

SENDING MORE PROCESS DATA WITHOUT ADDITIONAL CABLES

(Networking Sensors using Existing Plant
Infrastructure, COG WPIR 0172)

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ABSTRACT

The as-built data transmission capability in CANDU plants is fully employed. Long delays and high cost make it often not feasible to retrofit plant equipment with additional sensors and bring the data to the office. One of the reasons is the unavoidable addition of data transmission cables. This presentation describes the results of work performed in 1996/97 to network sensors using existing plant infrastructure.

To provide an alternative solution, a general purpose data transmission system is being developed. It sends data over existing plant infrastructure such as power wiring and the telephone system. Its components are based on PC technology packaged in a "black box", using special hardware and software to appear to the user as a very simple, low cost, device. Its drawback is its rather limited transmission speed. This design is in marked contrast to the complexity of present commercial data transmission systems.

A point-to-point system has been demonstrated. A networked system is under development.

VALUE OF TRANSMITTING ADDITIONAL DATA

The existing plant information system appears at first glance to be fully capable of handling all necessary data – until one realizes that the system for which it was designed has undergone major modifications and procedural upgrades, that more of these are planned for the future and even more will not be realized unless made feasible. A list of potential benefits to transmit additional data follows.

- Potential for process improvements through increased process monitoring.
- Potential to remove some condition based maintenance (CBM) and other surveillance and diagnostic tasks from outage task list.

- Conditions that exist only during plant operation could be monitored.
- Reduction of labour costs and radiation dose for manual data collection.
- Improved maintenance planning through representative, rather than sampled, data.
- Improved management of imminent breakdowns through continuous monitoring.
- Potential for diagnostics assistance by remote expert.
- Correction of design oversights.

SITUATION AT HAND

Retrofitting an operating nuclear power station with increased data transmission capability is principally difficult for two reasons: it modifies the station license and there are restrictions to access major plant areas. The list below summarizes the situation.

- Retrofitting of equipment for surveillance and diagnostics includes data transmission capability.
- The number of data lines out of containment and other remote areas available for additional surveillance and diagnostics data is insufficient for both large scale and individual monitoring systems.
- There is no realistic possibility to add low value containment penetrations and data lines because:
 - retrofitted cabling must meet the original station design requirements,
 - getting approvals is a lengthy process because a comparison with as-is, rather than as-designed, station layout and operation must be made,
 - safety, operation and access restrictions make cable retrofitting costly, and
 - cable retrofitting work would compete with outage repair and maintenance work.
- Existing backfitted surveillance and diagnostics data transmission systems suffer from being unique.
- Neither spare computing power nor general purpose, generic PC technology are available in containment to preprocess or concentrate data.

FACTORS USING EXISTING CABLES TO TRANSMIT ADDITIONAL DATA

It would be desirable to expand data transmission capability by simply adding more data to the existing transmission facility. However, not only are these transmission channels already used to their fullest extent but any modifications would interfere with the intent of the original design. If one wanted to send additional data over any other plant infrastructure such as power lines or radio then one must find practical, efficient and expeditious means that avoid the same obstacles that prevented the conventional solutions. This points to three restrictions:

- Safety

- No safety relevant data are to be transmitted (cost, delays, training, documentation).
- Data transmission must not interfere with any special plant equipment to avoid the need for certifying each installation (this factor excludes wireless transmission from the list of options).

- Cost

- Initial development and demonstrations,
- Designing for manufacture,
- Manufacturing of initial batch of hardware,
- Individual installation costs, and
- Training, troubleshooting, and upgrading.

- Availability of Suitable Cables

OPTION 1: Extending LAN throughout containment

If the station's Local Area Network (LAN) would extend into the containment then most data transmission problems would disappear. Unfortunately, this is not the case. The option of retrofitting the containment with a LAN may be summarized as shown below.

- Requirements

- Needs computing power in containment.
- Needs additional LAN cables in containment.

- Technical Risk

- Negligible, standard technology.

- Logistics

- Commercial equipment is readily available.
- Laying cables in containment is very expensive and would probably take several years to accomplish.

- Reality Check

- Best long-term solution.

Unlikely to be implemented in existing plants.

OPTION 2: Use existing 110/220 VAC power lines and spare phone lines; connect to LAN inside or outside containment

If the containment cannot be retrofitted with a LAN then other options must be explored. The most ubiquitous cables installed in a station are power and telephone lines. Though they could lead directly to an office where the current data could be evaluated, one must be able to review past data and relate them to plant conditions. Therefore, they have to be tied into the LAN and the LAN may as well transport the data from a convenient point to the office. Figure 1 shows both arrangements, where Path #3 shows the direct connection and Path #5 shows the transfer using the LAN. A summary for both options follows.

- Requirements

- Needs computing power in containment.
- Needs development of generic repeater system.

- Technical Risk

- Small, but technology needs development.

- Logistics

- Equipment needs custom assembly of commercial sub-systems.
- Consider station needs: maintenance and warehouse stocking.

- Additional Restrictions

- Only one data path per 110 VAC circuit (between transformers) unless well separated.
- Spare phone lines are connected to Junction Boxes.

- Reality Check

- Adequate solution for many, but not all, data transmission problems.
- Achievable in the short term.

PAST WORK

Work on this project started in 1996 for COG under WPIR 0172. The following work was performed.

- Identified requirements, see Table 1.
- Developed repeater lab prototype based on PC.
- Demonstrated transmission string consisting of: instrument PC, power line, repeater, phone line, and office (or LAN gateway) PC with the following results:

- generation of electric noise on power lines was insignificant,
- speed was typical of phone lines (340 characters/s), slowed down by plant noise,
- recovered automatically from breakdowns,
- no error detected for 660 000 characters (100 pages of text).

PRESENT WORK

The present work is concerned with the more realistic conditions under which a retrofittable data transmission system would operate in a station. Work goes on in the following areas:

- Assemble PC-based repeater with the following features for use in containment at 60°C (unusually hot):
 - decontaminable (by hosing off and steam-cleaning),
 - shock-proof (but not seismically qualified),
 - connector replacement without need for access to inner sanctum,
 - enhanced reliability (no fan, no disk drive), generic (spare capacity),
 - black box installation (no local controls),
 - runs any user software (under DOS, Windows CE to be investigated)
- Develop first generation software for point-to-point link.
 - remote control, automatic recovery, command string entry
- Demonstrate PC and point-to-point link to station staff:
 - confirm causing no interference with plant equipment,
 - demonstrate PC for containment use to get user input regarding packaging.
- Develop lab prototype network for specific application:
 - consider application at feeder pipe wall monitoring at G-2,
 - integrate system with station LAN,
 - build data acquisition front end and generic user interface.

FUTURE WORK

In the next year, a prototype system will be installed in a station, for demonstration and refinement and also to lead to the manufacture of such systems.

Thus, the capability to transmit more data would become available for widespread use. The envisaged tasks are listed below.

- Install and operate a point-to-point link in a plant.
- Advance networked transmission system to become field useable.
- Develop specs for manufacturing the initial batch of hardware.

SPIN OFFS

Besides adding data transmission capability, the system will help to realize other benefits:

- Making available a PC for general use in containment.
- Leading the way to use spare LAN capacity for CBM data.
- Making attractive:
 - "guided tour troubleshooting", remote supervision, and remote; temporary diagnostics for commissioning and testing.
- Leading the way to retrofit remote controls.

DATA RATES

The critical question is the amount of data that may be transferred by each system. A power or telephone line based system employs inferior transmission media than specially designed data cables but one only needs to employ a reduced capability for a limited number of retrofit applications. Tables 1 and 2 show the following:

- There exist two signal classes depending on their data rate, see Table 1: gauges and other.
- There are two classes of transmission media, depending on data rate, see Table 2: 110/220 VAC, telephone in one class, and other media.
- Each 110/220 VAC or telephone POTS line can accommodate dozens of gauges.
- All other signals must go over other transmission media.

Table 1: Typical Transmission Rate Requirements from Single Sensors

Origin	Data	Data Generation Rate
Gauges: temperature, pressure	ASCII or binary	24 characters/second at 2 samples per second
Accelerometers, raw signals	ASCII or binary	several kb/s (depending on upper frequency limit)
Video camera (uncompressed)	video	15 kb/s
Computer screen dump	bit map	several kb/s

Table 2: Maximum Specified Data Rates of Some Transmission Media

Transmission Medium	Standard	Maximum Data Rate (kb/s)	Maximum Repeater Separation (m)
110 VAC	not applicable	28.8 (ezPhone)	70
Telephone	POTS	28.8	practically unlimited
unshielded twisted pair	Category V	10 000	100
Telephone	ASDL	4 400, downstream 441, upstream (Aware, Inc.)	2800
Coax	Ethernet	10 000 100 000	100

BLOCK DIAGRAM

Figure 1 shows two options to transmit sensor data to an office, see system components in the shaded area:

- over dedicated telephone line (Path #3)
- over a minimum number of cables through containment wall (Path#4).

PC = Personal Computer

PC#1 located close to sensing instruments to minimize cable length in Path#1

PC#2 concentrates data traffic through containment wall

PC#3 repeater, interfacing between Path#4 and Path#5, not required if Path#4 is Ethernet LAN

Path#1 serial communications lines (RS-232, RS-422 or RS-485)

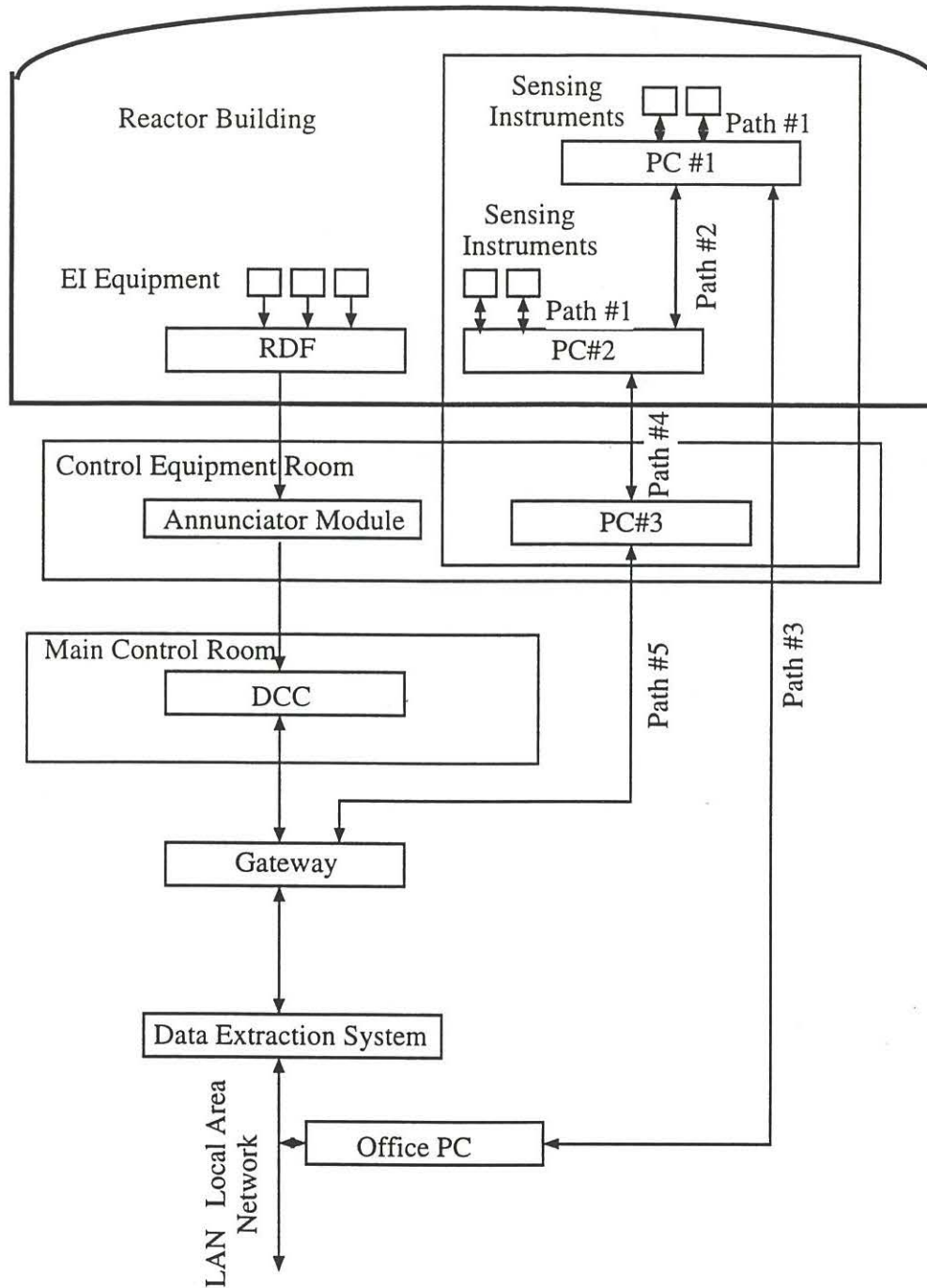
Path#2 direct link between serial ports (RS-232) or 110/220 VAC power line

Path#3 analog telephone line (POTS)

Path#4 either wideband [coax (Ethernet) or Category 5 twisted pairs], for high data rates, or

110/220 VAC power line for low data rates

Path#5 coax for Ethernet LAN.



Example of System Configuration