THE PROBLEM ANALYSIS OF DATA PROCESSING PERFORMANCE IN NUCLEAR POWER PLANT COMPUTERIZED INFORMATION & CONTROL SYSTEM

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ABSTRACT

This paper is based on the data processing performance problems of operating command delay and system display not updating real-time for nuclear power plant computerized information & control system. The plant computerized information & control system is responsible for monitoring and controlling the plant operation, and it is a key part in the plant DCS system. Its data processing performance will affect the operation stability of nuclear power plant. The architecture, hardware configuration and data communication for plant computerized information & control system among the different levels in DCS are described. The main reasons affecting data processing performance in different signal channels are analyzed according to the plant load test results. The CPU load curves for real time server and central processing server are displayed, although the detailed cause for operating command delay and system display not updating real-time are not found, central processing server load is heavier than real time server which remind us to analyze the data processing of software resource scheduling deeply. So the resource distribution problem of software execution task is also analyzed according to CPU load test results. This paper provides the optimization analysis for data processing performance, and it is available and effective according to the latest test results.

Key Words: data processing performance optimization

1 INTRODUCTION

The plant computerized information & control system (KIC) is responsible for monitoring and controlling the plant operation, and it is a key part in the plant DCS system. The plant DCS system is designed into 4 different levels (ref. Fig.1), the level 0 is the field devices interface level, mainly including transmitters, sensors, actuators and etc. The level 1 is the automatic control level, mainly including field acquisition module (FBM) and field control processor (FCP).The Level 2 is the monitoring and controlling level (KIC ,ADACS), mainly including information treating servers, operator workstations, and the level 3 is the information management level. The data processing performance problems for level 1 and level 2 is the key part in this paper.

2 THE SIGNAL TRANSMITTING CHANNEL

The signal data transmitting channel in DCS are as figure2: the Level 0 signals are acquired into FCP through FBM, after packing with blocks, these level 1 block signals are transmitted to level 1 application interface server (API) which is responsible for communicating with DCS level 2 through level 1 network (MESH network), correspondingly in level 2, there is a front-end processing server (CFR, application interface client) communicating with level 1 API server to receive the level 1 block data, then CFR transmit these block data to the central processing server (CCT, level 2 core processing server), after calculations by CCT, the plant device signals are processed and displayed in the operator workstation place (OWP, operator workstation in the main control room of nuclear power plant) through the real time server (STR).

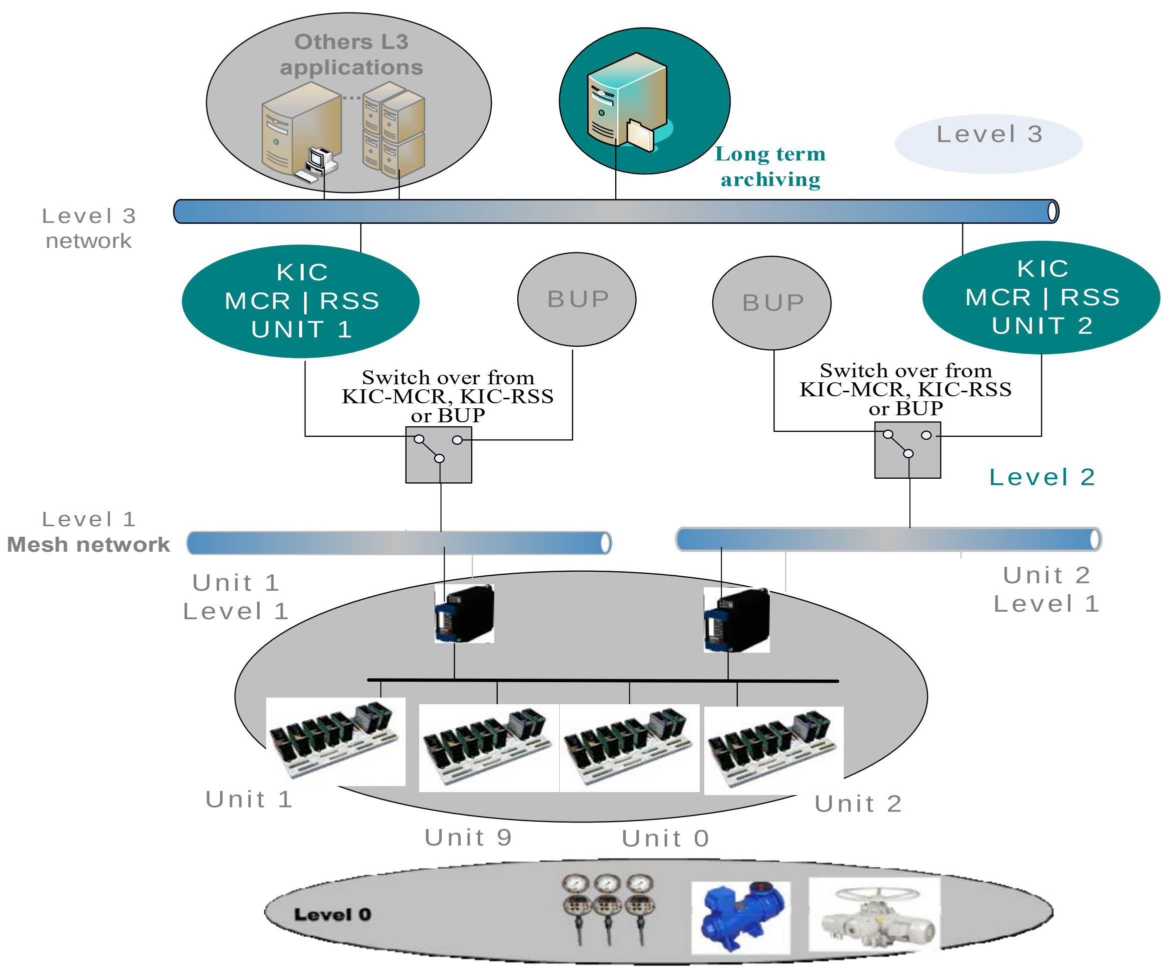

Figure 1. 4 levels for plant DCS system

The signal data transmitting channel is two way, one is receiving the local device signals or feedback, the other is sending a command to motivate the local device when an operator clicks on a command button from OWP. The STR receives this command signal and passes it to the CCT for treatment, after calculation CCT sends the command to CFR, and CFR passes the command to level 1 for executing. After the command execution or other case from the local device, the feedback signals are sent to level 1 and level 2 with above signal channel.

3 THE PERFORMANCE PROBLEMS ANALYSIS

From FQ/FJS nuclear power plant project, there are the data processing performance problems of operating command delay and system display not updating real-time. From the above description, it is clearly that the CCT plays a key role in both sending command or receiving signals from level 1, its performance will affect the whole level 2 performance. But the performance data of each part in the signal data transmitting channel shall be analyzed if we want to solve it finally.

AW: it is mainly to supply the data interface from level 1 to level 2, 3 types of signals are transmitted to CFR, binary values, analog values and signal validity. There is not clearly improvement for the AW CPU load during the disconnection from grid test, so this point should not be the factor affecting the whole level 2 performance.

CFR: 2 cores CPU is used in CFR, from the figure 3 load curve, the CPU load is in the range 7%-13% when the test is began, there is not clearly improvement during the test at the 100% power level, so the CFR is not bottleneck affecting the whole level 2 performance.

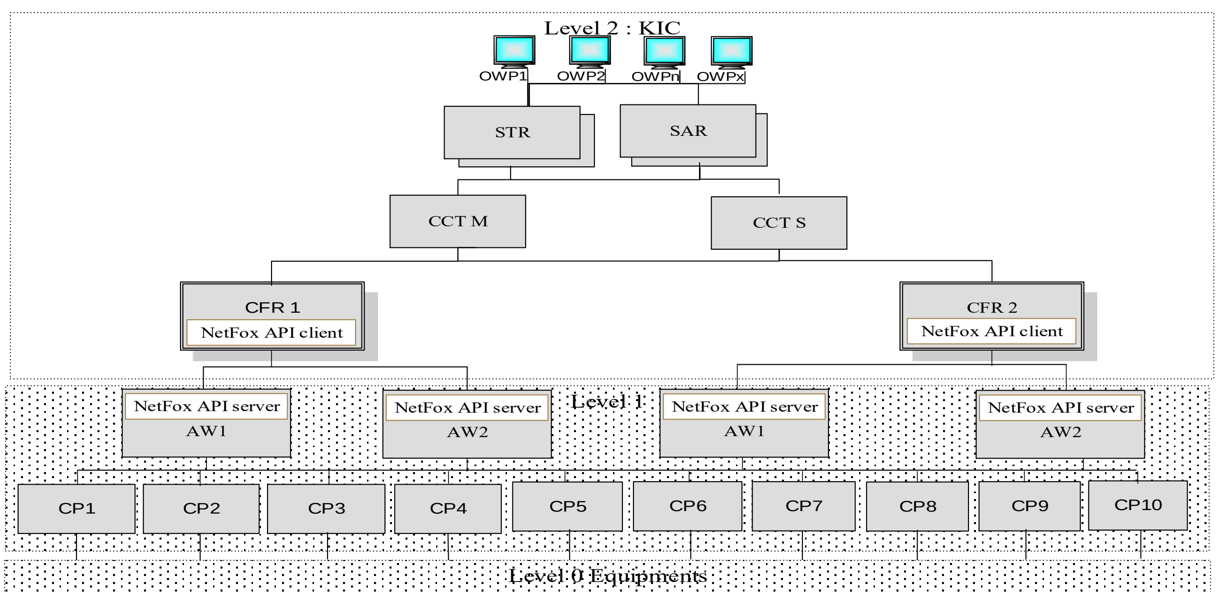

Figure 2. 4 levels for plant DCS system

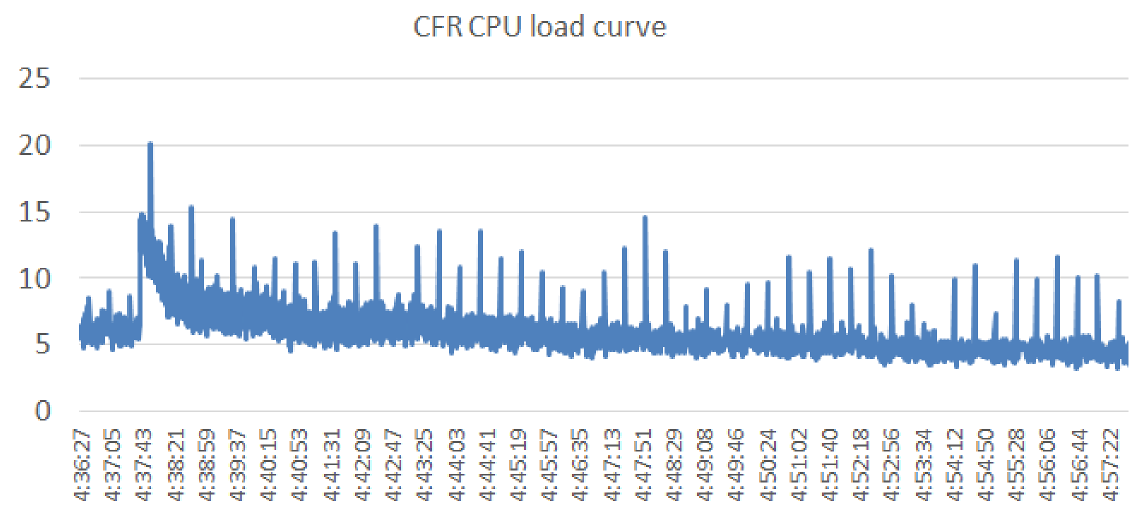

Figure 3. CPU load curve of CFR

STR: The whole data load is divided into many servers of STR, and the heaviest load server will be analyzed, and the load curve is as figure 4. The load value is sharply up when the test is began at 8:55, but the total CPU load is not over 45%. The 2 cores 4 threads CPU is used in STR servers, if the system is multithreading and the thread load is balance, STR will be not the bottleneck affecting the whole level 2 performance, otherwise it is one of the bottlenecks.

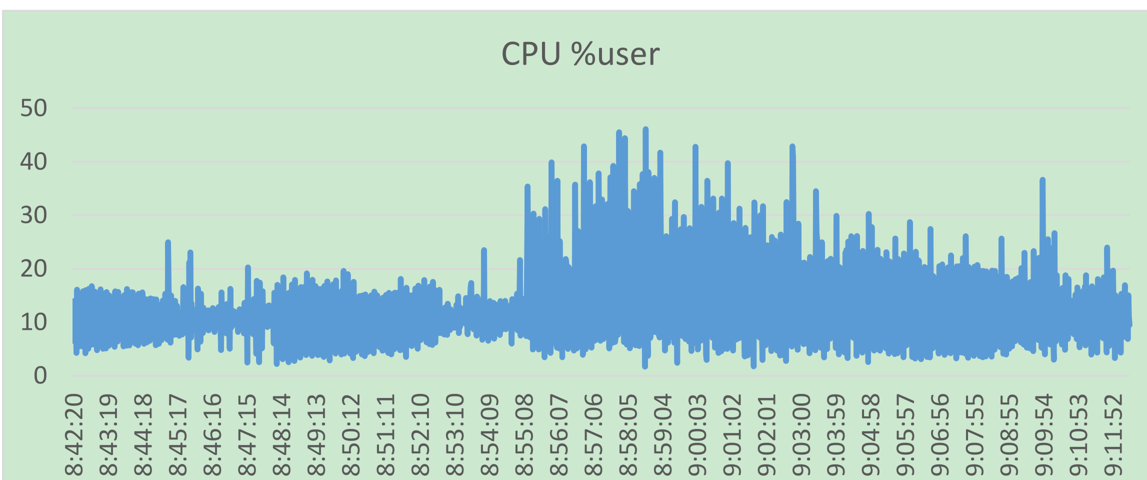

Figure 4. CPU load curve of STR

CCT: The 2 cores 4 threads CPU is also used in CCT servers. The load value is up when the test is began at 8:55, and the total CPU load is not over 65% as figure 5, but the value is average of 2 cores. CCT is responsible for all the calculation of the Level 2 system, if the system is multithreading and the thread load is balance, CCT will be not the bottleneck affecting the whole level 2 performance, otherwise it is key point of the bottlenecks.

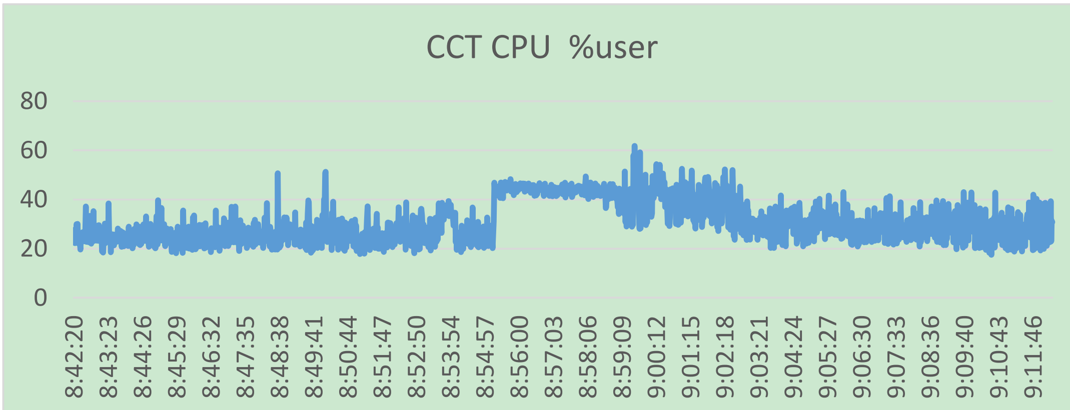

Figure 5. CPU load curve of CCT

Although the detailed cause for operating command delay and system display not updating real-time are not found from above data curve, CCT load is heavier than STR, so CCT data processing of software resource scheduling will be analyzed deeply.

4 THE TASK SCHEDULING OF SOFTWARE EXECUTION

Table I and table II are the CPU loads of processes and threads in CCT server which is 6 cores 12 threads.

Table I. The processes operation data

Top:18:14:57 up 2 days, 2:38, 9 users, load average:1.23, 1.21, 1.22					
Tasks:224 total, 1 running, 223 sleeping, 0 stopped, 0 zombie					
CPU(s):7.98%users, 1.5%system					
Mem:6221572k total, 4623636k used, 1597936k free, 244324k buffers					
Swap:6096656k total, 0k used, 6096656k free, 3836552k cached					
PID	**USER**	**%CPU**	**%MEM**	**TIME+**	**COMMAND**
12735	adacs	109.5	4.8	492:42.06	cct1
4679	adacs	0.3	0	00:00.01	top
12628	root	0.3	0	04:56.70	arlic
1	root	0	0	00:01.90	init
2	root	0	0	00:00.23	migration/0

Table II. The threads operation data

Top : 18:14:57 up 2 days, 2:38, 9 users, load average:1.23, 1.21, 1.22					
Tasks: 634 total, 2 running, 632 sleeping, 0 stopped, 0 zombie					
Cpu(s): 8.0% users, 1.4% system					
Mem: 6221572k total, 4622644k used, 1598928k free, 244324k buffers					
Swap: 6096656k total, 0k used, 6096656k free, 3835196k cached					
PID	**USER**	**%CPU**	**%MEM**	**TIME+**	**COMMAND**
13020	adacs	96.3	4.8	422:50.42	cct1
13025	adacs	7.6	4.8	41:27.81	cct1
12738	adacs	4.6	4.8	20:18.70	cct1
12739	adacs	0.7	4.8	03:19.40	cct1
4679	adacs	0.3	0	00:00.01	top
12630	root	0.3	0	01:05.68	arlic
12631	root	0.3	0	00:25.67	arlic
12644	root	0.3	0	00:58.31	arlic
12657	root	0.3	0	00:51.49	arlic
12797	adacs	0.3	4.8	00:02.49	cct1
12807	adacs	0.3	4.8	00:03.64	cct1
1	root	0	0	00:01.90	init
2	root	0	0	00:00.23	migration/0

From table I and table II, the total CPU load from users and system is just 9.4%, it's in a low level and has no reason leading to the display not updating real-time or sending command delay. But the server CPU is 6 cores 12 threads, the CPU load value is average one not actual value of each thread. From the table data, we can see that CCT has only one main process, and this process includes one main thread which is judged by operation time. The main thread CPU load is 96.3%, and others are 7.6%/4.6%/0.7%/0.3%/0.3%, the main thread load is heavier very much than others. With the displays refreshing not real-time and the command sending delayed, the main thread CPU load peak value will often be 100% while doing the experiment of disconnection from grid under 100% power level.

5 THE PERFORMANCE OPTIMIZATION ANALYSIS

5.1 Task scheduling optimization

The current system level 2 structure, data processing and task scheduling are highly centralized in the single application of the CCT server, the threads load is not balance very much. Therefore, during system design, the distributed calculation conception should be applied into the CCT application implementation, the CCT function can be distributed to multiple threads and multiple cores. The task scheduling can be optimized to eliminate the bottle neck from structure aspect.

5.2 The signal data processing optimization

Input data type includes binary input and analog input, for binary input values, the values are acquired based on change. For analog signals, the values are acquired and processed periodically by preset scan time. In the CCT, there is one parameter named TOX (Treatment Of Exploitation)to measure the CCT calculation frequency per second. The number of TOX activation per second is a key element to judge the performance and load of the CCT.

The Figure 6 shows the trend of total TOX and also the trends of TOX activations for 3 critical data types. The vertical blue line is the start point of disconnection from grid. From figure 6, the recorded TOX is in the range 500-1400 when CCT was in busy condition, inside, the analog input and analog internal variables contribute the most TOX to CCT, especially, the TOX number of analog internal variables increase sharply from the start point.

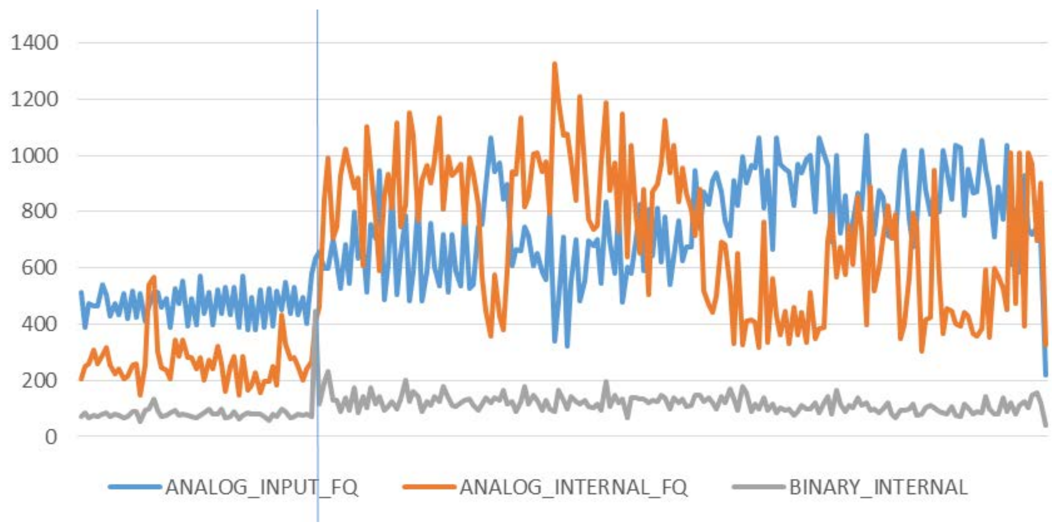

Figure 6. The trend of total TOX for 3 data types

5.2.1 Scan rate optimization

The Level 2 default scan rate configuration of analog signal is set to 100ms, according to the supplier experience which they have supplied control systems of previous projects, the scan rate configuration for analog data is 1s-120s. For the scan rate 100ms, most of plant analog signals change rate cannot reach such high frequency in reality. After scan rate optimization, this optimization is effective which has been proved by FJS Unit1 and FJS Unit2 test feedback.

5.2.2 Analog signal acquisition accuracy optimization

For most of analog signal, the minute change for their values can be ignored. Increasing the dead band can not only decrease the CPU processing load, but also makes the value trends smoother. FQ/FJS engineers set and modify the analog signal acquisition accuracy according to the real plant requirement.

5.2.3 Internal variables optimization

For level 2 analog internal variables, complicated internal variable and simple internal variable are used and the complicated internal variable is divided into several simple internal variables. During the processing of these complicated internal variables, CCT has to spend extra efforts to process these embedded internal variables. So a lot of the resources of CCT are occupied when analog signal and related analog internal variables change a lot under the test of disconnection from Grid, and other real-time tasks are delayed. Therefore the analog internal variables optimization will improve the level 2 system performance very much.

6 CONCLUSIONS

The data processing performance problems of operating command delay and system display not updating real-time for nuclear power plant computerized information & control system are analyzed. The optimization solutions from task scheduling, analog signal scan rate, analog signal acquisition accuracy, and internal variables calculation are proposed in this paper. The solutions were proved to be successful in FQ/FJS nuclear power plant and they are benefit for plant safe operation very much.

7 REFERENCES

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