Performance Monitoring and Analyzer Tool for CG SCADA

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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in

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Submitted By

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*Performance Monitoring and Analyzer Tool for CG SCADA* ", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Information Security* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Mr. Sumit Miglani* and *Mr. Haresh Joshi* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

Supervisory Control and Data Acquisition (SCADA) is widely used to control and keep track of equipment or a plant in industries like water and waste control, telecommunications, energy, transport, and oil and gas refining. It gathers data from the distant site, presents data to the operator through the Human machine interface (HMI) and transmits control signals to the remote site. So it is critical to monitor and analyze SCADA performance. To address this issue, we present performance monitoring and analyzer tool used for CG SCADA (Crompton Greaves SCADA) system which can monitor and analyze performance parameter such as CPU utilization, memory usage and page fault rate from time to time on demand. This tool is used to monitor and analyze the CG-SCADA in two different states viz. in real time and on the basis of logged information. The real time analyzing is provided detailed tabular display and line graph representation. The logged information analyzing is done on filter condition as per user requirement and it provides the filtered information in line graph representation. This tool achieves real time monitoring and analyzing of SCADA performance parameter during the CG-SCADA operation. At the same time, it also record monitoring data in database within specified intervals and show recorded data on client HMI.

Keywords : SCADA, CPU utilization, Memory utilization, Page fault rate.

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INTRODUCTION

1.1 SCADA

SCADA refers to Supervisory Control and Data Acquisition is an essential part of modern manufacturing and industrial system environment where it is used to gather real-time data, monitor and control equipments and processes in the critical infrastructures such as, electrical power transmission and distribution, oil and gas pipeline plant control, process monitoring, water treatment and distribution, coal, renewable resources[1]. It gathers the information (like where a fault occurs, status of circuit breaker etc) from remote site, carry out necessary analysis and control, alerts the home station (that fault has occurred) and display the information on graphical user interface.

1.2 History of SCADA

Supervisory control first developed in electric utility systems when a requirement to operate remote substation equipment without help of operator in personnel at the remote site was felt. In 1940s, a pair of wires was used to connect every unique equipment of multiple sites. The potential of multiplexing on one pair of lines was soon put to use taking ideas from the Magnetic Stepping Switch developed by telephone companies in the 30s. Security being an issue, a select-check-operate procedure was implemented where the operator had to wait for acknowledgement from device before finally operating it. Taking further help from the telephone relay systems and its coding schemes, Westinghouse and North Electric Company developed the Visicode supervisory control. Most of the Electric and Control Corporation had developed their own independent supervisory control programs. These programs were used in railway, airports for runway landing lights, pipelines and gas companies. These systems were most popular during 1950 and 1965 for monitoring and controlling purpose. By that time, i.e. in 1960s Telemetry was developed for monitoring purposes. Before 1970’s generally there was need of operator and technician to enable and control the function of panel instruments and tone telemetry. But with the beginning of low cost software, computer technology,

and computers enabled the performing of the functions panel instruments and tone telemetry.

At the first time the 8 and 16 bit computers were used which was called minicomputers. At several years later microprocessors were used. Computers provided flexibility in communicating with field data acquisition units and programming that was previously being done by hard wired equipments. This was the beginning of SCADA. Many organizations have been working with the standardization of SCADA systems since then, including American National Standards Institute, the IEEE, Electric Power Research Institute, International Electro technical Commission, DNP3 Users group etc [2].

1.3 SCADA Architecture

The SCADA architecture consists of the following components:

1) **Human Machine Interface (HMI):** It is an interface which presents process data to operator and provides facility to control input in a variety of formats including windows, touch screen, graphics, pull-down menu etc.
2) **Field Device**: Field device works as a slave in the master/slave architecture. It Sends control signals to the remote device under control, obtains data from these devices, and transmits process data to the Central Server. It may be programming logic unite (PLC), Remote Terminal Unite (RTU), Intelligent Electronic Device (IED).
3) **Central Server:** Central server functions as a master in master/slave architecture. It collects data from the field device, presents data to the human operator through the HMI and transmits control signals to field device. The data rate of data between the central server and field device is relatively low and the method of control is open loop.
4) **SQL DB:** SQLDB is a database which is used to store the configuration information about all components of SCADA.
5) **Logical processor:** Logical processor performs the logical computation for Central Server. It provide the additional derived parameter by performing computation on existing parameter for example it compute the power (P) by multiplying two additional parameter current (I) and voltage (V).

6) **Web Server:** Web Server provides the web support to the Central Server .It present the Central Server data on the web.
7) **Master Protocol:** It is used as a communication protocol for central server. It works as a client (Central server) in client- server architecture and always takes data from other party (field device RTU, IED etc).
8) **Slave Protocol:** It is used as a communication protocol for field device and third party product. It works as a server in client- server architecture and always gives data to central server.

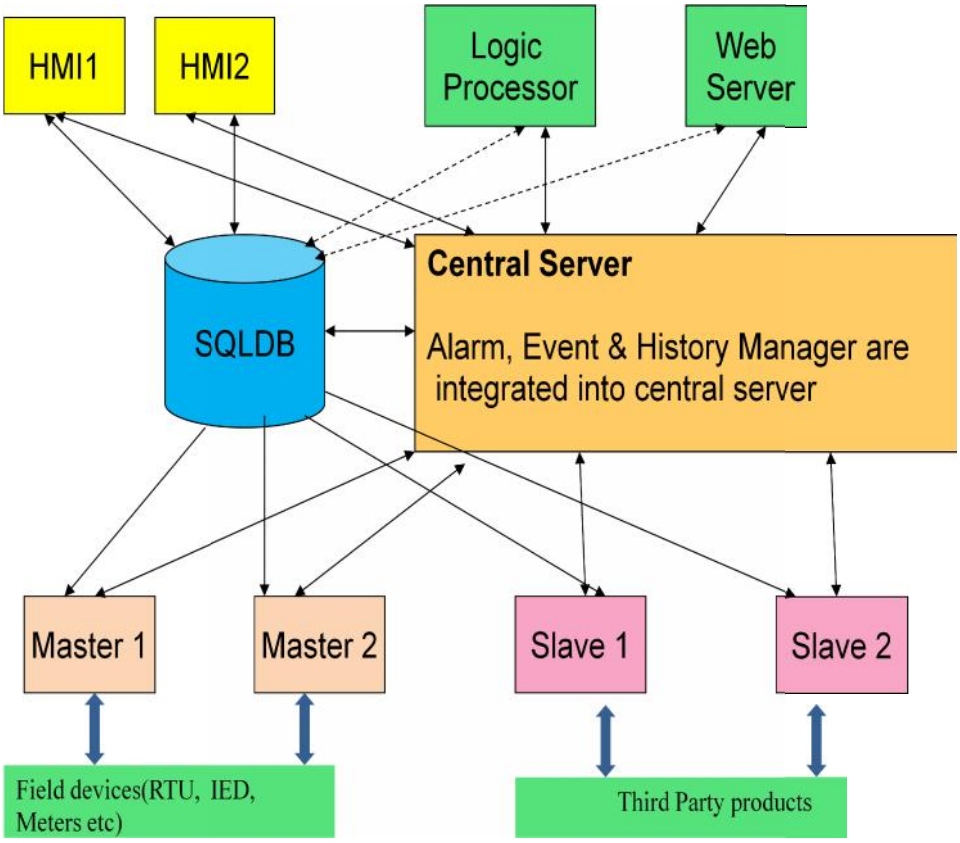


Figure 1.1: Typical SCADA system architecture

As shown in figure 1.1 at the start point Field device Sends control signals to the remote device under control, obtains data from these devices and transmits process data to the Central Server via Master 1 and Master 2 protocol. Further Central Server collect process data and presents data to the human operator through multiple HMI (HMI 1, HMI 2).Central Server also provide data to the third party product using slave protocol (Slave1, Slave2).

1.4 Functions of SCADA Systems

A SCADA system offers the following minimum functionality [3]:

1) Possibility of creating alarm panels, which demand the presence of the operator to recognize a shutdown or situation of alarm, with registry of incidences.
2) Generation of signal history that can be used for other programs.
3) Execution of programs, that modify the control law, annul or even to modify the tasks associated to the system, under certain conditions.
4) Possibility of numerical programming, that allows arithmetic calculations of high resolution on the CPU of the computer.
5) With them, applications for computers can be developed, to capture data, analysis of signals, presentations in screen, shipment of results to disc and printer, etc.

1.5 SCADA Applications

SCADA is used in the numerous applications which are listed as follows:

1) **Manufacturing:** In manufacturing environments, SCADA is used to make sure that targeted productivity is met and all systems run smoothly. It is also used to check the production line track that how many unite of production have been completed and how many are in various stage of completion [4].
2) **Food Production:** In food production temperature is very important. SCADA is used to monitor and control the temperature, the movement of liquid and solid ingredients and mixture in production process.
3) **Electric and Gas Utilities:** SCADA is used to provide reliable and good quality electric and gas supply. To monitor and control the distribution of gas and electricity and keep the supporting telecom infrastructure online utility companies uses SCADA device.
4) **Telecom and Information Technology (IT):** In information technology SCADA system is used to monitor the temperature of server and other equipment. It is also used to monitor physical intrusion at remote site by using passive infrared (PIR) motion sensors and door sensors.
5) **Water Distribution:** The SCADA system widely used in water distribution system to monitor and control parameters such as system pressure and tank

level. It is typically situated in a control room at a treatment plant .it also supervise activity, such as sedimentation, filtration and chemical treatment.

6) **Pump Stations:** SCADA is typically used in various pump station such as water pump to monitor pump run times ,pump starts, pump status such as stop, running ,failed ,off, forced off and forced on , pump Generator status ,power status.

CHAPTER 2
LITERATURE SURVEY

2.1 Performance Monitoring

Today IT system is used from basic office machine to the critical system that run business operation .It play major role for any company and present behind all area of the business activity. Any fault or problem in corporate IT system can cause major losses through interruption, delay. It can also change the market needs, regulatory requirement and evolution of global market. To overcome this losses a competitive company uses performance monitoring tools to evaluate the system performance time to time.

With the increasing the use of IT system, development of new software, new technologies and new application's make Performance monitoring of IT system as an important task [5]. ISO described that performance monitoring is a way to optimize the Quality of Service and to identify the changes in performance. In performance monitoring it is important to collect statistical performance data from time to time [6-7].The collected statistical data not only useful to the performance management but also help to detect faults in the fault management. This data also used to adjust system configuration in the configuration management [8-9].

2.2 Need for Performance Monitoring Tool

Some companies use the standard monitoring tools (like task manager) supplied with an operating system (OS) to monitor servers and processes running in their IT system. Others use event logs and system logs. A drawback of standard OS tools is that they only report failures of system after the event occurs. This type of reporting requires real time response and rectification. But real time response is not possible every time and it is difficult to implement preventive measure in real time so Company requires a performance monitoring tool which can predict potential failure before they occur. This performance monitoring tool store monitoring information over a period (such as a day, a month) in the database log. Performance monitoring of servers and processes is important to ensure that corporate IT system will run smoothly. System administrators must be able to prevent problems from arising and they must be able to

promptly identify any faults that do occur and eliminate the cause. System administrators must be able to access the information about server resources and application performance in order to promptly identify any faults that can affect corporate IT system and to eliminate the cause. Finally system performance monitoring is important to ensure operational stability of the corporate IT system and it plays a major role to change the business environment.

2.3 Performance Management Cycle

Performance management cycle involves three phases - monitoring, analysis, and planning which is essential to ensure operational stability of the corporate IT system. It also helps to understand the problem experienced by users in order to increase the performance of IT system.

2.3.1 Monitoring

The monitoring phase involves the monitoring of system resources (like CPU, Memory, Database) in specified time interval and stores the monitoring data in system database.

2.3.2 Analysis

In the analysis phase monitoring data stored in system database is used to analyze and to identify the cause of potential failure and error as they occur. It also helps to predict the level of performance and operational stability of system. This phase consist analyze the problem experienced by users and continually modifying.

2.3.3 Planning

The planning phase uses the analysis report to determine whether the IT system is working efficiently and providing a supportive environment for users. This phase evaluate any system modification or upgrade requirement.

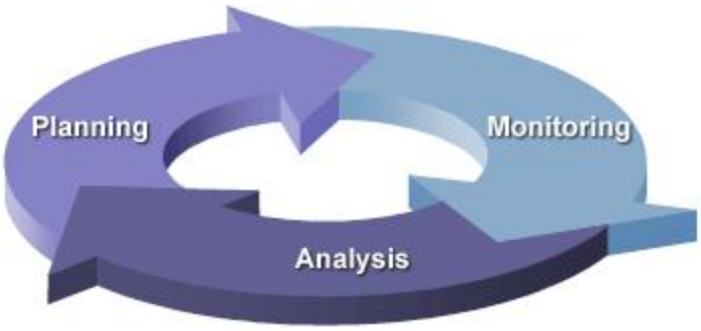


Figure 2.1: Performance management cycle [10]

2.4 Performance Monitoring System

Monitoring the performance of computer based system is essential to effectively manage system resources, evaluating and examining system. Performance monitoring is mainly divided into two main categories: real time and log-based monitoring. Real time monitoring is concerned with monitor the current system state and provides up to date information about the system performance. Log-based monitoring record system performance information for post-processing, analysis and to find trends in the system performance.

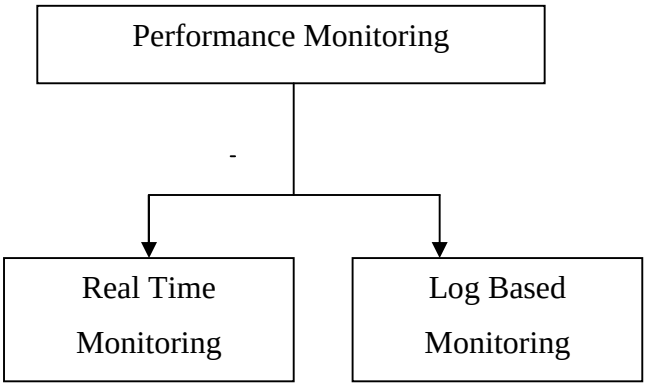


Figure 2.2: System modules [11]

2.5 Real Time Performance Monitoring Tools

Real Time Monitoring Tools is used to monitoring and displaying the current system performance. These tools extract the performance reading with the help of system calls that are built in operating system. This tool does not affect the system performance because of system calls are built in operating system [12].

2.5.1 Microsoft Windows Task Manager

Microsoft Windows Task Manager is used to monitor Windows operating system (OS). It helps users to monitor, manage and troubleshoot the process running in the system. As a monitoring tool, Task Manager displays basic performance data (CPU utilization, memory usage, swap file) in the form of tabular and graphical representation. Later versions of Task Manager also display networking details and disk storage. There are few tabs providing almost anything about system as normal user requires identifying system bottleneck that may be responsible for performance degradation of system [13].

1) Processes tab shows information about all processes in the system, how much CPU they are using, how much memory they are consuming.
2) Performance tab shows CPU and memory utilization in graphical representation.
3) Networking tab shows network usage.

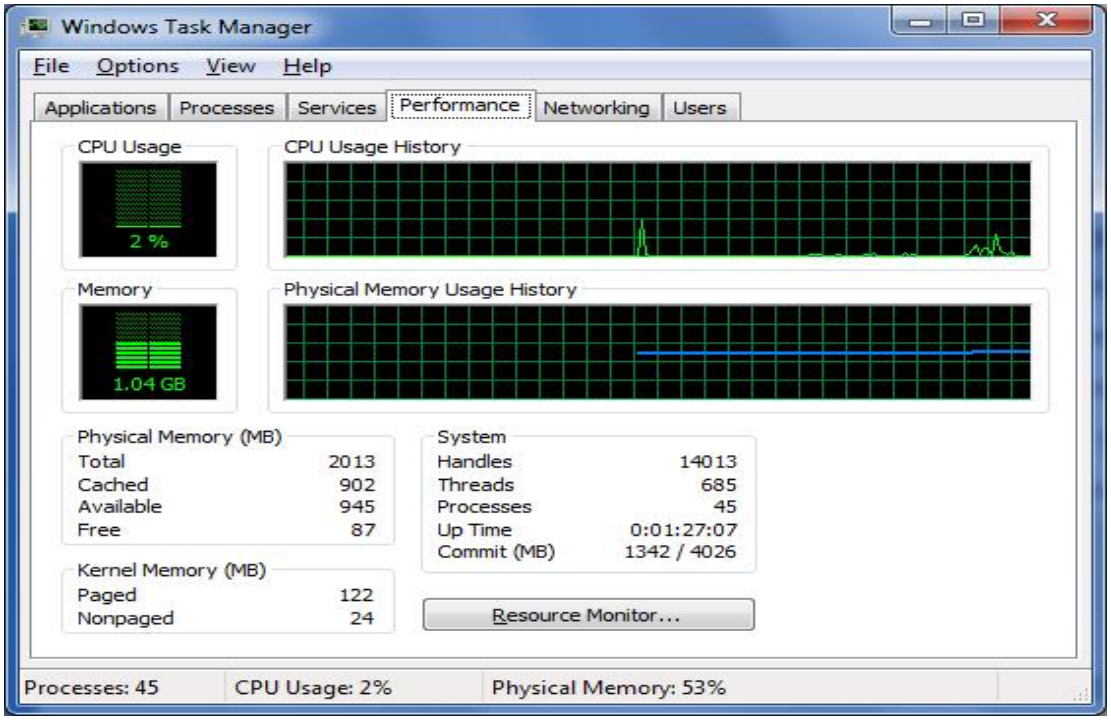


Figure 2.3: Performance tab of Microsoft Windows Task Manager

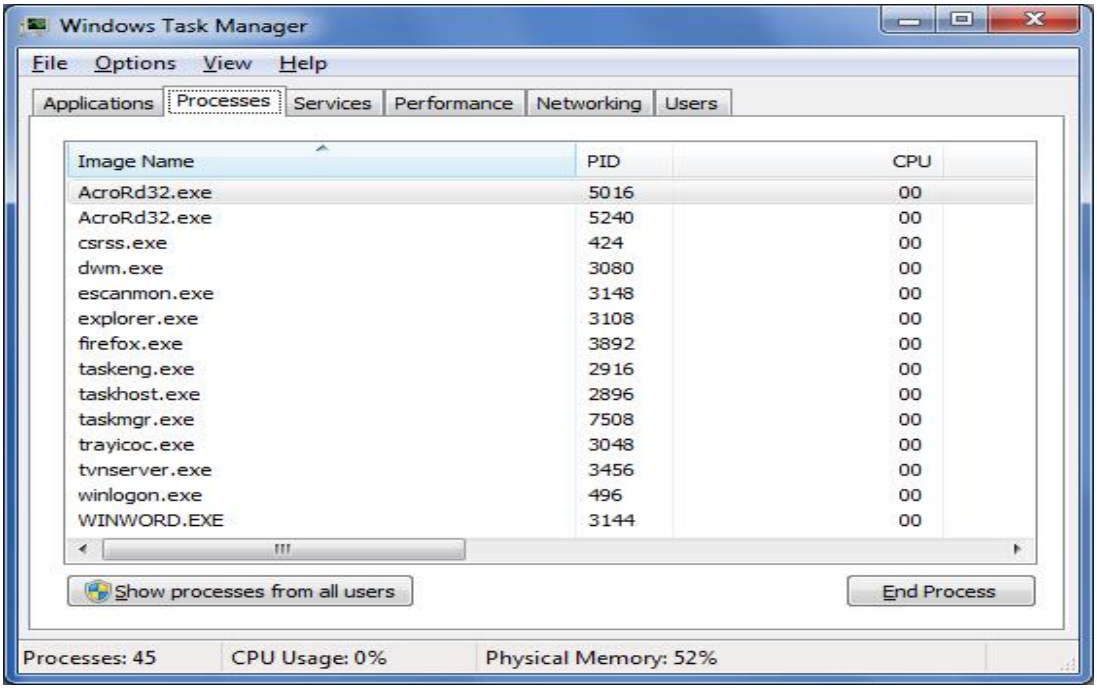


Figure 2.4: Processes tab of Microsoft Windows Task Manager

2.5.2 Process Monitor (pmon)

Process Monitor tool is used for real-time monitoring of process performance. Functionality of this tool is similar to the task manager but it does not provide any control over the processes. It shows output (performance data about process) on command prompt screen of windows [14]. Process Monitor does not provide configurable update interval only one update rate every five second. Process monitor mainly used by the user who prefers simplest view of information about process running on a machine or users who is more comfortable with the command line interface.

2.5.3 Process Explode (pview)

Process Explode is another performance monitoring tool for computer based system. It provides a vast amount of performance information about process, memory, threads and the system. It displays all performance information in a single window. It updates the performance information as per user requirement. It does not provide the facility like logging or any alert. It can stop the running process, change the process priority and permission. The advantage of Process Explode over Task Manager is that it shows more performance measurement but it does not give the quick summary about

CPU and memory utilization of all process running in the system.

2.5.4 Process Viewer (pviewer)

Process Viewer provides the functionality similar to Process Explode but it display a subset of the process performance measurement displayed by Process Explode. It is more user-friendly as compare to the other monitoring tools [15]. This is much easier for user to read the performance data displayed by the Process Viewer. Like Process Explode it update the performance data as per user requirement .It also provide the facility to control over the process like kill the process, change process priority etc. This tool is more useful for monitoring of memory utilization because it provides a separate memory detail window.

2.6 Log-Based Performance Monitoring Tool

Log based monitoring tool is used for the same reason as real time monitoring system used but it gives the different level of detail. Where Real time monitoring tool evaluates current status of the system and identifies the current resource utilization (like CPU, memory etc) of processes. Log based monitoring tool record the performance data in the system log in specified time interval (generally every five second).These recorded data is used for system analysis and to maximize the system performance.

There are many issues with log based performance monitoring tool.

1) This tool affects the system performance while it is measuring the system.
2) Due to the tradeoff between monitoring accuracy and monitoring overhead it is very difficult to set the best sampling rate for performing monitoring.
3) With this tool, performance data have to written permanently to the disk storage. This is a high overhead operation.

2.6.1 Event Log Service and Event Viewer

Event Log Service is widely used log based monitoring tool in computer based system. This tool records system events and all application in to logs. Further user uses Event viewer is used to view the contents of logs [16]. This view helps to recognize system problem and to determine system performance for future. The main

drawback of the tool is that it does not provide log based information for performance resources like CPU, Memory etc.

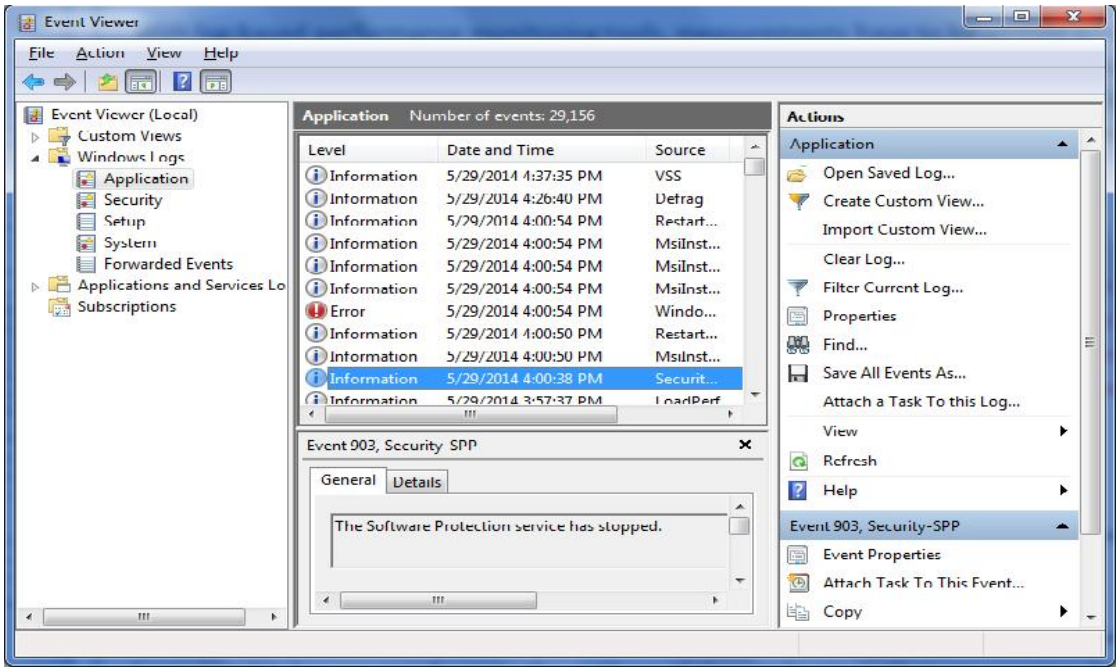


Figure 2.5: Event Viewer showing events logged by applications

2.7 Advantages of Performance Monitoring

There are several advantages to periodically performance monitoring of IT System [17].

Continuous system performance monitoring can do the following:

1) Sometimes minor system performance problem have an adverse effect on system and can slow the system for a long time. Continuous monitoring detects such minor problem and send a report to the system administrator.
2) Many system problems affect the user productivity. Continuous performance monitoring helps to identify that problem.
3) It gathers data when a problem occurs for the first time.
4) It helps user to establish a baseline for comparison.

Successful monitoring involves the following:

1) Periodically collect performance-related information about the server and applications running in the system.
2) Store the performance information in the log table of database for future use.

3) Report the performance-related information to the system administrator to identify any faults that can affect corporate IT system and eliminate the cause.
4) Detect changes made to the system and applications. Reporting to the user and system administrator for this changes time to time.

2.8 Performance Parameters

Mainly performance of IT system depends on the following parameters.

1) **System Load**: It specifies the total number of applications and process running in the system.
2) **Memory Utilization**: It is defined in terms of
    a. Swap Memory Utilization: It specifies amount of virtual memory utilized by a process and system.
    b. Physical Memory Utilization: It specifies the amount of physical memory utilized by a individual process or system.
3) **Page Fault**: Page fault occurs when a process access the page of memory that is not currently available in memory working set.
4) **CPU Utilization**: It specifies the total percentage CPU used by the system or individual process.
5) **Disk Utilization**: It describes the hard disk space utilized by the system or individual process.
6) **Disk I/O Stats**: It specifies disk read/write rate and transfer rate for each device.

2.9 SCADA System Performance Monitoring Overview

2.9.1 Monitoring Basics

With the significant growth of SCADA applications in the management of critical infrastructure as well as modern industrial facility such as electricity and water distribution system. It makes performance monitoring and analyzing of SCADA as an important task. Many processes like database operation, HMI, DNP3 Master etc runs in SCADA [18]. Degraded performance of one or more process like process use overload processor, high page fault etc can cause the performance degradation of SCADA and it can compromises the overall SCADA operation [19]. So performance

monitoring is to recognize the gradual degradation of SCADA and to correct it before degraded performance compromises the overall SCADA operation [20].

2.9.2 SCADA Performance Monitoring Parameters

The parameters to monitor the performance of SCADA include:

2.9.2.1 CPU Utilization

It is most useful parameter to recognize the performance degradation of SCADA. In most cases performance degradation of SCADA is direct result of overloaded processor or CPU overloading. SCADA can be expected to perform acceptably by maintaining the CPU Utilization of SCADA below established norms on ongoing basis [21], and can be prevents overall SCADA System to be compromised.

Following statics of CPU utilization are important to monitor for SCADA.

1) Current percentage of CPU utilization for every process running in SCADA. It reflects how busy the processor.
2) Current Total percentage of CPU utilization for SCADA.
3) Percentage CPU utilization for every SCADA process over a period such as a day or month.
4) Total percentage CPU utilization for SCADA over a period such as a day or month.

2.9.2.2 Memory Utilization

Memory utilization of SCADA is gradually change over time to time as new processes are added to the system environment .it does not changes much during the normal operation of system .without monitoring of amount of memory utilization over a period of year it can cause too little memory .Too little memory can gradually decrease the performance of system and convert it to the very sluggish system when no one monitor amount of memory utilization of system over a period of year then by the time a serious problem can developed. The best solution of this problem may be to add more memory or reduce the number of process running at a time.

Following statics of memory utilization are important to monitor for SCADA.

1) Current percentage of memory utilization for every process running in SCADA.
2) Current Total percentage of memory utilization for SCADA.

3) Percentage memory utilization for every SCADA process over a period such as a day or month.
4) Total percentage memory utilization for SCADA over a period such as a day or month.

2.9.2.3 Page Fault Rate

When SCADA system is using up a significant part of its processing time with retrieving pages from disk, the performance of the system suffers accordingly. In SCADA, page fault rate changes from month to month .Every month much new process is added to the SCADA without the proper tuning or addition of memory. Page fault rate depends on the speed of the particular processor, the disk access speed of server the efficiency of disk caching and other factor.

Following statics of page fault rate are important to monitor for SCADA.

1) Current page fault rate for every process running in SCADA.
2) Current Total page fault rate for SCADA.
3) Page fault rate for every SCADA process over a period such as a day or month.
4) Total page fault rate for SCADA over a period such as a day or month.

2.10 Benefits of SCADA System Performance Monitoring

There are many benefits of performance monitoring of SCADA system [22].

1) Improves availability of system.
2) Enhance Substation Safety.
3) Prevent SCADA System Failure at Off Hours.
4) Increases performance of SCADA application.
5) Decreases capital expenditures.
6) Provides real-time report generation and analysis.
7) Delivers historic report generation and analysis.
8) Provide a facility to analyze the root-cause system problems.
9) Provides detailed performance information about overall system and each system process.

CHAPTER 3

PROBLEM STATEMENT

There are various standard performance monitoring tools (like task manager) supplied with an operating system (OS) to monitor servers and processes running in their IT system. But they do not provide advanced monitoring such as alerting, log information. They only report failures of system after the event occurs. This type of reporting requires real time response and rectification. But in CG SCADA real time response is not possible every time and it is difficult to implement preventive measure in real time there was a need to develop a performance monitoring solution which was to be integration with CG SCADA and can predict potential failure before they occur. This tool involves the following features.

1) It shows the current performance information (CPU utilization, memory usage, page fault rate) about all process running in CG SCADA in the form of tabular display and graphical representation.
2) It also shows the current state of the system performance in the form of line graph.
3) By using this tool operator can see the performance of the system over the filtered time period. It record monitoring information over a period (such as a day, a month) in the database and display the recorded information as per user requirement in the form of line graph representation.

CHAPTER 4
DESIGN ALGORITHM

This section gives insight to the procedure involved in the development of required tool and describes various modules involved in tool design algorithm. As shown in *Fig.1* the analyzer tool design algorithm is divided into four layers.

4.1 Performance.dll

Performance.dll is a collection of functions which supports the retrieval of the performance parameter like CPU utilization, Memory utilization and Page Fault Rate. This Performance.dll involves the following functions

1) *FindProcessID (process Name)*: This function takes processName as an input and return ProcessID.
2) *GetPocessCpuUsage (ProcessID):* This function takes ProcessID as an input and return percentage CPU utilization.
3) *GetProcessMemory (DWORD ProcessID)*: This function takes ProcessID as input argument and return PMInfo structure. This structure contains the following member.
    1) Physical Memory
    2) Virtual Memory
    3) Total System Memory
    4) Number of Page Faults

4.2 Database Design

The Performance monitoring of system generates a lot of monitoring data. For viewing and analysis this monitoring data it is important to store it in to relational database [22]. The system database composed by two tables: tbl_processinfo, tbl_processlog . The structures of the tbl_processinfo table and the tbl_processlog table are as in Table I, Table II. The tbl_processinfo will contain the entire process name required for CG-SCADA. Initially when PA Service (will discuss in the next section) will start this table will provide the process name to service and in response service update all the parameter of this table in 1 sec. Based on the processloginterval configured by operator process information will be recorded in the tbl_processlog.

Later for logged information representation, data will be retrieved from tbl_processlog.

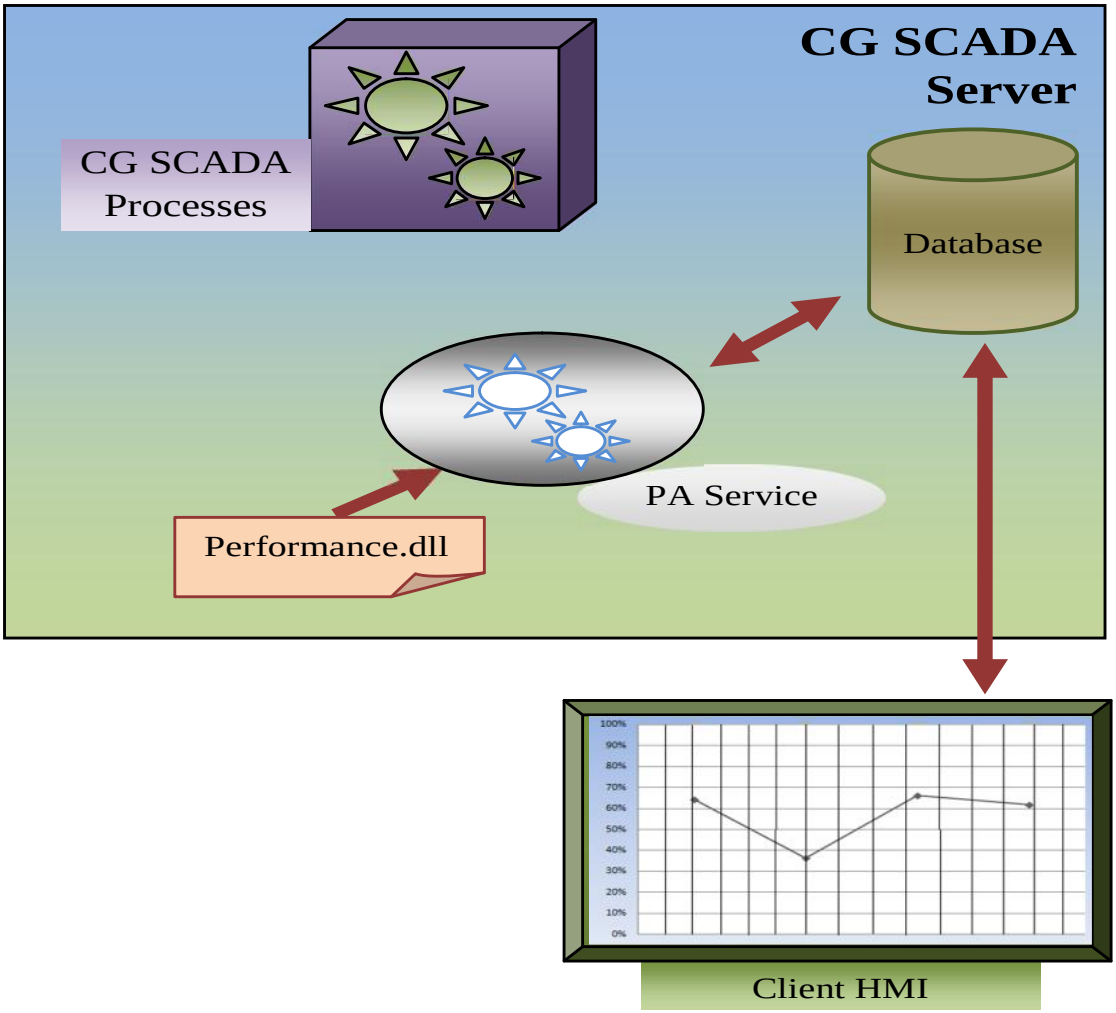


Figure 4.1: Design of Performance Monitoring and Analyzer Tool

4.3 PA Service

PA Service is a dedicated background process. It has the ability to start automatically when SCADA system boots and also can be manually pause or stopped or even restart [23]. PA service is used to continuously update performance parameter in database table for this purpose it uses following steps.

1) Get ProcessName of all process that will run in CG-SCADA from database.
2) Get ProcessID for each Process Name by calling Performance.dll function.
3) Get performance parameter (CPU utilization, Memory utilization, Page Fault Rate) based on ProcessID of process by calling Performance.dll functions.

4) Update performance parameter in database table tbl_processinfo in every 1 sec.
5) Insert logged information in different database table tbl_processlog in processloginterval.

Table 4.1 tbl_processinfo

Field Name	**Meaning**	**Data type**	**Primary key**	**Allow Empty**
ProcessID	Primary key	Integer	Yes	No
ProcessName	Process Name	Varchar	No	No
Processkey	Unique and dynamic identification of the process in the server	Integer	No	Yes
CPU	Percentage CPU utilization for a process	Integer	No	Yes
Memory	Physical memory utilization for a process	Integer	No	Yes
VirtualMemory	Virtual memory utilization for a process	Integer	No	Yes
PageFault	Page fault rate for a process	Integer	No	Yes

Table 4.2 tbl_processlog

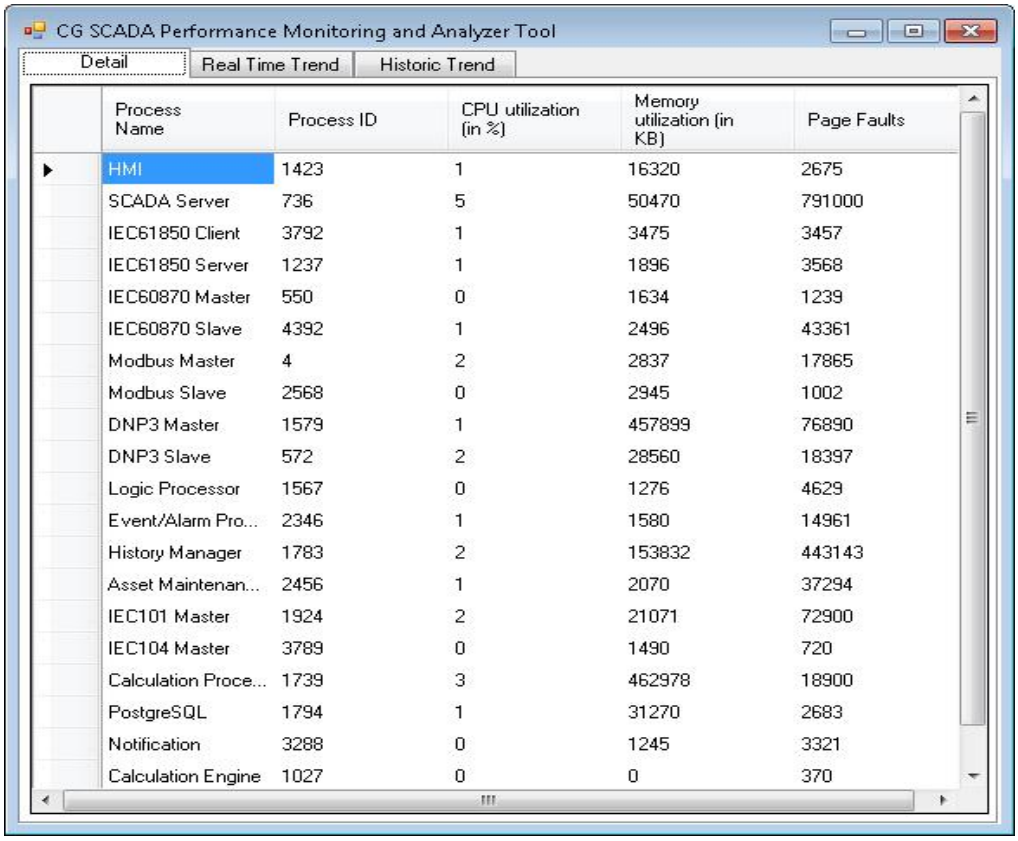
Field Name	Meaning	Data type	Primary key	Allow Empty
SerialID	Serial no. for logged information of a process	Serial	Yes	No
ProcessID	Foreign key referenced by tbl_processinfo	Integer	No	No
Processlogtime	Date and time of logged information	Timestamp	No	No
CPU	Percentage CPU utilization for a process	Integer	No	Yes
Memory	Physical memory utilization for a process	Integer	No	Yes
VirtualMemory	Virtual memory utilization for a process	Integer	No	Yes
PageFault	Page fault rate for a process	Integer	No	Yes

4.4 Client HMI

The Client HMI is used to represent the performance information (CPU utilization, Memory utilization and Page Fault Rate) about each process and system in the form of tabular and line graph representation so that operator can analyze the System Performance. Client HMI involves the following tabs.

1) Detail: Snapshots shown in Figure 4.2 this tab gives detail view of all process

running in CG SCADA system .it is invaluable if system is running slow for an undetermined reason .By viewing the process name, CPU utilization, memory utilization and page fault rate, operator can focus on the precise area causing trouble.



Process Name	Process ID	CPU utilization (in %)	Memory utilization (in KB)	Page Faults
HMI	1423	1	16320	2675
SCADA Server	736	5	50470	791000
IEC61850 Client	3792	1	3475	3457
IEC61850 Server	1237	1	1896	3568
IEC60870 Master	550	0	1634	1239
IEC60870 Slave	4392	1	2496	43361
Modbus Master	4	2	2837	17865
Modbus Slave	2568	0	2945	1002
DNP3 Master	1579	1	457899	76890
DNP3 Slave	572	2	28560	18397
Logic Processor	1567	0	1276	4629
Event/Alarm Pro...	2346	1	1580	14961
History Manager	1783	2	153832	443143
Asset Maintenan...	2456	1	2070	37294
IEC101 Master	1924	2	21071	72900
IEC104 Master	3789	0	1490	720
Calculation Proce...	1739	3	462978	18900
PostgreSQL	1794	1	31270	2683
Notification	3288	0	1245	3321
Calculation Engine	1027	0	0	370

Figure 4.2: Detail performance information about each process running in system

2) Real Time Trend: Snapshots shown in Figure 4.3 this tab includes three line graphs to show the performance of CG SCADA system.
    a) Top graph show the CPU usage of overall system or an individual system process at the moment and for the past few minutes. If graph show the high percentage means that the system is requiring a lot of CPU resources which can slow the overall system.
    b) Middle graph show the memory being used by individual process or overall system in real time. If graph show high percentage means that SCADA system is requiring to install more memory or to reduce the number of process have opened at one time.

c) Bottom graph show the page fault rate for individual process or system in real time. If graph show high percentage means many new process is added to the system without the addition of memory and it is required to add more memory to the system.

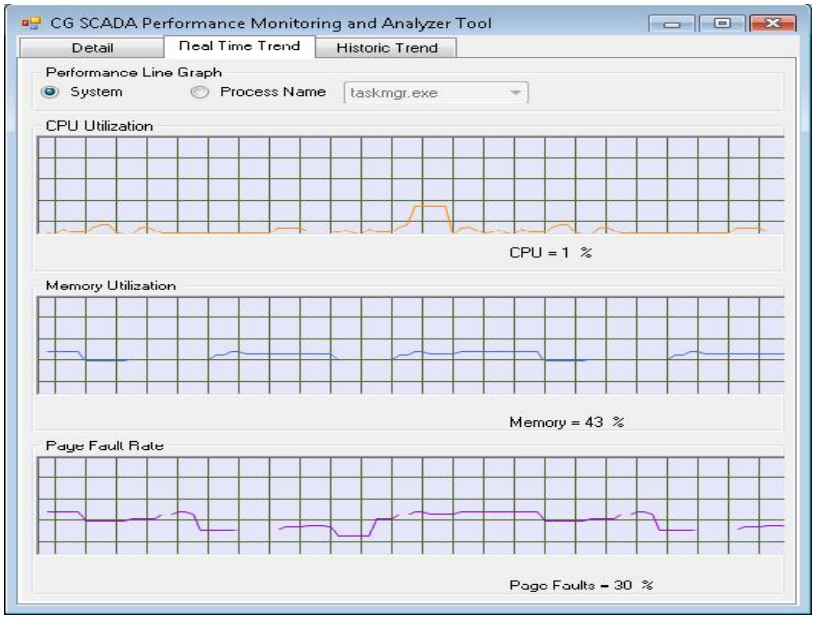


Figure 4.3: Performance information for overall system in real time

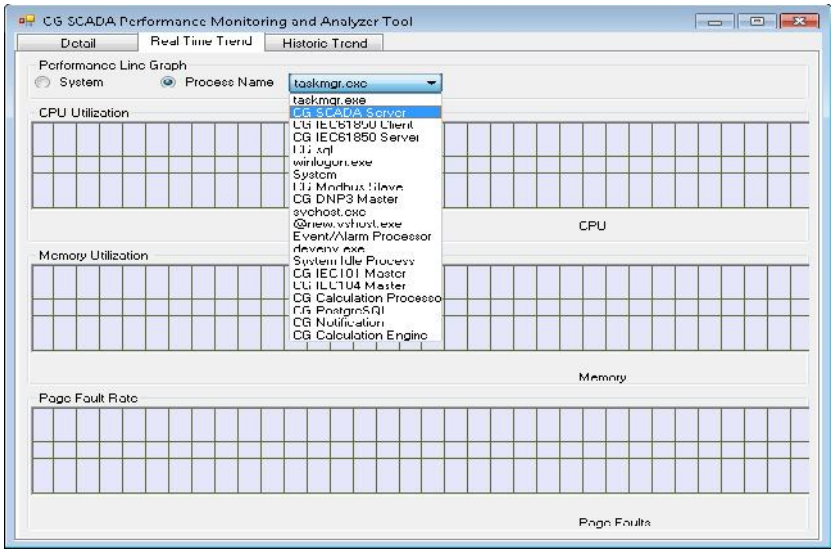


Figure 4.4: Performance information for selecting process from Process Name list in real time

3) Historic Trend: Snapshots shown in Figure 4.5 this tab shows the historic performance of CG SCADA system using three line graphs over a filtered

period (between from and to date-time). By analyzing line graph it can be easily seen that which performance parameter was responsible for degradation of SCADA performance over filtered period .Top, middle, bottom graph show CPU usage , memory usage, number of page fault of individual process and overall system over a filtered period respectively.

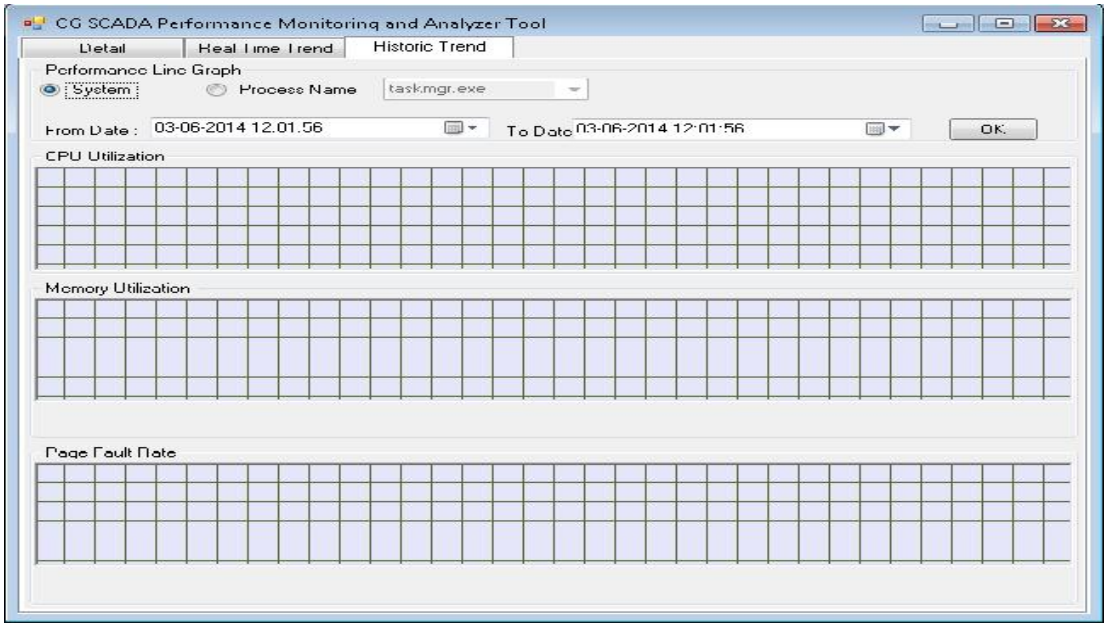


Figure 4.5: Performance information for overall system over filtered period

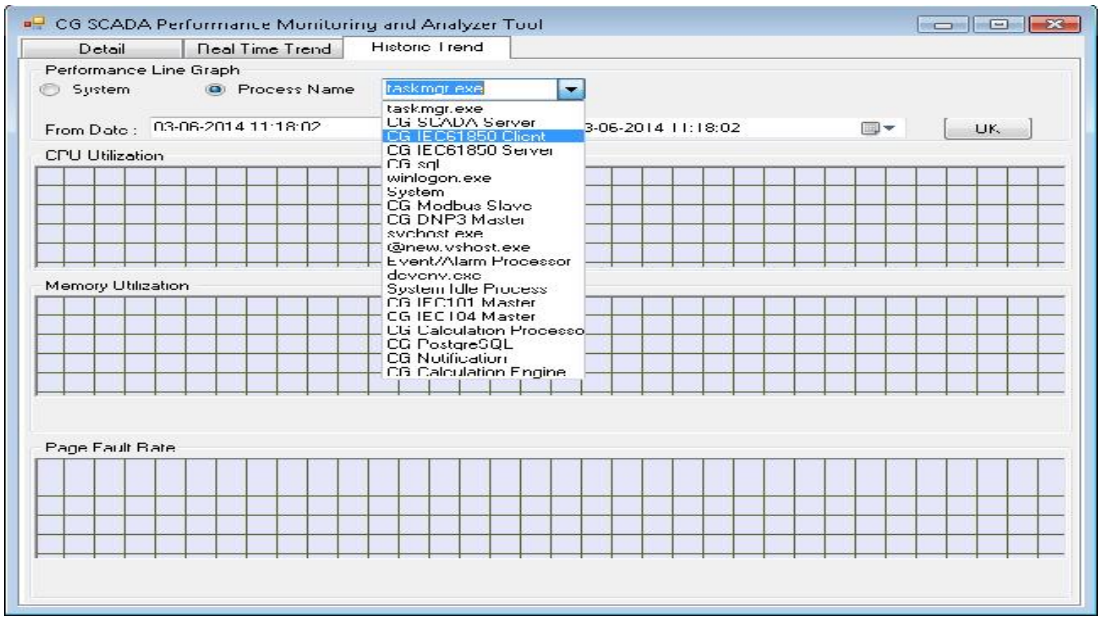


Figure 4.6: Performance information for selecting process from Process Name list in real time

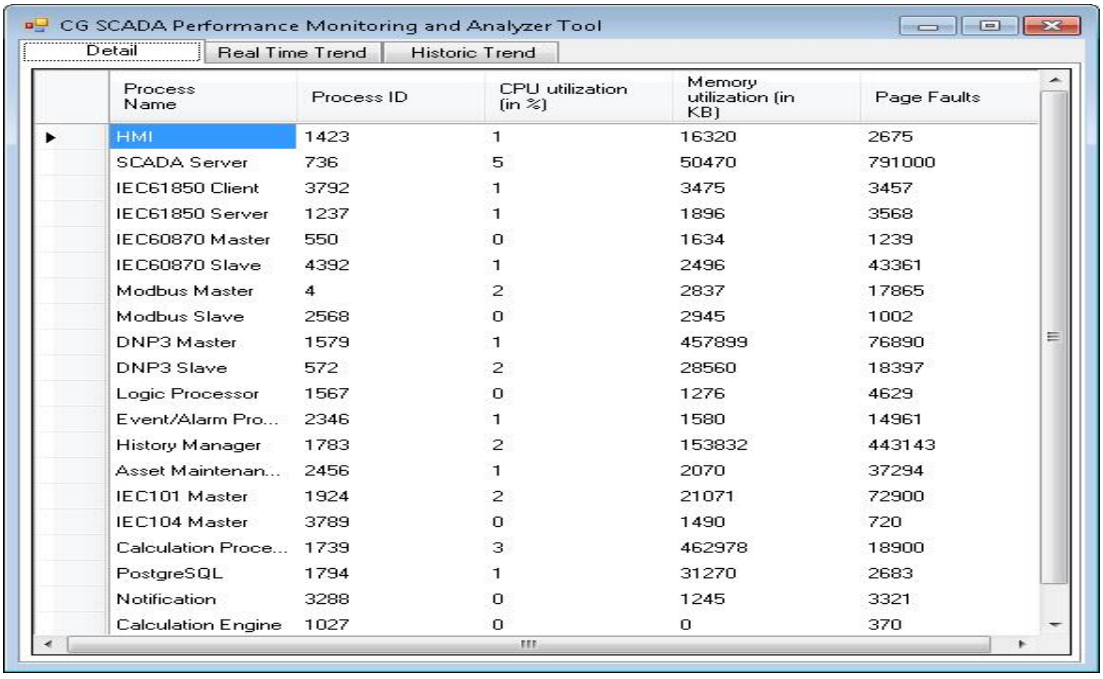
CHAPTER 5
RESULTS

For testing we have run the analyzer tool in CG SCADA system. To run analyzer we performed following steps.

1) Run the database of CG SCADA system.
2) Run performance analyzer service.
3) Run client HMI.

Client HMI displays the following result.

As snapshot shown in Figure 5.1 HMI opened the Detail tab by default. It properly showed the name all the process running in CG SCADA with performance information (CPU utilization, memory, page fault rate) in tabular form. We have monitor and analyzed performance of each process successfully.



Process Name	Process ID	CPU utilization (in %)	Memory utilization (in KB)	Page Faults
HMI	1423	1	16320	2675
SCADA Server	736	5	50470	791000
IEC61850 Client	3792	1	3475	3457
IEC61850 Server	1237	1	1896	3568
IEC60870 Master	550	0	1634	1239
IEC60870 Slave	4392	1	2496	43361
Modbus Master	4	2	2837	17865
Modbus Slave	2568	0	2945	1002
DNP3 Master	1579	1	457899	76890
DNP3 Slave	572	2	28560	18397
Logic Processor	1567	0	1276	4629
Event/Alarm Pro...	2346	1	1580	14961
History Manager	1783	2	153832	443143
Asset Maintenan...	2456	1	2070	37294
IEC101 Master	1924	2	21071	72900
IEC104 Master	3789	0	1490	720
Calculation Proce...	1739	3	462978	18900
PostgreSQL	1794	1	31270	2683
Notification	3288	0	1245	3321
Calculation Engine	1027	0	0	370

Figure 5.1: Detail performance information about each process running in CG SCADA

After analyzed detail view we clicked Real Time Trend tab of HMI. As shown in Figure 5.2 by default it showed line graph for performance information (total CPU utilization, total memory, and total page fault rate) of CG SCADA at that moment and few moments before. By using line graph we obtained that the SCADA using 1 % CPU, average 43 % memory, average 30% page fault rate. Analyzing this data we concluded that there is no requirement to increase memory or to maintain the CPU utilization and SCADA is working fine.

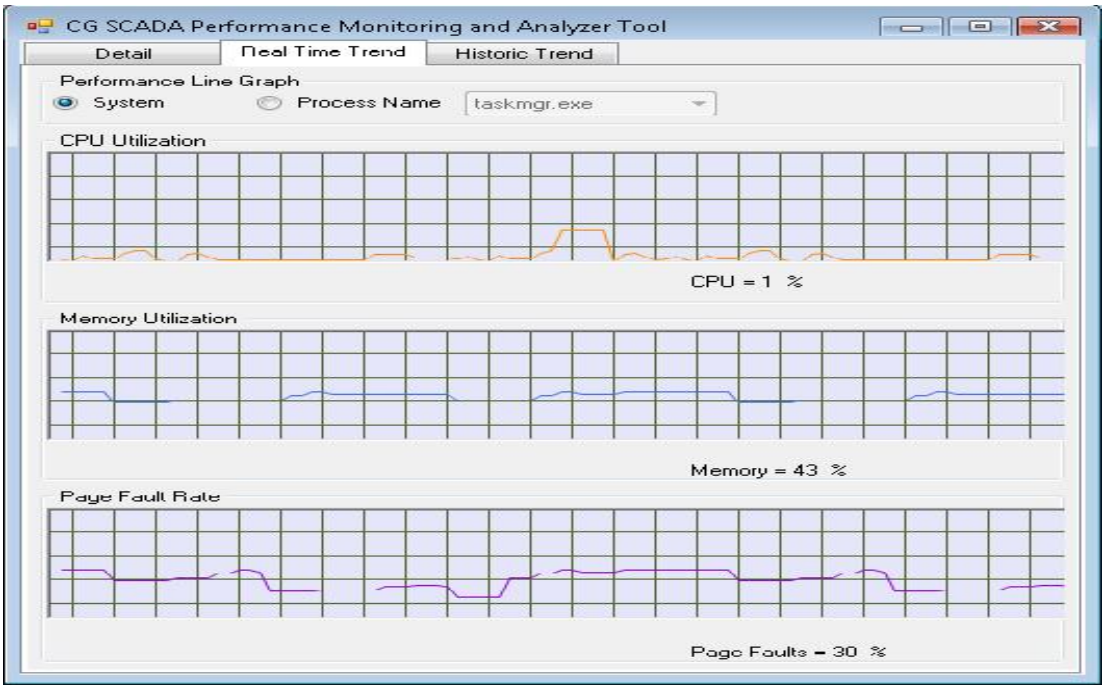


Figure 5.2: Performance of overall CG SCADA system in real time

The line graph of performance information (As shown in Figure 5.3) of individual process at that moment by selecting process name (like CG SCADA Server) from process name list and we analyzed that process is not using more memory and CPU. That process is not influencing the overall performance of SCADA.

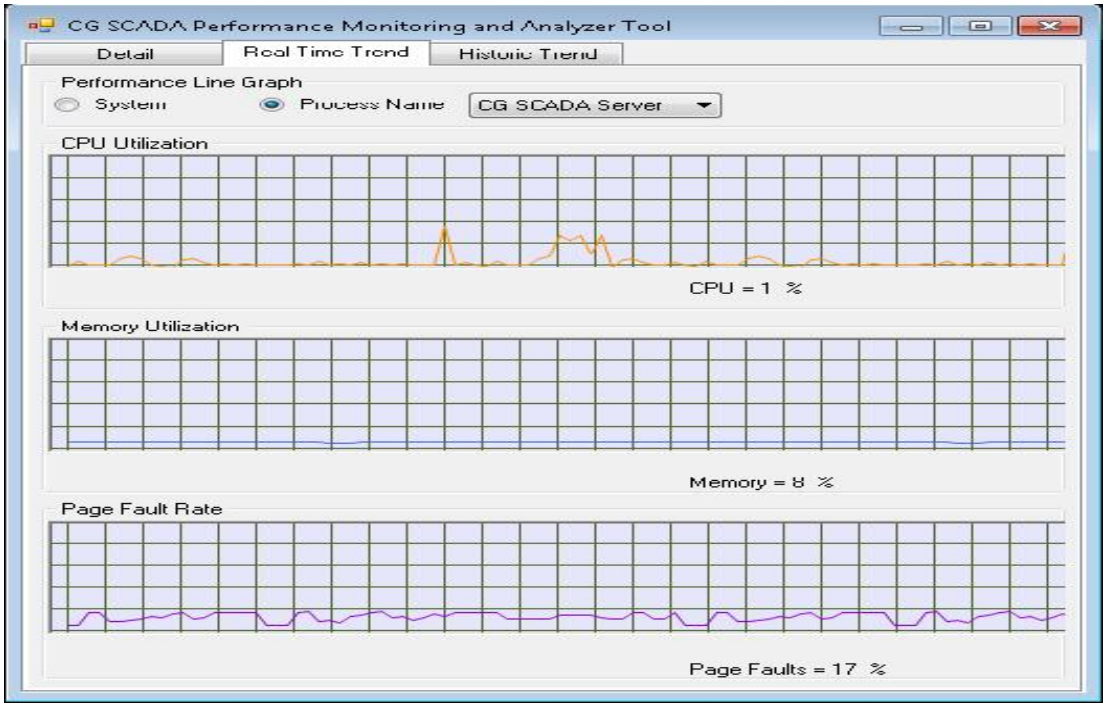


Figure 5.3: Performance of CG SCADA Server (process) in real time

After analyzed Real Time Trend we opened Historic Trend tab of HMI as snapshot shown in Figure 5.4 and select system radio button ,entered from date -time and to date -time then click ok then it showed line graph for performance information of system over a filtered period (between from and to date-time). By using line graph we obtained that the system used average 10% CPU, average 50% memory, average 40% page fault rate over filtered period (10 days).Analyzing this data we detected that SCADA degradation was not happened over filtered period.

We also analyzed the performance of each process as shown in Figure 5.5 by enable process Name radio button, selecting the process name from Process Name list.

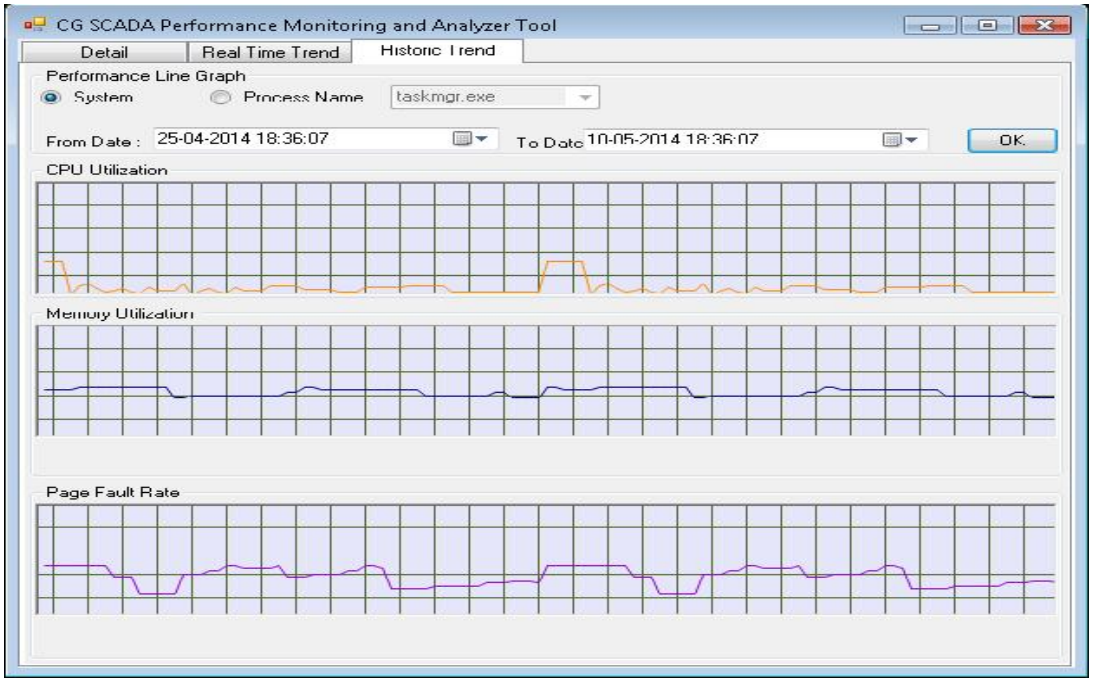


Figure 5.4: Performance of CG SCADA system over a filtered period (10 days)

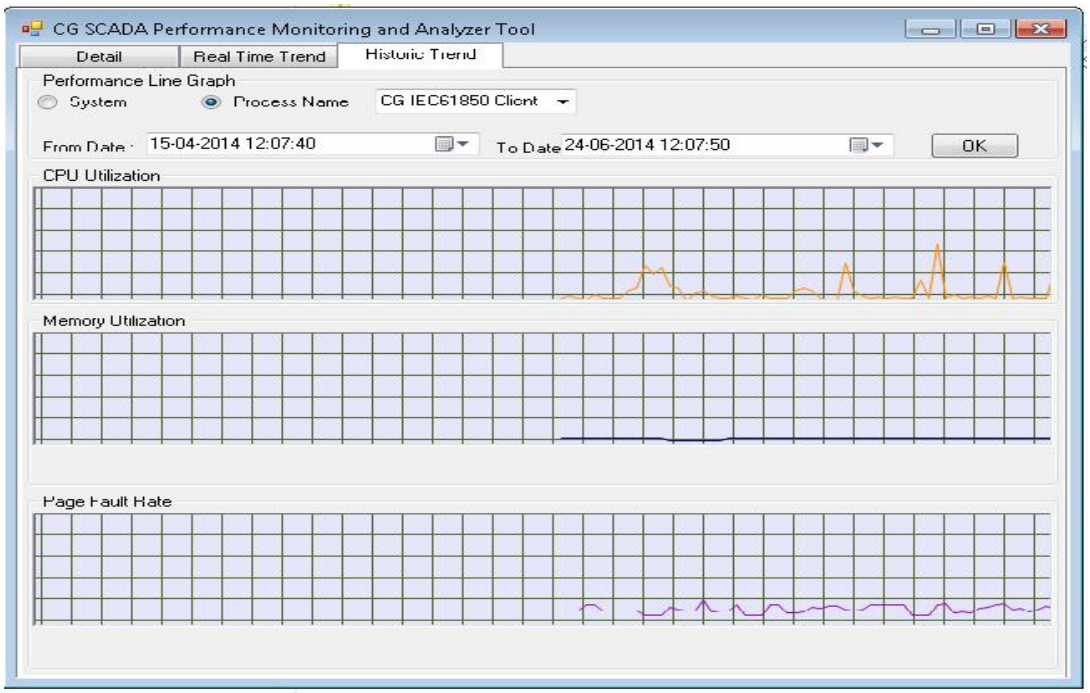


Figure 5.5: Performance of CG IEC61850 Client (process) over a filtered period (10 days)

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

Conclusion

In the thesis, the design algorithm of performance monitoring and analyzer tool for CG SCADA system is presented. The result shows that the tool achieves real time monitoring and analyzing of system performance parameter with detailed tabular display and line graph representation during the system operation. At the same time, it also record monitoring data in database within specified intervals and show recorded data on client HMI. The logged information analyzing is done on filter condition as per user requirement and it provides the filtered information in line graph representation.

Future Scope

Designed Performance Monitoring Tool can be optimized further by adding alarm alerts attributes. The system generates alert messages to notify administrator when a predefined condition is met, such as when an activated SCADA process uses higher percentage of CPU Utilization. Alerts can be sent out as e-mail/e-page/mobile SMS. Alerts can be preconfigured and user-defined alerts. In preconfigured alerts administrator set the threshold value of performance parameter. User can not modify and delete preconfigured alerts. Whereas in user-defined alerts user can set alert properties for the alert, such as the threshold, duration, frequency, and so on.

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LIST OF PUBLICATION

Published

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