AUTOMATIC EARLY WARNING SYSTEMS FOR THE ENVIRONMENT

by

Martin LESJAK

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Computerized, continuous monitoring environmental early warning systems are complex networks that merge measurements with the information technology. Accuracy, consistency, reliability and data quality are their most important features. Several effects may disturb their characteristics: hostile environment, unreliable communications, poor quality of equipment, nonqualified users or service personnel. According to our experiences, a number of measures should be taken to enhance system performances and to maintain them at the desired level.

In the paper, we are presenting an analysis of system requirements, possible disturbances and corrective measures that give the main directives for the design, construction and exploitation of the environmental early warning systems. Procedures which ensure data integrity and quality are mentioned. Finally, the contemporary system approach based on the LAN/WAN network topology with Intranet/Internet software is proposed, together with case descriptions of two already operating systems, based on computer-network principle.

Key words: environmental monitoring, early warning systems, system reliability, data quality, monitoring network design

INTRODUCTION

Environmental early warning systems provide users with accurate real-time environmental data, giving also short-term predictions and alerts for possible alarm situations. The Chernobyl accident (1986) has proven that the possibility of severe nuclear accidents is reality and that transport of pollution could be long-distance under certain meteorological conditions. The Chernobyl accident initiated the development of radiological early warning systems in several States. Air pollution monitoring systems, tornado alert systems, and automated seismologic early warnings are other examples of early warning systems.

Regardless of their use, early warning systems have a number of common features:

(1) Their structure is *territorially distributed*. Parts of the system, usually involving sensors and/or monitors, are placed at dislocated (could be very distant) locations over a monitored area. Criteria for the selection of measuring locations are different, always tending to provide representative data for the purpose of the system.

(2) Their structure is *hierarchically distributed*, consisting of measuring instruments/stations that are connected in a hierarchical order with sub centers, centers, down to the users.

(3) Dislocated measuring equipment is often installed at exposed places where it could be affected by:

- poor line power (unstable voltage and/or frequency, voltaget ransients, overvoltage spikes, power breaks),
- overvoltages on the communication channels (telephone lines, radio equipment, antennas),
- overvoltages in power, communication and signal lines, caused by electromagnetic induction during atmospheric discharges,
- differences in electric potentials through improper grounding (ground loops),
- microclimatic and environmental conditions (wind, dust, sand, precipitation, humidity, salt, frost, *etc*.), and
- vandalism.

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Author's address:
AMES d.o.o.
Jamova 39, SI-1000 Ljubljana, Slovenia

Author's e-mail:
martin.lesjak@ames.si

(4) Systems must provide their data in *real time*. When a system has to trigger environmental alarms (*e. g.* radiological early warning system), real time means an *immediate response* to the alarm condition. With systems designed primarily to provide historical data, real time could be understood as data transmission at reasonably acceptable time intervals (half an hour, hour, day …) [1]. Moreover, we could speak of *prolonged real time* in cases when systems collect the missing data from the dislocated measuring points after communication breaks, maintaining automatically the integrity of the system databases. Generally, any loss of communication affects the global system performance [2]. The degree of system degradation depends on the importance of data that were lost or received too late.
(5) Environmental monitoring systems are meant to provide environmental data over long time periods (years or decades). Therefore, their global MTBF (mean time between failures) should be as long, and their MTTR (mean time to repair) as short as possible. This is not easy to achieve, having in mind all hazards from paragraph (3). In practice, this calls for correct system design, proper choice of equipment, and good maintenance by qualified personnel.
(6) Broadly speaking, environmental early warning monitoring systems represent very complex measuring instruments. They must fulfill all requirements for measuring accuracy and repeatability, which can only be ensured by regular maintenance and calibration of measuring equipment.

It can be concluded that the operation of computerized environmental early warning systems depends equally on correct operation of all system elements: sensors, monitors, measuring stations, central computers, communication equipment, and communication channels. It can easily be understood that maintaining of such systems in constant operational state is sometimes a task more complicated than to procure and install the equipment itself.

DESIGN AND CONSTRUCTION

System designers should be aware that automatic environmental systems *are not equal* to industrial process systems. Almost every environmental system is unique from the aspect of required measuring equipment and overall system performance. It must be designed (data collecting, data distribution, data quality controls, databases, data presentations, application of models) to fit its specific needs [3].

Early warning networks involve, as already mentioned, measuring stations, central units, and data-users.

Data links within the system are the critical part of the systems. The global system reliability, functionality, mobility, and operation costs depend on the correct choice of data transmission media (leased lines, switched telephone network, mobile telephones, radio links, Internet) and communication equipment. A particular system could be optimized by simultaneously using different ways of data transmission, *e. g.* fixed lines for stationary stations, cellular phone for mobile units, and switched telephone for accessing remote users. Today, TCP/IP is more and more used, especially for center-center or center-user data transmission.

System reliability

In our system, we have enhanced the reliability of system operation by several measures:

– reliability of measuring stations is enhanced by proper protecting of all power, communication and signal lines against transients, stabilizing supply voltages, providing backup power (UPS), automatically detecting abnormal conditions (high temperature, smoke, intruders …), performing watchdog function of operation of station software, providing proper grounding and lightning protection, *etc*., and
– reliability of central units is achieved through watchdog circuits, redundant (doubled) equipment, software algorithms that automatically ensure the integrity of all databases [2] and by automatic supervisory procedures, integrated in the software.

Automatic data quality controls

Automatic data quality controls implemented at our measuring stations and the central units are additional tools for raising system reliability. They automatically mark all data that have failed at any of the control procedures. In principle, this doesn't mean explicitly that the marked data are bad, but rather warns the system operator to check the cause of control failure.

We are implementing the following data quality controls:

– controls of physical acceptability of data (data must lie within the specified, physically acceptable range. This range can be time or date dependent),
– controls of statistical distribution of data (extremes should not lie too far from or too close to the mean value; there are also controls of standard deviations, distribution of wind directions over time, *etc*.), and
– controls of measuring conditions (reference voltages, power supplies, internal temperatures, status signals, aspiration, air or water sampling, *etc*.).

EARLY WARNING SYSTEMS IN USE

Once constructed and put into operation, early warning monitoring systems need constant maintenance and supervision. Quality of system operation is always greatly dependent on the proper organization of the maintenance and on the qualifications and motivations of the maintenance personnel. Experience shows that best maintenance could be achieved by a combination of user's technical staff, combined with expert assistance of system integrator and equipment manufacturers.

User's technical personnel cannot maintain the system properly without in-depth training for all system elements. Thus, training (and re-training) is an essential part in planning good system maintenance.

In addition, regular scheduled analysis of system operation and preventive technical inspections of the system is a very good approach to ensure excellent system operation and avoid trouble in advance.

TRANSITION TO DISTRIBUTED SYSTEMS AND TO INTERNET SOLUTIONS

Most of the existing continuously monitoring environmental early warning systems are still built according to the classic, star-topology concept [4]. In practice, this means that measuring stations (representing the basic source of data) transmit their information in sequence to the local sub-centers, centers, and finally to the end users. Usually, special transmission media are used, such as leased lines, switched lines, or radio links. Systems use dedicated software, communication procedures, and hierarchically organized databases.

In the past few years, in our systems we have used the opposite concept that connects measuring stations, data-processing computers and information-users via local or wide-area computer networks. In this case, data transmission paths are the regular network computer interconnections (often not directly transparent in WANs), data transfer is realized by a standard network file transfer system, TCPIP or FTP, databases are distributed, and data can be presented by standard software (such as Internet browsers).

There are several advantages of this approach. First, the concept is much more flexible. It is open so it is easy add new system components (such as measuring stations, instruments, data processing and data storing computers and data users) to the net. Secondly, in a network environment, especially in wide area networks, (*e. g*. Internet), there are redundant connections, making the network less sensitive to the loss of communication. Thirdly, since computers share their resources, databases need not be multiplied throughout the system. Instead, the system can maintain virtually unique, but in reality distributed database, available to all the system computers. And finally, information can be disseminated to users by use of modern tools, such as Internet browsers and multimedia.

In our opinion, real future of data distribution for environmental information systems lies in the extensive use of Intranet/Internet environment. Browser-based data presentations can enable unlimited number of authorized users from all over the word to access data from the environmental WEB servers with no need of special software [5]. Moreover, all changes in WEB data presentations are done at a single location (on a server) and are immediately transparent to any user.

The main disadvantage of Internet information system lies in the fact that WWW, as a vast conglomerate of servers and diverse communication links, has so far no global warranty of communication speed and reliability. If an Internet-type system is installed in a known and controlled network environment (Intranet), its performance is better. If used globally, it could be seriously affected by over-traffic or communication breaks, without any possibility to control or avoid such incidents. Improvements towards a guaranteed WWW communication performance will overcome possible disadvantages of purely Internet systems.

EXAMPLES: KRŠKO AND BRESTANICA SYSTEMS

Following modern trends, an Internet based radiological environmental early warning system was built in the Krško (Slovenia) Nuclear Power Plant [6]. Software uses scripting procedures, server-generated active documents and some specialized programs (*e. g*. for wind roses and graphical presentation of data) that are initialized by a HTML request from the browser and are executed on the server.

Krško Nuclear Power Plant environmental monitoring system consists of four meteorological / radiological stations and ten additional radiological monitors. The power-plant station has a 70-m meteorological tower with meteorological sensors on three levels. Central computers, located in the plant, process collected data transferring them by File Transfer Protocol (FTP) to the state authorities (fig. 1).

An Internet WEB server is provided for the fully interactive distribution of Krško EIS data. Programs that we have developed for this task are:

– Dedicated C-written programs transferring data from the Nuclear Power Plant to the Internet server by FTP. They perform data quality controls and maintain the local database. In addition, they generate some regularly updated GIF images for the public information over the Internet.

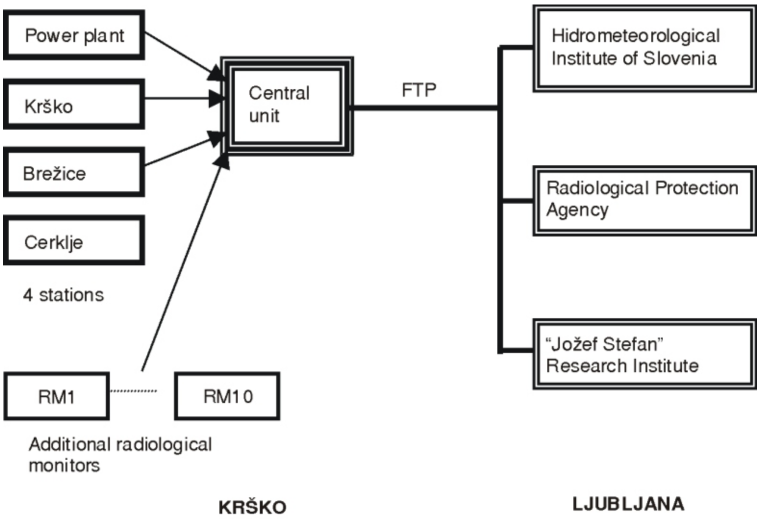

Figure 1. Krško NPP early warning system

- Internet Server (WWW Publishing Service), which takes over the Internet distribution of documents.
- Active Server Pages (ASP) providing the interactivity in normal presentations of data from the ODBC – linked database. They also perform some data-analysis (*e. g.* daily or monthly data processing, and system performance analysis).
- Dedicated C-written programs called from the ASP documents providing special interactive data presentations (*e.g.* graphs or wind profiles).

ASP we selected to generate interactive documents, since all processing in ASP environment is done at the server side. Users receive just pure HTML documents as a response to the supplied input parameters.

In cases when ASP cannot generate the required response, external programs are called, started by VBASIC ActiveX component. Their results are returned to the ASP and passed on to the Internet server.

Using the scripts and SQL queries ASP documents can provide most of interactive Internet data presentations. They are used to present tables of data for the selected measuring station, parameter, and time interval. They also make daily and monthly data reports, as shown in fig. 2.

ASP scripts calculate daily averages for temperature, RH, wind, precipitation and dose rate for each day in the month, calculate monthly averages, and report the percentage of valid, non-valid, and not transmitted data.

Figure 3 presents the program structure of the Internet-based information system for the Krško Nuclear Power Plant.

Some graphical data presentations, such as wind roses, interactive graphs, or vertical wind profiles, cannot be realized with the ASP scripts only. They require dedicated programs external to ASP. These programs must follow the basic Internet requirement for generating proper concurrent responses to an undefined number of users, each providing its own input specifications.

In our solution to this problem, each request to ASP for the special graphical screen generates an "ini" data file which contains user-supplied input pa-

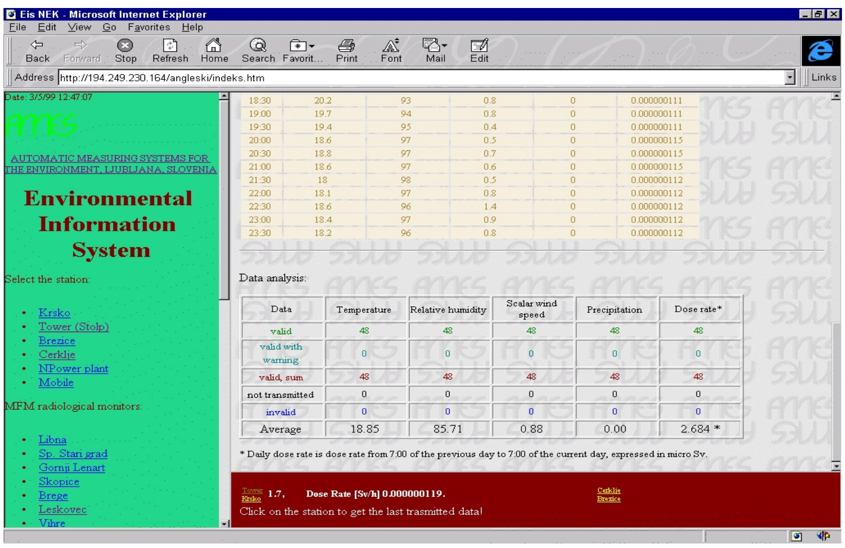

Figure 2. ASP generated response to the request for data

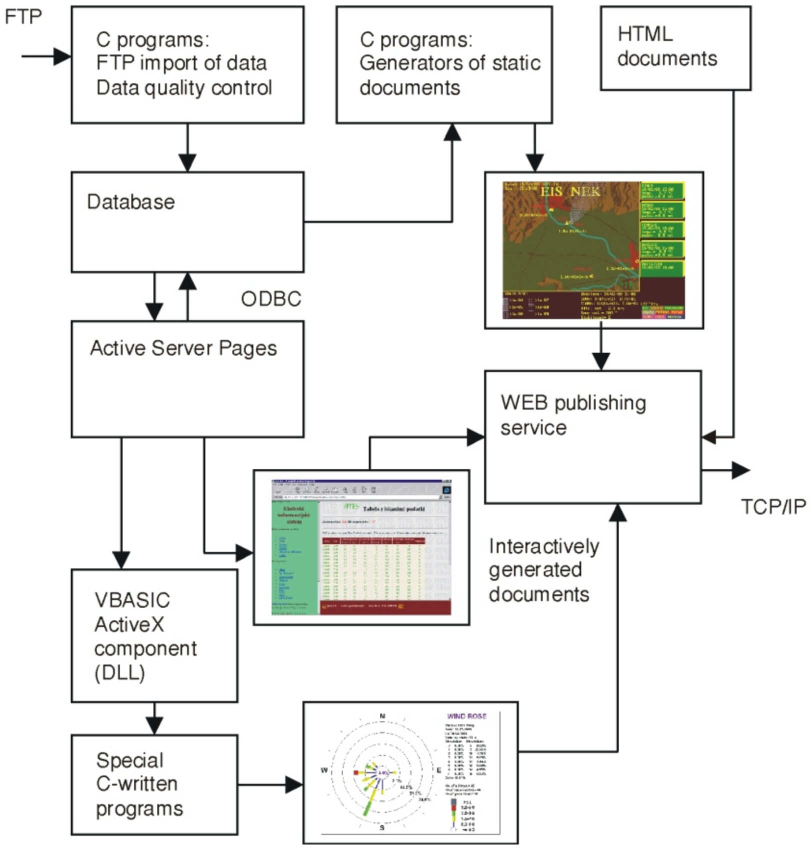

Figure 3. Structure of programs within Internet information system of Krško NPP

rameters and has a unique, randomly generated name. ASP then start a new version of a dedicated C-written program (in addition to the possible concurrent versions of the same program, initiated by some prior requests). ASP pass the name of the "ini" file to this program which, according to the input parameters in the "ini" file, extracts the data from the database, generates the graphic ".gif" files, and aborts itself after having returned the control to the ASP. ASP pass the ".gif" files as a part of a standard HTML document to the user that has demanded them. In the end, both ".ini" and ".gif" files are deleted (fig. 4).

An unlimited number of versions of the same program can run concurrently, each corresponding to its own user and each working with the unique

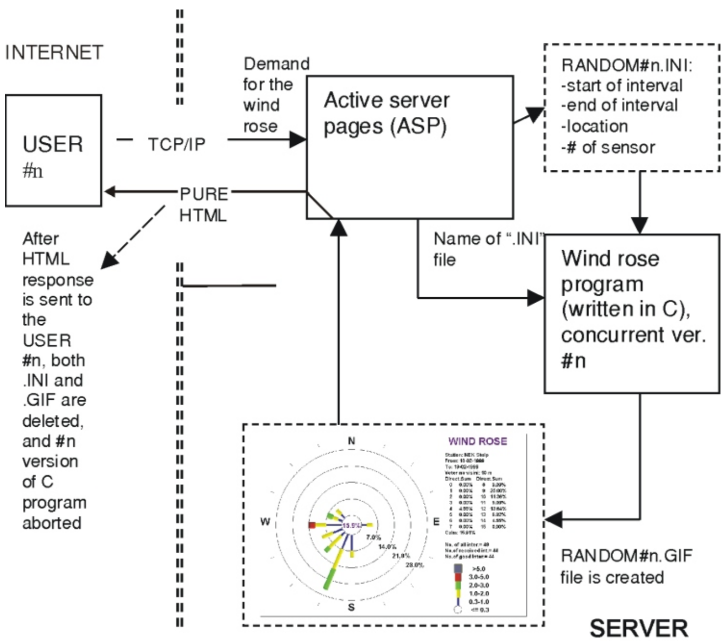

Figure 4. Generating dedicated graphical outputs by external programs in conjunction with ASP (example: wind rose)

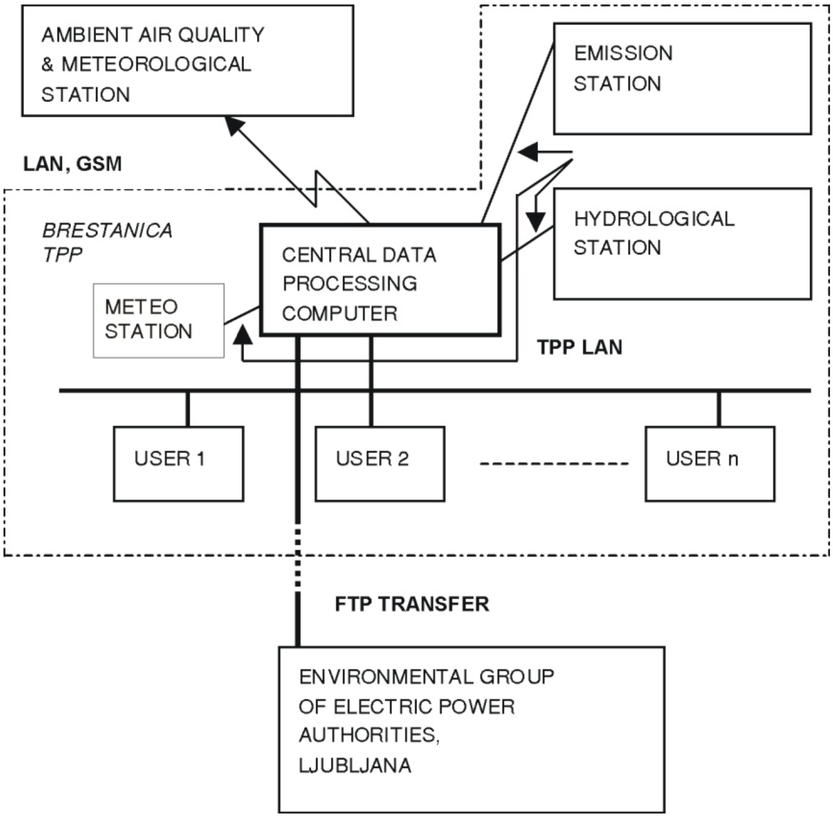

Figure 5. Environmental information system of the Brestanica TPP

input and output files. System itself takes care of clearing all files from the memory and aborting itself after having completed its task.

Internet system, using the real-time data from the Krško NPP, has proven to be an ideal way to interactively distribute the environmental information. It's power lies in its extreme flexibility, ease of the system maintenance, use of standardized software, true interactivity, and global connectivity. Improvement of WWW towards the guaranteed communication performance will overcome the main disadvantages of the present Internet Information Systems: possible slow response and system unreliability (parameters that are controllable in the closed Intranet environments).

In 1999, Brestanica (Slovenia) Thermal power plant Environmental monitoring system has been constructed. The System consists of an ambient air pollution station, emission station, hydrological station, meteorological station, local central computer (capable of supplying data to several local users), and a remote (100 km) data user (Environmental group of the Electric Power Authorities in Ljubljana).

From the beginning, we planed the system on all levels to be a real computer network, as schematically shown on fig. 5. Main system elements are:

- ambient air quality (and meteo) station,
- emission station,
- hydrological station,
- meteorological station on the location of Brestanica TPP,
- data-processing computer inside the TPP,
- computers of local users, and
- remote computer in Ljubljana.

The network is realized in four different ways: with the transportable field station, there is a connection through the GSM cellular phone. With the emission, meteorological, and hydrological stations, there are optical links. Central data processing computer and local users are connected to the existing infrastructure of the plant LAN. With the distant user in Ljubljana, Internet connection and FTP transfer are used.

Regardless of different physical ways of interconnection, the whole system acts as a unique computer network. There is no specialized data transfer between the computers. Databases, though located locally at each measuring point, are globally accessible from the whole net.

CONCLUSIONS

Planning, designing, constructing and running the environmental early warning systems is a complex task. It cannot be compared to the normal, even distributed, industrial systems. In fact, it can only be an expert work, based also on practical experience. For a contemporary information system, expertise from the past should be combined with the interdisciplinary knowledge on the latest technologies comprising sensors, environmental monitors, computer and communication equipment, net-working, and Internet software. With such an approach, it was possible to build a reliable and quality operating system of the next generation.

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Мартин ЛЕСЈАК

АУТОМАТСКИ СИСТЕМИ РАНОГ УЗБУЊИВАЊА ЗА ЗАШТИТУ ОКОЛИНЕ

Рачунарски базирани системи за континуални мониторинг околине и рано узбуњивање су сложене мреже које повезују мерења и информационе технологије. Најзначајнија својства су им тачност, усклађеност, поузданост и ваљаност података. Више чинилаца може пореметити њихове особине: неповољна околина, непоуздане везе, лош квалитет опреме, нестручни корисници или сервисна служба. На основу искуства, треба предузети бројне мере да би се унапредиле перформансе система и одржале на жељеном нивоу.

У овом раду, изложена је анализа системских захтева, могућих поремећаја и корективних мера, које представљају главна упутства за пројектовање, изградњу и коришћење система раног узбуњивања за заштиту околине. Наведени су поступци који осигуравају интегритет и квалитет података. Предложен је савремени системски приступ заснован на ЛАН/ВАН мрежној топологији са Интранет/Интернет софтвером, заједно са описом два система који су засновани на принципу рачунарских мрежа, а налазе се у раду.