, 4, 5	5	
3. Containment Area Radiation	1	
4. Station Vent Gas Radiation	1	
5. Wind Velocity	1	
6. Wind Direction	1	
6. Others		13
TOTAL		108

( ) : same as*

for this hardware configuration is shown in fig. 1.

Data Acquistition Subsystem for unit 2 and for the Environmental Radiation Monitoring System(ERMS) are Z-80 based microprocessor system with 64KB memory, four serial ports and a programmable Read Only Memory board. DAS for unit 2 is connected to Westinghouse

P2500 data log-in computer with RS-232C serial interface. DAS for ERMS is interfaced to a serial port of SENTRI-1011 Z80-based micro-computer system. For unit 3, however, there is no equipment that can be classified as data acquisition subsystem. A small program installed at VARIAN-73 process computer instead sends out the required data to our DCS.

Data Communication Subsystem is located at the offices of the resident officials from MOST and from NSC. It is aimed at building up a communication link between NSC and the resident officers. The officers can use this system to access the computer system at KAERI, Westinghouse P2500 computer, or the SENTRI-1011 ERMS. [3] At unit 3, however, neither the resident officers *nor* the personnel at NSC are allowed to access the VARIAN 73 plant process computer exceiving predetermined set of data at regular intervals.

Operations Center Subsystem, located at the nuclear emergency response center of NSC, provides communication links between the host computer system at KAERI and Data Communication Subsystems at each of the resident offices. Display control for safety parameters penel at NSC is also provided by this subsystem.

One of the major reasons to include OCS and

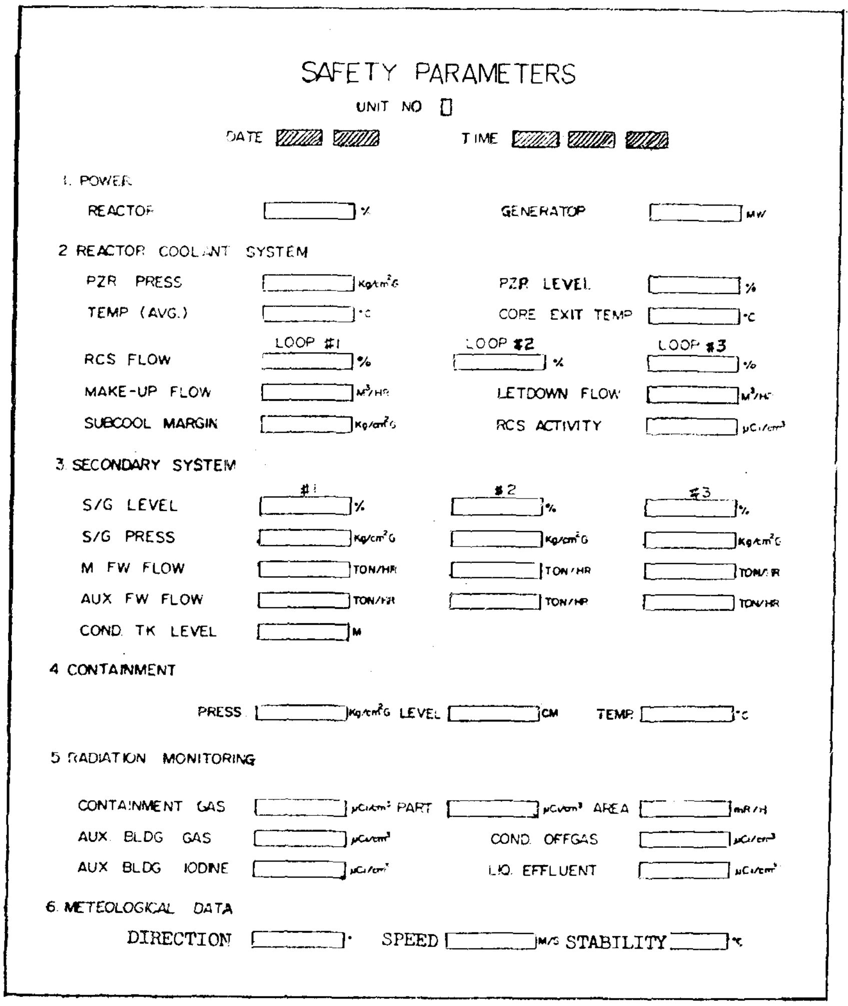

Fig. 2. Design of Safety Parameter Panel

DCS in the Nuclear Data Link system is to share the dedicated long distance phone line between NSC and the plant site for voice and data communications. Voice communication is necessary not only for the daily report from resident offices to NSC thru voice or facsimile, but also for the trouble shooting the malfunctioning of the data link system.

2.3. Safety Parameter Panel

Safety Parameter Panel is designed to provide a quick overall view of the plant operational status for the technical personnel at NSC. It consists of 39 LED sets, each set consisting of two to four digit display units. The 39 parameters are as shown in fig. 2. They include unit number, time, meteorological data and some of the informations.

3. Software Development for the SPMS

3.1. Programming Environment

A ROM-based Z80 Assembler has been used as a basic developmental tool instead of diskette based DOS. Main reasons were to avoid possible software overhead by using some of DOS routines, and to avoid any complications due to delay in DOS I/O.

Thus, for the permanent storage of programs, one of the two KAERI computer systems Cyber 174-16 and VAX-11/780 had to be utilized. And a file transfer program had to be written so that a source program stored at one of the two host computer systems can be down-loaded to Z-80 Assembler file, and conversely, a Z-80 Assembler file can be transferred into a source data file.

3.2. Plant Process Computer Interface

In case of KNU 3, one can easily write a program on the plant process computer VARIAN 73 system to sent out a set of parameters to a predesignated port at a regular time interval. Hence, there is no need for a data acquisition subsystem as mentioned in section 2 above.

Westinghouse data login computer P2500 at

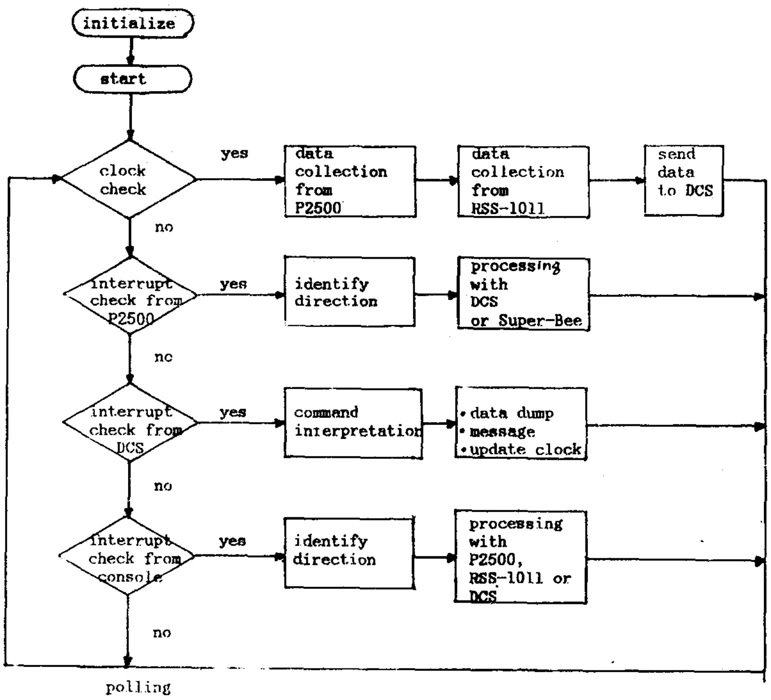

Fig. 3. Flow Diagram of DAS Software

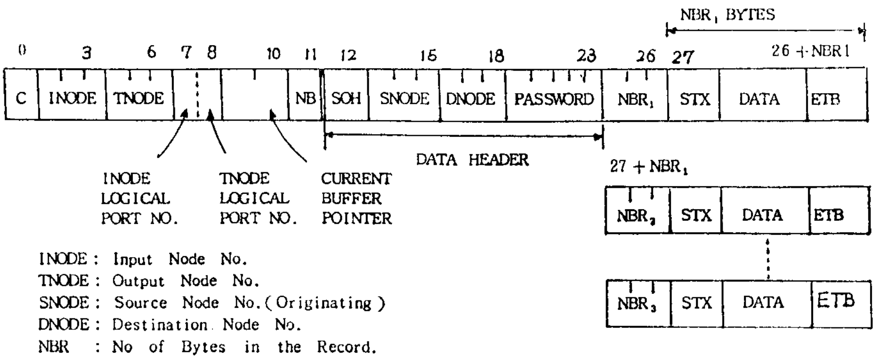

Fig. 4. I/O Buffer Format for "Communication" Type Port

KNU 2 is different, however, in that there are a few difficulties in incorporating a program with above features into the operating software. Thus, DAS software requests a set of parameter values to P2500 and sends the received values to the data link system.

Two of the important features for this interface software are the use of software key to open the lock provided by P2500 whenever a command is to be entered, i.e. 'Control A' should precede every command, and the proper time delay that must be taken in between every character typed into the P2500.

3.3. Pseudo-Network Software

The major functions of the software for DCS and OCS are directing data flow, buffered I/O, buffer storage management, automatic initiation of certain tasks, and handling the clock on the clock board.

Thus, the software had to have a network-like capability and the basic feature of the software we developed is as seen through fig. 3 and fig. 4 which are one of the system flow diagram and the few buffer formats used.

Tasks initiated automatically include requesting predetermined set of data to Westinghouse P2500 computer and to Environmental Radiation Monitoring System at 15 min intervals. Initiating a receiving program for the host computer at Operations Center, when a set of data is arrived at OCS, is also such a task. Clock handling routines are, initialzing the clock, checking the clock time, setting the clock time from a local CRT or from a remote location for the syncronization.

4. Kori-ERF Project Overview

In the following, we explain some of the results obtained through pre-projects for the development of the Kori-ERF system.

4.1. Selection of Input Signals

In the conceptual design of the Kori 4 units ERF system, KOPEC selected a minimal set of input signals as shown in Table 2. These are considered to be necessary for the evaluation of the plant status during and after an accident as defined in Reg. Guide 1.97 and Reg. Guide 1.23.

4.2. System Configuration

A block diagram of the Kori-ERF system that KAERI has proposed to KEPCO is shown in Fig. 5. We have chosen a distributed system so that data acquisition computer takes some of the load off from the host computer, and thereby allowing some flexibility in the management of the system load.

Note also that there is a fifth computer for Radiation Dose Assessment System(RDAS) in Fig. 5. RDAS is for the display of plume

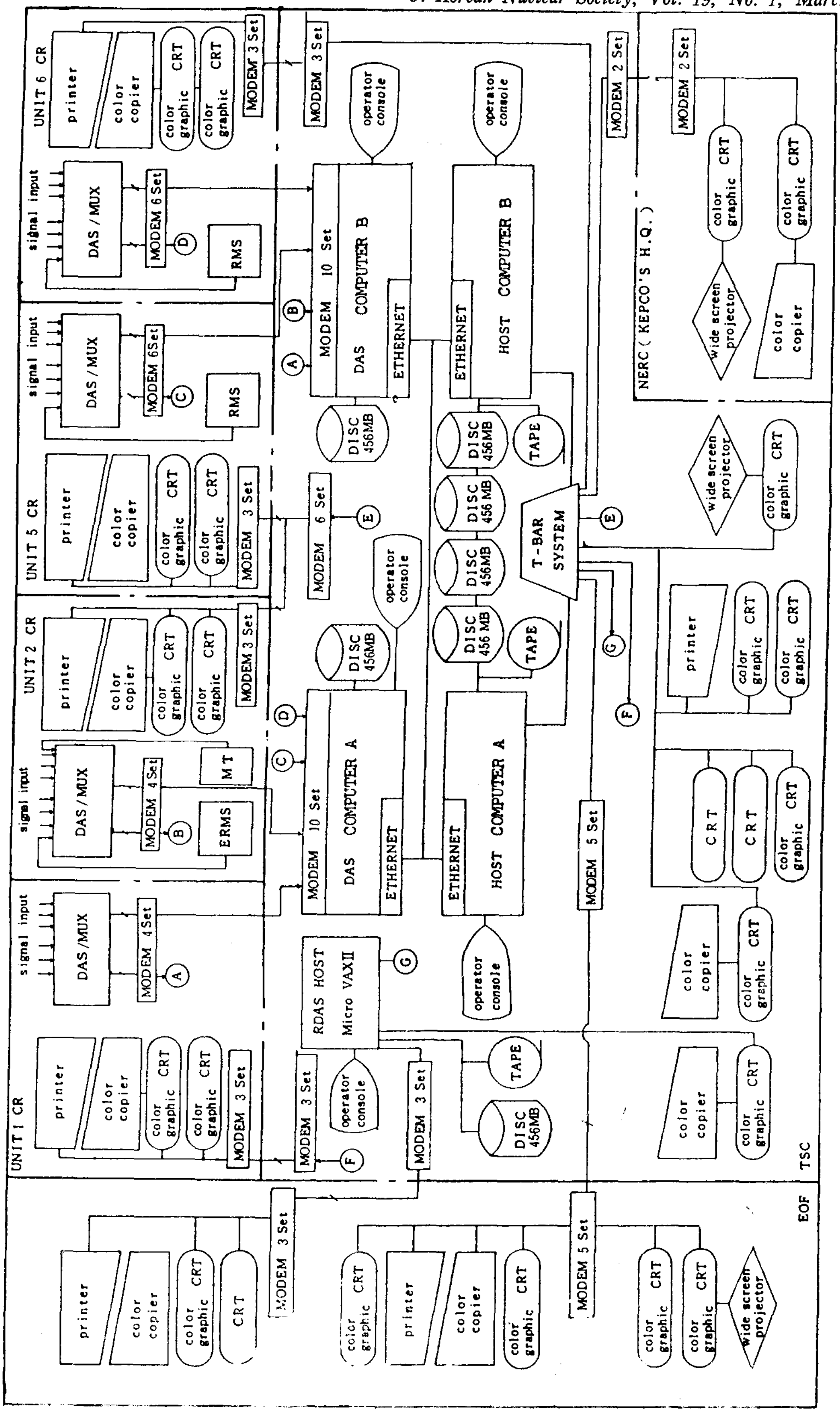

Fig. 5. Block Diagram of Kori-ERF System

Table 2. Summary of the Proc. Spec Signal List

Safety Function	KNU1	KNU2	KNU5	KNU6
1. Sub criticality	24	20	25	25
2. Core Cooling	39	39	49	49
3. RCS Integrity	23	20	28	28
4. RCS Inventory	13	13	13	13
5. Containment Integrity	69	65	87	87
6. Heat Sink	25	25	46	46
7. Radioactivity Control	18	11	16	16
8. Residual Heat Removal System	18	18	20	20
9. Safety Injection System	18	16	24	24
10. Primary Coolant System	57	59	82	82
11. Secondary System	38	40	77	77
12. Containment Cooling System	15	13	15	15
13. Incore T/C Temp. Map	20	20	20	20
14. Chemical and Volume Control System	7	9	11	11
15. Component Cooling Water	15	17	27	27
16. Radwaste System	0	0	33	33
17. Ventilation System	9	6	14	14
18. Power supplies	13	18	22	22
19. Invironmental Radiation and Meteorology	0	14	0	0
20. Turbine Status	23	23	23	23
21. Daily Operating Status Report	18	18	20	20

dispersion as specified in NUREG-0654[4] at TSC and EOF. Due to the fact that full scale RDAS software requires a great deal of number crunching capability, we have decided to have a separate system with a computing capacity equivalent to micro VAX-II.

4.3. Direction for the Localization

For the localization of technology involved in the development and installation of the first ERF system in Korea, one may divide the works into five different phases; training, joint design, implementation, local hardware manufacturing, and validation & verification.

For software development, participants are expected to take about a few month training followed by three to four month joint design. And during the implementation phase, consulting service by a resident engineer from an experienced vendor is considered to be essential.

For the localization of hardware, we see that localizing standard computer products through this project does not seem to be feasible, and hence multiplexer/data acquisition portion of the hardware along with the isolators are considered to be the target. Hardware engineers could, similarly, take a few month training followed by a serveral month of joint design.

For the systems engineering which includes preliminary design, display designs, writing safety analysis reports, and system integration, participants should go through some of the training in both software and hardware as well as training in its own field.

The work for validation and verification is to be carried out by an independent agent so that credibility of the system and requirement satisfaction are guranteed. This work includes system requirement review, design review, and attending both factory and site acceptance tests.

5. Conclusion

From the experience of developing the safety parameter monitoring system, we have come to the following remarks;

· Establishment of good communication lines between any two of the equipments is very critical for the reliability of the total system. Lowering the data transmission speed may help somewhat, but cannot solve the problem in its entirety.

· In addition to good quality communication lines, high quality communication equipments must also be used to maintain the reliability of the total system. The equipments like modems or those for simultaneous transmission of voice and data are relatively inexpensive in terms of cost, but they turned out to be crucial for the reliability of the system.

· Training of the related operators and human interactions are found to be very important, and they cannot be over emphasized.

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