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Development of a Remote Monitoring and Control System for Nuclear Power Plants

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Abstract

Nuclear power plants (NPPs) will be highly connected network enabled system and need to be monitored and controlled round the clock for high safety and availability. Using the network and web enabled tools, NPPs can be monitored remotely by operators at anytime from any place connected to the network via a general web browser. However, there are security and performance issues associated with such tools, as will be further discussed further. We developed a web-based remote monitoring and control system (RMCS) that uses prevalent web technology. This work, as a preliminary study, performed the conceptual design of the web-based RMCS and developed the prototype.

1. Introduction

Newer generation nuclear power plants will take advantage of more automation in operation and maintenance, fewer operators, digital technology, and advanced computer and software technology. It is likely that faster, more powerful computer processors and display technologies will allow better, more reliable control and operational strategies. The international use of computing and networking at nuclear power plants (NPPs) can

only grow: increasing use of computer applications and displays seems inevitable simply because they have been adopted by virtually every other industry that is associated with the nuclear industry. At the same time, faster and more secure computer networks will allow better collaboration between human experts and software applications. This increased bandwidth and security will come about because government and industry demand it.

NPPs are highly connected network enabled system and need to be monitored and controlled round the clock for high safety and availability. With the advance in information technology, NPPs can be monitored and controlled remotely and in real time over the internet. Today, computer network is not only fashionable, but it is easily accessible for many applications. It allows people from great distances to communicate and share information through a simple and easy means. In the Engineering field, network can be utilized for the development of remote monitoring and control system. Network-based systems provide the advantages as follows;

- the operator can control the system by the same interface from any places connected to the network without constructing specific infrastructures for communication,
- the system can utilize skills of operator who is in a distant place,
- the operator is able to communicate with other operators through systems physical interaction
- the operator can use many resource which are connected to the network, and
- the system may also utilize the world wide network resources.

NPP monitoring system using network which real-time monitor plant status is already implemented in some NPPs. In Korea, the web browser based remote monitoring systems are developed and installed in Ulchin NPP, Units 3 and 4. It can only show plant status and important variables to operator and others who use web browser connected network. In this paper, we would add operation function to that and it could not only monitor but also control plant. It should have some advantages. The operator can control the system by the same interface from any places connected to the network without constructing specific infrastructures for communication and communicate with other an operators, through system's physical interaction. Also, the system can utilize skills of operator

who is in a distant place. It however, will have some problems because of network's characteristics. Security and faultless are very important conditions in NPP but this system cannot guarantee those conditions. By using intranet, the security problem of network could be somewhat improved.

2. Architecture of Remote Monitoring and Control System (RMCS)

The web-based RMCS is a four tier system, as shown in Figure 1, which consists of four subsystems. The subsystems are as follows:

- Plant
- Database Server
- Control Server
- Web Server

Web server manages the communication among database server, control server, and users. Users can monitor and control the plant on the web. Control server delivers control requests from users to the plant. Database server manages all data of the NPP.

3. Web Server

Main function of the web server is to manage the communication between clients and RMCS. In order to provide the information required by clients, the web server is connected to the database server. It is also connected to the control server so as to transfer control signal from clients to the plant. The web server should meet the following requirements.

- The web server displays the real time data of plant requested by clients.
- The web server transfers control signals from clients to control server in real time.
- The web server has an efficient graphic user interface.

The web server has basic features as follows.

1) Log in

The clients of the RMCS are divided into three classes for security. Then, the access is limited according to the classes. The classes are as follows:

- Administrator
  - read, delete, update and backup data
- Registered user
  - read all data
- Guest
  - read public data
  - log-in not needed

2) Monitoring function

Connected to the data server, the web server shows the current state of the plant to clients in real time. The web server has monitoring functions as follows:

- The web server shows the current information requested by clients.
  - as systems, or as functions
  - indicator, alarm, status window
  - by text or graph
- The web server shows the trend graph of specific data.
- The web server shows updated time of the data
  - This function prevents clients from misbelieving current data as the latest when a network accident happens.
- The web server controls the amount of information provided for clients.
  - The web browse has spatial limitation. Therefore, the web server should provide the essential information with which clients can recognize the state of plant.
- The web server shows the real time images of the plant using CCD cameras.

3) Control functions

The web server delivers the control signal from clients to the control sever.

- control icon
  - on/off control, analog control, digital control
- control support
  - confirmation of the control signals, validation of the control signals
- to check that a control signal is correctly transferred to the control server

4) Intelligent user support

It may be difficult for web clients to identity correctly the state of the plant because the clients should monitor and control the plant through the web. Therefore, the functions to support the clients are necessary. The functions are as follows:

- to diagnose abnormal state and suggest appropriate procedure
- to validate the control signals from clients
- the take over between automation and manual operation

4. Database Server

In RMCS, database server has five requirements: (1) data management - First, Database must minimize its loss of data while maximizing its integrity. If the same data duplicate, space is wasted. Therefore the efficiency of database decreases. The discord of data diminishes the reliability of the database. Secondly, the data storage process must be simple. If the process is not simple, overhead occurs when the data stored. So the efficiency of system is decreased. (2) real time extraction of plant data - The data which users demand must be transmitted faster to the users. (3) security level management - Each user must have different permissions when accessing the database. If all users are able to change the data stored in the database freely, the data stored in the database would not be reliable. Furthermore, if someone who is not allowed succeeds in corrupting the database, the stability of whole system would be broken. (4) Transfer of the requested data to web server - The user connects to the web page and requests data. Therefore the database must be able to link with web server. (5) data backup - Data

backup is necessary to protect the data from unexpected situations that could lead to data loss or damage.

In this work, the FISA-2/WS simulator is used in place of a real NPP for the developing the prototype of RMCS. FISA-2/WS is based on KORI unit 2 in 1992, and it can simulate various accidents such as LOCA, SGTR, and so on. Variables which are defined in plant simulator would be entity. The number of variables is 188. These variables can be classified in several different ways. The groups are as follows: (1) classification variable type - Some variables are classified into monitoring variables that can express conditions of NPP. Some of the others are classified into control variables that can control NPP. (2) classification plant system - The variables of plant simulator also can be classified into plant system. Except for the above classifications, there can be more classifications. For example, if it is a requirement that the user be able to categorize the variables by the functions of a plant system available to the power plant during remote administration, then the variables must be categorized by function of a plant system and added to the ERD beforehand.

A new type of data model is introduced by this work. The name of the data model is radial relation. It is shown in Figure 2. 'Radial relation' means that relations among the entities have radial structure. All entities except for the central entity only have the relation with central entity. Since all entities are each other independent, inserting new entity or deleting existing entity is done freely. The structure of the radial relation is so intuitive that the developer can easily grasp the whole structure of the database. In conclusion, a database used the radial relation can be easily repaired, maintained and expanded. Since each entity is separated independently, user can join the entity only to be need. Therefore the size of a table can be minimized with using radial relation. On that score a database that uses radial relation is faster than a database which has all attributes in one table. In RMCS, to validate and verify that radial relation is efficient, it is necessary to develop RMCS actually.

An Example of ERD is shown in Figure 3. The ERD that uses radial relation would be used at database in RMCS. In Figure 3, each entity has several attributes. Of course, thanks to the radial relation, the developer can insert a new entity or delete a existing entity anytime. Even after development of the database is completed, amendment of the database is possible.

There are two methods to access to database from web. One method is using application. For example, we can use the programming languages like visual C++, visual basic and JAVA etc. All these application use ODBC (Open DataBase Connectivity) to access to database. Using ODBC, application can access to all types of database. The other method is using server-side HTML embedded scripting language like Personal HomePage tools (PHP), Active Sever Pages (ASP) etc. ‘Sever side’ means that the requests of users are ran after passing web server. This work uses the PHP. The merits of PHP are as follows: (1) It is easy to learn - Therefore development proceeds faster. (2) It is possible to develop with HTML, so the PHP code is suitable for access to database from web server. (3) It is safe. Because PHP parser attached to the web server process users' input, there is no danger of exposing data not allowed to the user.

To validate the efficiency of database, a test is performed by measuring response time of database and comparing response time of a database that uses radial relation with a database where all attribute inserted into one table. The response time is measured by searching the data for several different strings and the times are recorded for each. As shown in Table 1, the database that uses radial relation is faster than the other database. From the results so far, in cases where the number of searched is small, the difference in the response time was not too large. However in cases where the number of the searched is large, the gap widens.

As the number of searched data increases, so does the efficiency of the database. Since RMCS is a system with data which has many variance and different types. Therefore if a database using radial relation is used at RMCS, the performance of RMCS would improve.

5. Control Server

Since RMCS is a network-based system, network accidents can isolate human operators in remote place from NPP. In network accidents, local operators must manage the NPP. However, if some accidents isolate human operators in local as well as in remote area from NPP, there will be no one who can manage the plant and it can cause serious accidents. Therefore, we need to develop automated operating procedure system to cope

with these emergency situations. Even in normal and abnormal situations, operators are usually to handle lots of information. The automated operating procedure system (ATOPS), which is to monitor the plant status, to detect and diagnose the status, and to perform control actions, can act as an operation support system and it can reduce the human operator's workload.

ATOPS envisioned is an automated operating system with the additional ability to aid operators performing procedures. ATOPS performs actions as main control room (MCR) operators do: it monitors the plant status, detects anomalies, diagnoses the status, and performs control actions on the plant according to corresponding operating procedures in order to maintain the plant in a stable state when the emergency situations such as network failures occur without any support of both local and remote operators. If some accidents isolate human operators in local as well as in remote area from NPP, then ATOPS begins to work. In these cases, ATOPS manages NPP autonomously in order to maintain stable and safe state of the plant until the accident is recovered.

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ATOPS is an automation system which operates a NPP according to prescribed procedures using fuzzy colored Petri nets (FCPN). FCPN, which is a colored Petri nets

added with fuzzy concept, is a kind of Petri nets and it has more expressive power than other Petri Nets. In unexpected situations not prescribed in operating procedures, human operators should judge current status by their own experience. For this kind of flexible decision making capability, ATOPS needs to have the knowledge database. The knowledge database of ATOPS is for intelligent functions of ATOPS. The knowledge database has much information on various situations such as experiences of human operators. In unexpected situations, ATOPS can analyze a current state and decide the next action using information in the knowledge database.

ATOPS will enhance safety of NPP by maintaining it in a stable and safe state in emergency situations even when the operators are not available. And ATOPS can not only be used as the automation system against emergency situations, but also as the operator support system for normal and abnormal states. Various operation processes of NPP can be executed by ATOPS and it can prevent human errors and reduce workload of operators in normal and abnormal states. Developing ATOPS can also help evaluate operating procedures, since detailed analysis of operating procedures is required for the development of ATOPS. ATOPS can also test the operating procedures in connection to real plants or simulators. Automation is a big trend of control technology in industrial field, so ATOPS will support evolution of automation technology.

6. Conclusion

We developed a web-based RMCS that uses prevalent web technology, as shown in Figure 4. The aim of the system is to monitor and control NPPs from distant remote places using network. This work, as a preliminary study, performed the conceptual design of the web-based RMCS and developed the prototype.

Since the web-based RMCS is connected using networks, it has several problems to solve. The first is security. Arbitrary persons should not be allowed to access the plant, since NPP is a safety-critical system. However, the web technology is open to public. The second is network accident. If operators can not access the plant due to network problems, the plant comes into the out-of-control situation. Therefore, this work performed the conceptual design, considering these problems.

The web-based RMCS is a four tier system which consists of four subsystems. The

subsystems are as follows: plant, database server, control server, and web server. Web server manages the communication among database server, control server, and users. Users can monitor and control the plant on the web. Control server delivers control requests from users to the plant. Database server manages all data of the NPP. This work also developed the prototype of web-based RCMS. The communication between servers is performed by socket program. We implemented web server using JAVA language. Database server can be accessed through ODBC (Open DataBase Connectivity). And we developed ATOPS which is a function of the control server using FCPN.

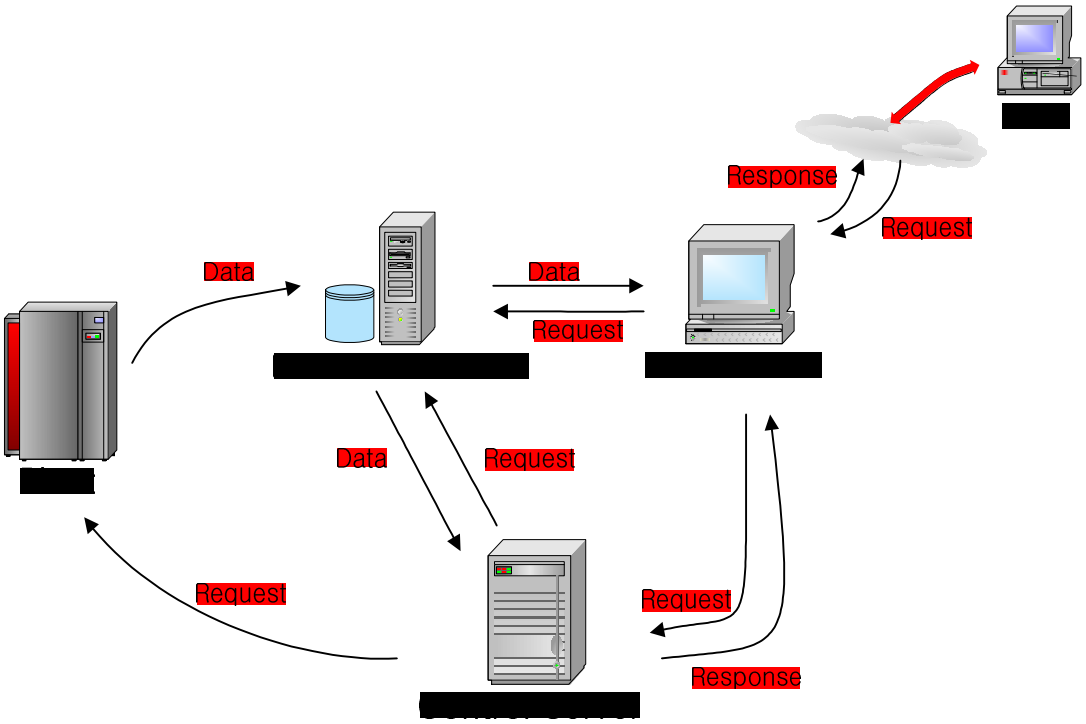

Figure 1: The architecture of RMCS

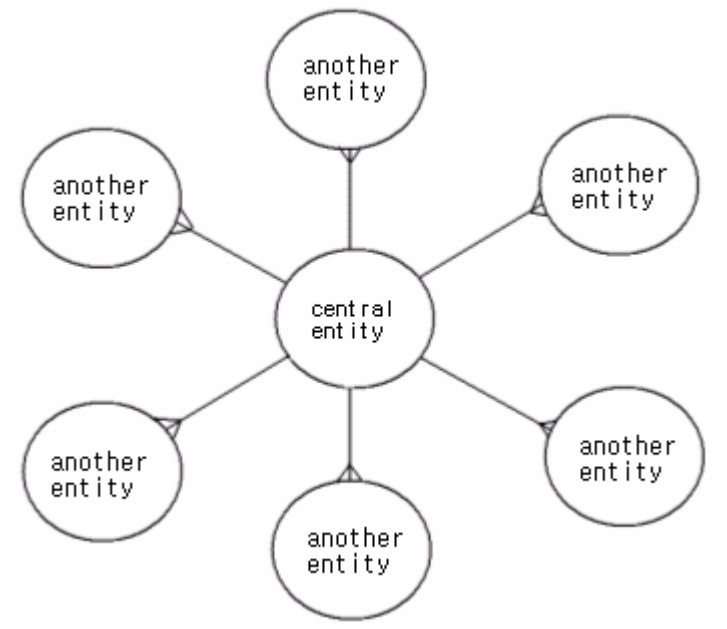

Figure 2: The radial relation

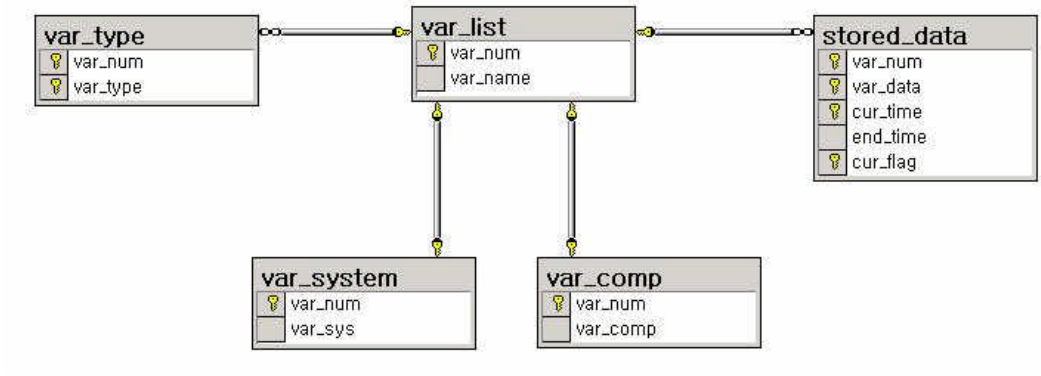

Figure 3: ERD of the database using relational database in RMCS

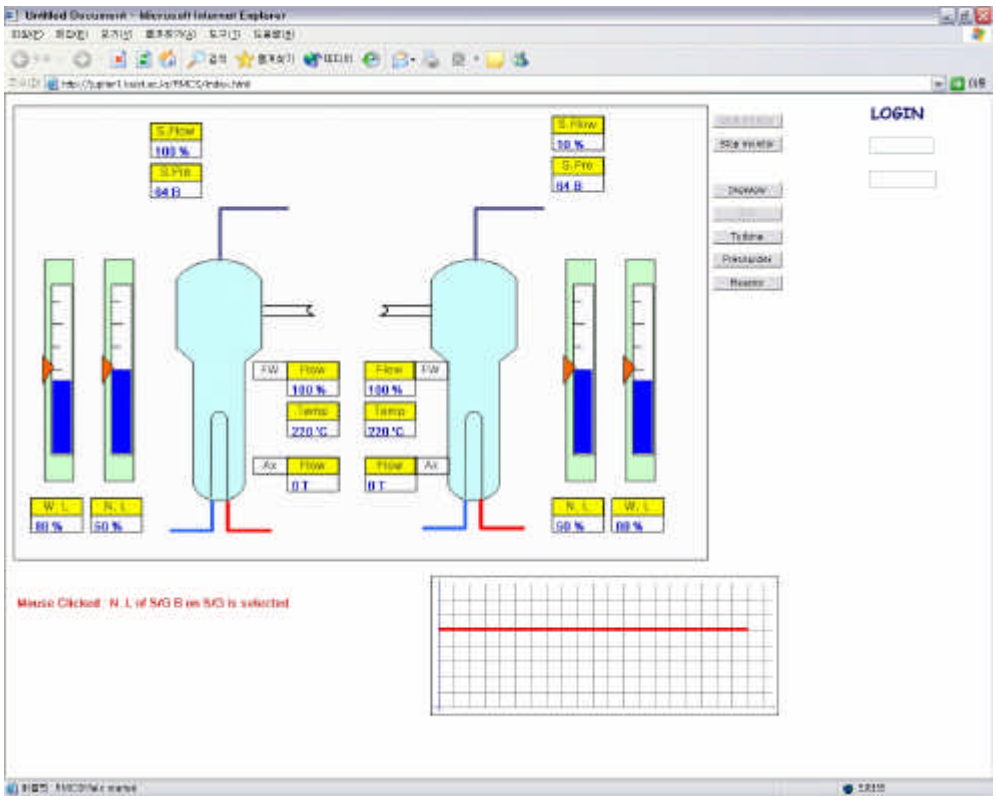

Figure 4: Prototype of RMCS

Table 1: Comparisons of the response times

string	number of data to be searched	response time of radial relational database (ms)	response time of the other database (ms)
cur_flag=1	11	15.10	15.40
cur_flag=0	81390	107.42	167.66
var_flag=1	7410	210.89	279.80
var_comp=SG	44401	1287.24	1389.19
var_num=1 and cur_time='00:00:00'and '01:00:00'	720	21.50	28.46
var_num=1 and cur_time='00:00:00'and '05:00:00'	3600	63.50	98.47