A REVIEW OF THE CHARACTERISTIC FEATURES OF SUPERVISORY AND DISTRIBUTED CONTROL ARCHITECTURE AND ITS IMPLEMENTATION SCENARIOS

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ABSTRACT

The paper presents the SCADA architecture, their interface to process hardware and its applications. The characteristics of SCADA are reviewed and salient features are illustrated. The development opportunity and application flexibility are clearly mentioned. Some expectations of the users and its limitations are discussed. The scope and need for further development are described. The industrial standards as well as the potential benefits are summarised. Two case studies presented to illustrate the effectiveness of its application. The use of SCADA in intelligent product development and their services including prototyping control strategy, test and implementation are indicated.

Keywords: *Air Separation Unit, Automation Technology, Distributed Control Systems, SCADA Architecture, Product Service System and Control Strategy*

1. INTRODUCTION

Supervisory Control and Data Acquisition (SCADA) has been around us as long as there are supervisors since ancient time. Currently, this is the most widely used software for industrial process control [1]. Supervisory Control generally activates through binary coding scheme like OPEN/CLOSE, ON/OFF, UP/DOWN, 0/1 and also multiple choice options like recipes, programs, and set the points for continuously variable processes [2]. It acts as a constant vigilance to regulate carefully to ensure the process variables are within acceptable limits. Data acquisition is a pre-requisite of supervision and control. In order to supervise the system must recognise the conditions and facts about the process to be controlled. The supervisor must have data about the key parameters and integrate all information which forms the basis to issue commands.

SCADA systems are used not only in industrial processes, e.g. steel plants, power generation and distribution, chemical plants but also in some experimental facilities such as nuclear fusion and laboratory test [3]. SCADA systems have evolved rapidly and are now available with several 100 thousands of I/O channels. There is even a possibility of the development of 1 million I/O channels in the future [4]. SCADA can run on DOS, VMS and UNIX operating systems [5]. Recently all SCADA vendors have moved to PC and some are also to Linux. Most SCADA packages are a recreation of Visual Basic [6]. The next revolutionary event will be Microsoft's .NET programming [7]. The automation supplier market shares will possible increase for the companies that supply "controls" or "add-ins" for .NET [8] programming languages. This will improve the product service system (PSS) and online maintenance facilities.

Some of the renowned industrial SCADA suppliers are Intellution [9], Wanderware [10], National Instrumentation [11], Trend Controls [12], Allen Bradley [13], SquareD [14] GE Fanuc [15]. The application of SCADA is enormous; it starts from data acquisition to prototype controller and implementation. In this paper case studies are presented which shows how SCADA can be utilised in the prototyping and implementation of a controller. Recently, a system known as operator terminal or controlstar [16] is available as an alternative to the SCADA systems; however it is based on SCADA functionality only.

The following section illustrates hardware and software architecture of a SCADA system; its main advantages and limitations as well as customer's expectations present through the case study that reflects the application of SCADA systems and discuss the future scopes.

2. SCADA ARCHITECTURE

This section describes the common features of SCADA products that have been evaluated in view of their possible application in control systems [1, 3, 4]. Two basic layers in SCADA systems are the "client layer" which connects to the man machine interaction (MMI) and the "server layer" which handles most of the process data for control action [17]. The server communicates with devices in the field through process controllers like PLCs, which are connected to the servers either directly or via networks or field buses [18, 19]. Servers may be connected to each other and to client stations via an Ethernet LAN and it can also be expended to WAN [19, 20]. The server and client stations are PC base window platforms. Figure 1 shows the typical hardware architecture of SCADA systems [21].

SCADA is a multi-tasking and a real-time database (RTDB [22]) located in one or more servers. Servers are responsible for all data acquisition and handling (e.g. polling, controlling, alarm checking, calculations, logging and archiving) on a set of parameters; typically those which are connected to the hardware [23].

However, it is possible to provide dedicated servers for particular tasks, e.g. historian, data logger, alarm handler. Figure 2 (see Annex) shows a SCADA software architecture that is available for most of the products [3, 4].

However, all the components may not be present in all SCADA systems. The common features of all SCADA systems comprises the communication protocol, application interfaces, scalability, man machine interface (MMI), trending, alarm handling, logging/archiving, report generation, development tools, object handling, security policies.

Open software architecture has identified important standards for this technology [24-26]. Adoption of these standards will turn many SCADA systems into "Open Software Products" [25] which can freely communicate with other software and easily extended to meet future requirements. This approach will add value to the software and increases its longevity. Hence, this will remove the causes of early obsolescence and enhances the market demand.

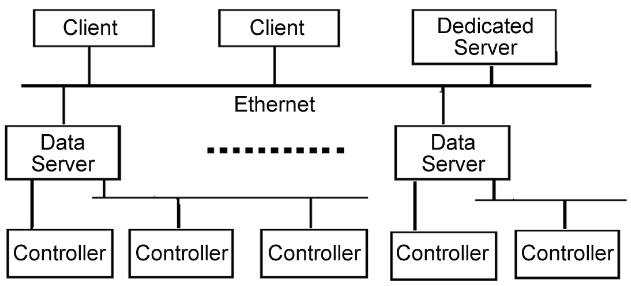


Figure 1: Typical hardware architecture of a SCADA system

The SCADA Process Historical Archiver (PHA [9-15]) copies the values of tags and other associated data. The values in the database can then be manipulated, examined, queried, used for rule-based decision making and other analysis. Most of the data historian support run-time archiving of project data to a disk file (database) that is compatible with the Microsoft Open Database Connectivity (ODBC [7-9]). The SCADA systems support standard ODBC-compliant database (e.g., MS SQL Server or Oracle, etc.) and can access using standard SQL queries. ODBC-compliant database managers, report writers, expert systems, custom software, and other applications can use to read and manipulate the archived data.

The customer's expectations are not limited to these but it extends to intelligent products and integrated services. Some of the expectations of the customers include minimisation of bandwidth and resources needs; capabilities of more data and high accuracy; runs under all windows platforms; wide network options like LAN, WAN, WWW; redundancy in controllers and data servers as well as LAN, I/O points, data history; low cost hardware; high efficiency and low cost communications and capabilities of more automated control and low cost labour. It is hoped that these can be fulfilled in the next generation of SCADA systems.

The benefits arise from the use of SCADA is enormous and some of them are mentioned below.

- A rich functionality and extensive development facilities.
- The amount of specific development that needs to be performed by the end-user is limited, especially with suitable engineering.
- These systems may be used for mission critical industrial process where reliability and performance are paramount. In addition, specific development is performed within a well-established framework that enhances reliability and robustness.
- Fault detection, data storage, process regulating, production history and analysis of performance can be done easily.
- Effective communication of data, visualising of process and ease of control.

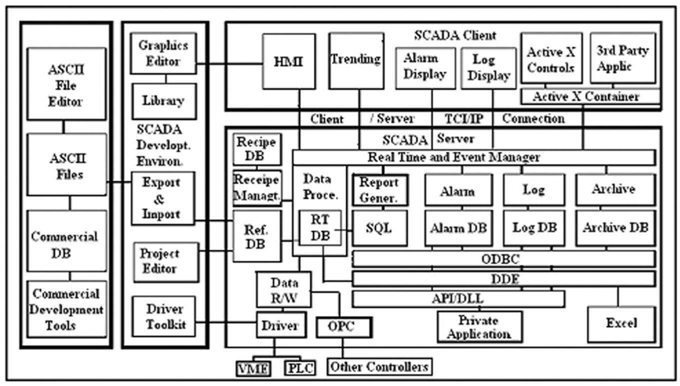


Figure 2: SCADA software architecture

device is commonly used for conversion of high voltage and current to 4-20 milliamps which can be fed to the COM port of the computer [17]. Sometimes amplifiers are used to boost the weak signals. A digi-board [28] or equivalent can help to increase the number of COM ports. Once the SCADA software is installed and run, the data image read the signals from the COM ports and stored in the data base. The SCADA is configured and the MMI is developed as per the process and operator requirements. Setting of the scan time is very important for each parameter. Each data point is defined a tag name and used for external data storage, trending, alarming and remote data transfer as well as control and monitoring. Excel, SQL, VB are helpful for many application development. These data sets are explored for development and implementation of model and controller respectively. Other applications like business and production planning, performance analysis can be developed. Uploading of inputs and operator commands can be handled directly from a user interface with appropriate authentication. However, except PID controller; SCADA does not provide facility to implement the controller online. In this paper the former case i.e. implementation of modelling, controller and product services are illustrated.

3.1 AIR SEPARATION UNIT

An air separation unit is typically found in an oxygen plant or nitrogen plant where air is compressed and condensed to liquid oxygen, nitrogen and argon and they are separated at different stages of the distillation process. The process is described in details in the literature [29, 30] as shown in Figure 3. Ten input parameters which affect the gaseous oxygen production and its purity are identified. They are flow rate of incoming air entering into the main heat exchanger, turbine inlet guide vane opening, and liquid oxygen draw rate, circulation of rich oxygen and rich nitrogen, turbine speed, medium and low pressure nitrogen draw rates, reflux ratio of pure nitrogen liquid stream and argon draw rate [29].

In this scheme set of data for the input and output parameters are collected over several days to implement a model base control strategy. Alternatively, a transit data set can be collected using step input on the major parameters. After careful analysis of the process, the input and output parameters which affect the process are decided. The raw data collected from the instruments are not consistent for direct use during modelling because it ranges from problems inherited to the associated data, such as missing or very anomalous value, or more subtle flaws and time lag in the production process. Hence, pre-processing and post processing are vital for the development of any applications. For examples; extremely

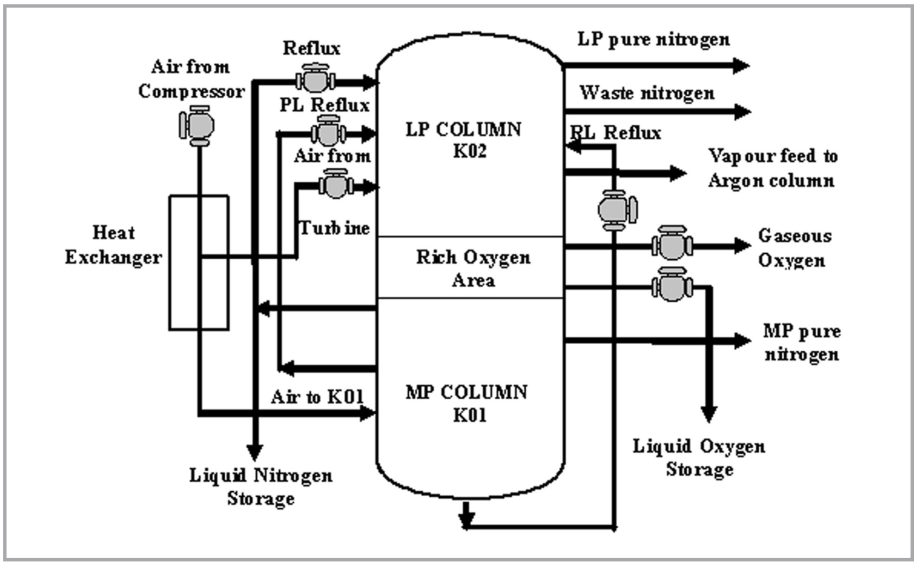
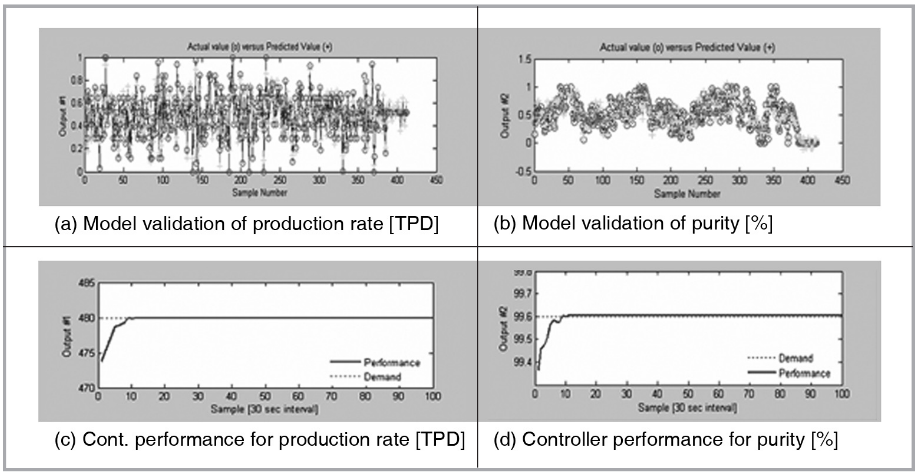


Figure 3: Schematic diagram of air separation unit



(a) Model validation of production rate [TPD]

(b) Model validation of purity [%]

(c) Cont. performance for production rate [TPD]

(d) Controller performance for purity [%]

Figure 4: Performance of the model and controller

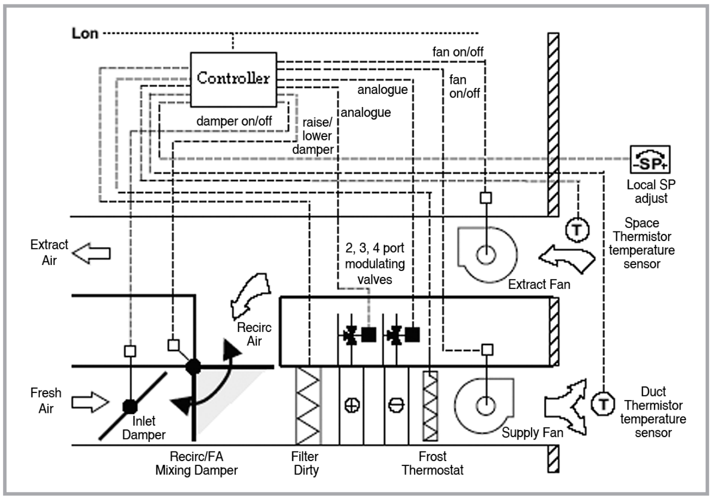


Figure 5: Schematic diagram of HVAC for integrated BMS

abnormal data can be adjusted to make the data consistent; values that are more than two standard deviations from the mean can be modified so that they must fall under two standard deviations away from the mean [31]. In some cases a minimum value for a variable can be specified. If two standard deviations below the mean are smaller than the minimum, the data adjusts to the minimum value [32]. This process removes many outliers from the dataset. Linear interpolation between measurements can generate approximate values for the missing data points [33]. A moving window technique can also be used to deter this problem [34]. The benefit of this technique is that it allows the use of same number of data points. Once the missing values and abnormality are removed from the data sets, the lag of each input variables are adjusted based on operator experience or experimentally or calculated by any other means like correlation factors [35]. Hence each input variable dataset is divided to its highest number and all the values fall between 0 and 1. The data set is then ready for development of a model in state space or transfer function. This strategy can easily be implemented as part of the SCADA system and can run through same computer to control the process.

A model base predictive controller (MPC [36, 37]) is developed and implemented. The performance of the model and controller are presented in Figure 4. It is seen that the developed model track the output in the subsequent phases and controller follows the input sequence. The output of the controller is then sent to the actuator via SCADA. The result shows an effectiveness of the performance and reliability.

3.2 INTEGRATED PRODUCT SERVICE SYSTEMS

In the second case study, a prototype rig test facility is developed for an air conditioning plant. The rig is used for testing of system integration, communication protocol, control strategy, fault identification. Additional measurement circuits and audio visual system which are needed for integrated facility management service (FMS) in a building management system (BMS [38, 39]) are included. Effectively it can demonstrate an integrated FMS with Tele-operation, Tele-control, Tele-maintenance, fault and alarm management [39, 40]. A basic configuration of a HVAC [12] is presented in the Figure 5. A thermocouple is connected in the outlet of the pump to measure the temperature. Actuators and valves are fitted to control the air flow. Differential pressure transducers are connected to measure the pressure in the duct.

The actuators and valves received command from the controller via a relay supply of 24VAC. The voltage across the relay output and current across the ground of the actuator are measured by reassuring circuits. These signals are fed back to the controller and they are utilised to identify and monitor the status of the relay, motor and valve positions etc. Similarly, circuits are fitted to the damper which measures the change in resistance; hence working status and position of the actuators and dampers are identified via these signals.

All measured parameters are finally fed into the controller via SCADA and a camera is connected to the network via a HUB. The information can be accessed from anywhere in the world. It is then facilitated to monitoring, controlling and servicing the system remotely. The system is demonstrated for the following:

(a) System integration: The signals from various circuits are tested on the rig. Especially the video signal is captured on the computer directly via network which can be accessed from SCADA environment. The control signals are sent to the valves, actuators and control the flow via network. Further the remote service like support system, fault detection; tele-operation; control and maintenance are tested via a remote PC connected to Ethernet. An audio - visual system is tested but due to transmission incapability of the controller, it is not possible to transmit the audio-visual signals to the remote site. SCADA is not yet capable to transmit the audio-visual signals via Ethernet. Hence, it is necessary to carry out more research on the SCADA.

(b) Remote service support: The technician is capable to identify the faulty equipment with the help of audio and visual system and fault detection technique set up on the SCADA. The remote engineer can restart the system and can send the signal to the controller. The remote engineer can also asses to the on site technician to do maintenance work.

(c) Fault detection support system: Additional measurements are used to identify the plant status. The signals (like power consumption, current or voltage) are trapped from various equipments that are under observation. These signals are sent to the controller and access from remote site. The status of the signals can identify the type of fault associated on the equipment.

(d) Tele-control, operation, monitoring and maintenance:

Tele-operation: The remote engineer can operate various equipments like actuators, pumps, blowers, dumpers which are connected to the controller. Operation of the camera can also be monitored remotely.

Tele-control: Set points of the actuators and control signals can send to the plant from remote site. Control strategy like PID has been tested. Two actuators (flow control valve and damper valve) are controlled from the remote site.

Tele-monitoring: All control signals as well as sensors data are monitored, sent or alerted to remote site or anywhere in the world via network. The performance of particular equipment, its power consumption as well as working status is identified from remote site.

Tele-maintenance: One way to say that the technician can get direct input from the experienced engineer who may not be on the site. The use of smart actuators can directly be maintained from remote site. This is normally done by resetting the equipment. In this concern, the use of web based controller has the power to download, change and build facility remotely.

Integrated product service system (PSS [41]) is a recent and on going research topic. SCADA has main role in this type of development. An integrated PSS has not only involved with data transfer but also audio and visual interaction. This type of system not only benefits the customer but also the product developer. The SCADA has not yet been fully capable and implement to do so. As mentioned in the previous section, that Microsoft .NET [7,8] can improve the situation in this respect. In addition, they will also support multi-team development. As far as new technologies are concerned, the SCADA products are now adopting; (i) Web technology, ActiveX, Java, etc. and (ii) Openness Productivity Connectivity (OPC [24-26]) as a means for communicating internally between the client and server modules. OPC [25] technology can eliminate expensive custom interfaces and drivers traditionally required for moving information easily around the enterprise.

It should thus be possible to connect OPC compliant third party modules to the SCADA product. There is still enough room to improve and include many features in the SCADA system. In the near future it is expected that high level of control strategy will be incorporated in the SCADA system.

4. CONCLUSION

The characteristics of SCADA have been reviewed. Its salient features have been illustrated. The development opportunities and application flexibility have clearly been mentioned. The case studies have illustrated the current need and future development of SCADA. These studies demonstrate the implication of SCADA in intelligent product development, its services and prototype the control strategy, testing and implementation. Attempt has been made in the paper to project the customer's expectations, need for future development and some directions towards the new technology.

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