# SURGE DRUM LEVEL CONTROL USING YOKOGAWA CENTUM CS3000 DCS

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*Abstract :* The purpose of a surge drum level control is to dampen the changes in controlled flow and keep the liquid level in the vessel between limits. For surge drums it is generally more important to allow levels to "float" in order to minimize flow rate variations. Surge drums are frequently located between process units to help reduce the effect of flow rate variations between interconnected process units. A low surge drum level can result in reduced capacity while a high level can cause liquid carryover. In an application characterized by alternating inertia and turbulence, stable level output is highly desirable. A distributed control system (DCS) is a platform for automated control and operation of a plant or industrial process. A DCS combines the following into a single automated system: human machine interface (HMI), logic solvers, historian, common database, alarm management, and a common engineering suite. Centum CS3000 is one of the commonly used DCS in many industries as it exhibits high reliability and more secure. Over 10,000 plants entrust Yokogawa's DCS to deliver their production goals. This paper presents the detailed study of the feature of Yokogawa DCS, development of a control strategy making use of lambda tuning which works effectively in controlling level in the surge drum and the implementation of the control strategy in Yokogawa centum CS3000 DCS.

***IndexTerms* - Surge drum, lambda tuning ,DCS, HMI, Centum CS3000**

## I. INTRODUCTION

The purpose of a surge drum level control is to dampen the changes in controlled flow and keep the liquid level in the vessel between limits. For surge drums it is generally more important to allow levels to "float" in order to minimize flow rate variations. Surge drums are frequently located between process units to help reduce the effect of flow rate variations between interconnected process units. A low surge drum level can result in reduced capacity while a high level can cause liquid carryover. In an application characterized by alternating inertia and turbulence, stable level output is highly desirable.

A distributed control system (DCS) is a platform for automated control and operation of a plant or industrial process. A DCS combines the following into a single automated system: human machine interface (HMI), logic solvers, historian, common database, alarm management, and a common engineering suite. Centum CS3000 is one of the commonly used DCS in many industries as it exhibits high reliability and more secure. Over 10,000 plants entrust Yokogawa's DCS to deliver their production goals.

The Yokogawa DCS delivers critical operational infrastructure and enhanced business performance. Key benefits include:
Simple, fast, and low-risk upgrades 40+ years of backwards compatibility , Highest field-proven system uptime, extensive advanced application portfolio service and consulting to ensure benefits throughout your lifecycle.

With the actual implementations in many plants and absolutely high reliability, CENTUM CS has been the best seller of the large scale DCS since its first sale in 1993. Since it was released in 1993, CENTUM CS is widely applied in the plants of oil refinery, petrochemical, chemistry, iron and steel, non-ferrous metal, metal, cement, paper pulp, food and pharmaceutical industries, and power, gas and water supply as well as many other public utilities. The excellent operability and engineering technique, and the high reliability proved by the abundant actual application results, guaranteed that the CENTUM CS will continue to play an important role in the 21st century.

This paper presents the detailed study of feature of Yokogawa DCS, developing a control strategy which works effectively in controlling level in the surge drum and the same is implemented in Yokogawa centum CS3000 DCS.

## II. SURGE DRUM

The surge drum is the one of the vital unit present in the process plant which ensures a smooth flow feed and product in and out of the plant. This chapter explains the surge drum level process and criticality involved in developing control strategy.

### 2.1 Surge Tank or surge drum

Surge Tank or Surge Drum is a water storage device used as pressure neutralizer in hydropower water conveyance system to resists excess pressure rise and pressure drop conditions.

**Fig. 2.1 Surge Tanks**

**2.2 Functions of Surge Tanks**

The surge tanks are installed to protect the conduit system from high internal pressures, help the hydraulic turbine regarding its regulation characteristics and store the water to raise the pressure in pressure drop conditions. In the petrochemical industries, the surge tanks are used in conjunction between the feed source and the reactor, which helps in delivering a stable flow of feed to the reactor.

**2.3 Types of Surge Tanks/ drums**

Various types of surge tanks used in the hydropower water conveyance system are as follows.

- Simple surge tank
- Gallery type surge tank
- Inclined surge tank
- Restricted orifice surge tank
- Differential surge tank

**2.3.1 Simple Surge Tank**

A simple surge tank is like vertical pipe which is connected in between penstock and turbine generator. These are constructed with greater height and supports are also provided to hold the tank. Whenever the water flow suddenly increased the water is collected in the surge tank and neutralize the pressure. Top of the surge tank is opened to atmosphere If surge tank is filled completely then it overflows to maintain the pressure neutralization.

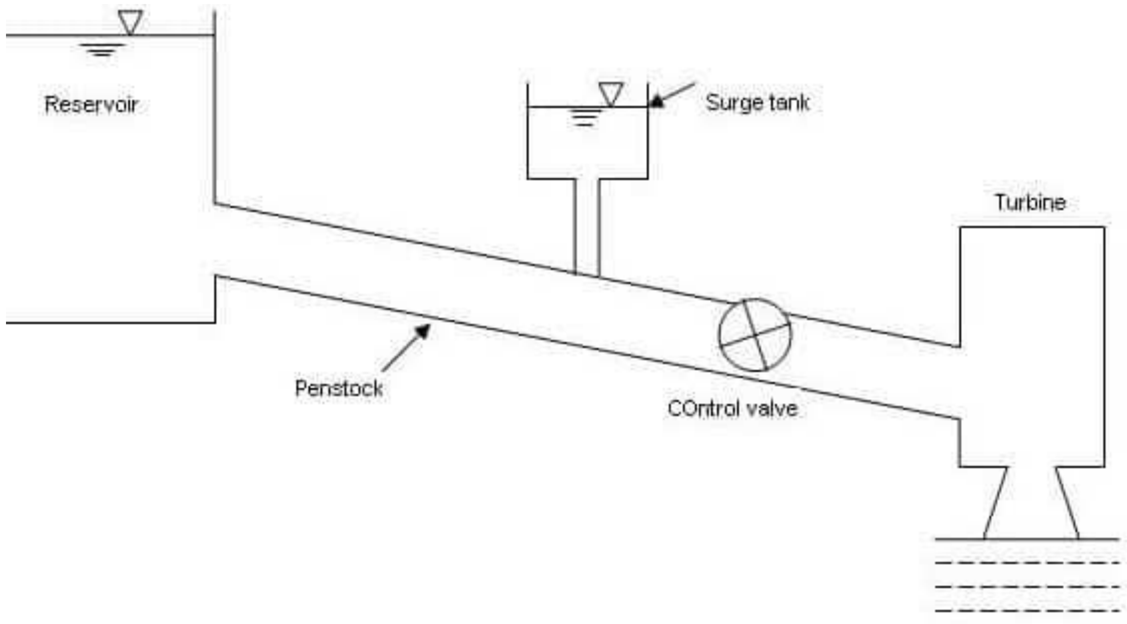


**Fig. 2.2 A simple Surge Tank**

### 2.3.2 Gallery Type Surge Tank

Gallery type surge tank consists extra storage galleries in it. These storage galleries are also called as expansion chambers. So, gallery type surge tank can also be called as expansion chamber type surge tanks.

These expansion chambers are generally provided at below and above the surge levels. Below surge level chambers are used to storage excess water in it and released when it is required or there is a brief drop in pressure. Upper surge level chambers are used to absorb the excess pressure.

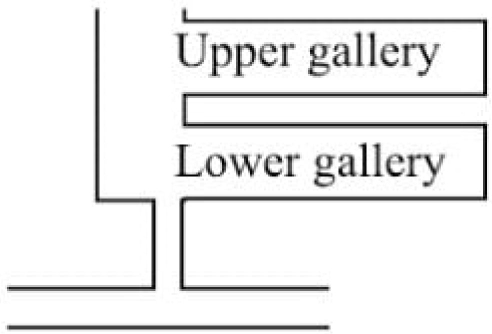


**Fig. 2.3 A simple Surge Tank**

### 2.3.3 Inclined Surge Tank

In case of inclined surge tank, the surge tank is provided with some inclination. It is provided when there is a limit in height of tank. By providing inclined surge tank the overflowed water under excess pressure is entered into inclined tank and pressure destroyed.

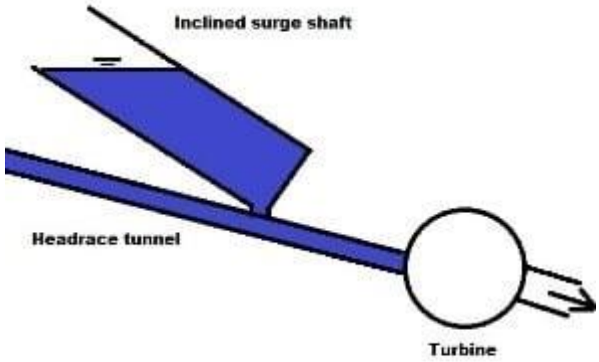


**Fig. 2.4 An Inclined Surge Tank**

**2.3.4 Restricted Orifice Surge Tank**

Restricted orifice consists an orifice between pipeline and surge tank. This orifice is also called as throttle so, it is also called as throttled surge tank. This throttle or orifice have very small diameter.

If the water overflows it should enter into the surge tank through this orifice. Because of small diameter frictional losses will developed and excess pressure in main pipe line is destroyed. This will creates quickly a retarding or accelerating head in the conduit. To reduce the water hammer effect, diameter of orifice should be well designed for full rejection of load by the turbine.

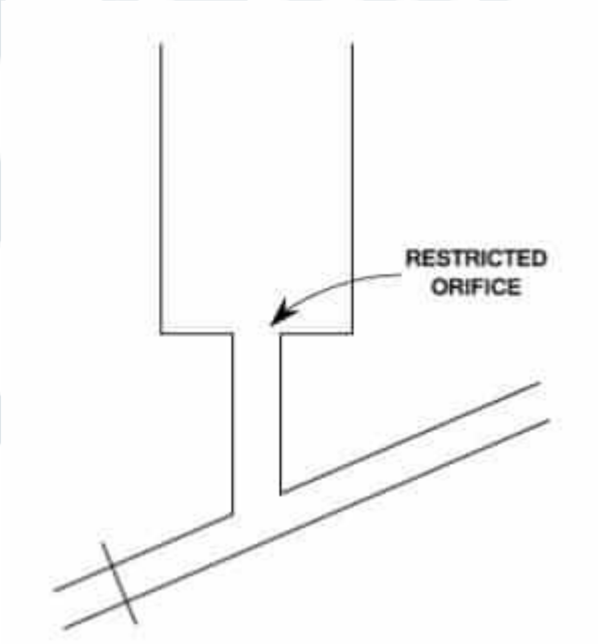


Fig. 2.5 Restricted Orifice Surge Tank

**2.3.5 Differential Surge Tank**

In case of differential surge tank, an internal riser is fixed in the tank. This riser have very small diameter through which water enters into the riser when it overflows. The riser also contains annular ports at its lower end.

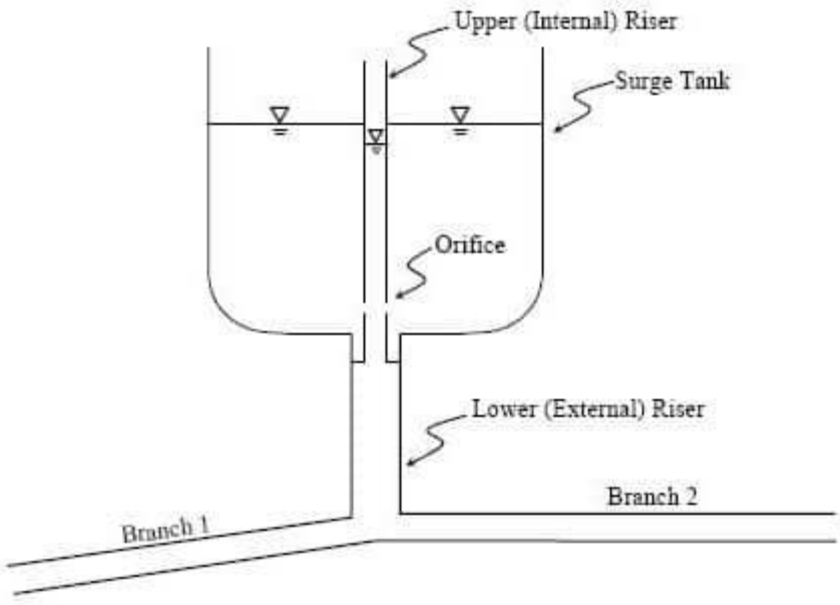


**Fig. 2.5 Differential Surge Tank**

These ports help the flow into or out of the tank. So, the excess pressure is destroyed by internal riser of surge tank and storage of water is done by outer tank. So, it is called as differential surge tank.

## III. SURGE DRUM LEVEL CONTROL

The feed surge drum usually located prior to the reactors. This protects the reactor from any sudden change in the feed flow because of turbulence or disturbance occurred at the previous stage of the process plant. Hence the level of the surge drum has to be maintained around the nominal value. Since the very objective of the surge drum is to provide smooth delivery of the feed , the tight control of level is usually not required. While all closed loop tuning rules that have been developed to provide the fast response, failed miserably to provides better control for surge drum level control. A good tuning settings for a surge tank control loop is required which guarantees better feed flow to the reactor or the downstream processing unit.

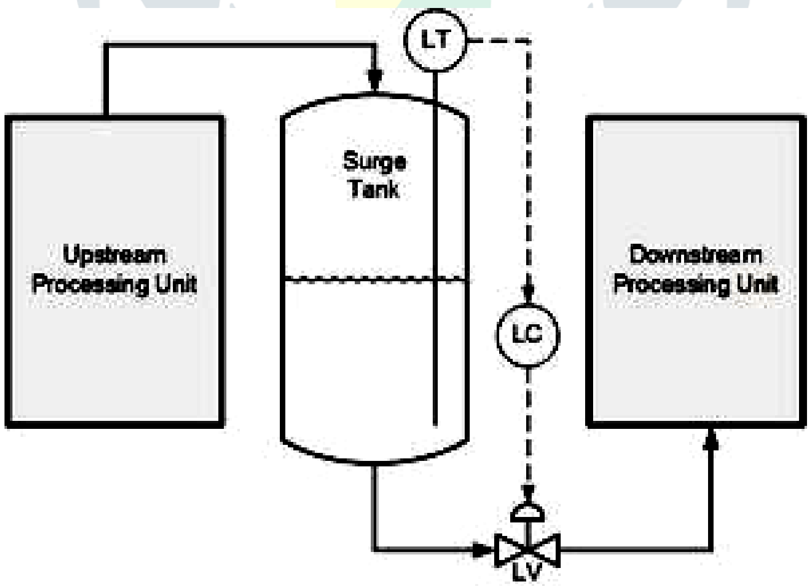


**Fig.3.1 Surge drum level control scheme**

As shown in Fig.3.1, a surge drum is placed between two processing units to absorb flow rate fluctuation's coming from the upstream process, so that the flow rate to the downstream processes to go up and down; therefore, the level controller must allow this movement and try not to hold the level close to its setpoint .the controller should simply keep the surge tank's level between its upper and lower limits, and do this with the least possible amount of change to its output.

The level-averaging method for controlling the surge tank level is preferred by most operators and engineers. This method minimizes control valve movement during disturbances, keeps the level between its limits, and brings the level back to setpoint over the long term.

## IV. YOKOGAWA CENTUM CS3000

Yokogawa delivers critical operational infrastructure for process automation. The Distributed Control System (DCS) enables automation and control of industrial processes and enhanced business performance. Over 10,000 plants entrust Yokogawa DCS to deliver their production goals. This chapter briefs various feature present in the Centum CS3000 DCS.

### 4.1 Architecture of Yokogawa Centum Cs3000 DCS

Drastic changes in the economy of manufacturing industries, has led to increasing demand for plant operations to reduce personnel, improve efficiency, and increase the operation rate of facilities. On the other hand, for plants to operate safely, improvements in reliability and operational safety cannot be neglected.

The role of the process control system used to be simply controlling plant operations, but now, there is the need to meet the requirement to closely link this to the enterprise management info1mation system and production management information system.

There have also been drastic changes in the field of information technology . Before we knew it, our office desks were occupied by personal computers.

In this climate of enormous change, open-architecture systems using de facto standards have become an integral part of current times. In 1997, Yokogawa introduced the CENTUM CS 1000 distributed control system for medium- and small-scale plants. The CENTUM CS 1000 is an open architecture DCS using Windows NT as the operating system of its human interface, which was already a de facto standard in the field of IT at that time,.

Now, as an evolution from the CENTUM CS 1000, we have developed the CENTUM CS 3000 process control system that is capable of controlling a large-scale plant. Featuring de facto standard functions and armed with control functions further enhanced from the sound functions of earlier CENTUM systems, the CENTUM CS 3000 gives the following benefits to users:

(1) Improvement of operation efficiency with multi-window display and other up-to-date technology

(2) Close link with information systems in an upper level

(3) Further improvement of automation and controllability

### 4.2 System overview

The greatest feature of the CENTUM CS 3000 is the use of WindowsXP as the operating system of components for operation and monitoring, which thus achieves a truly open architecture by allowing the application of general-purpose personal computers for the human interface. The Fig. 4.1 shows the system configuration of the CENTUM CS 3000.

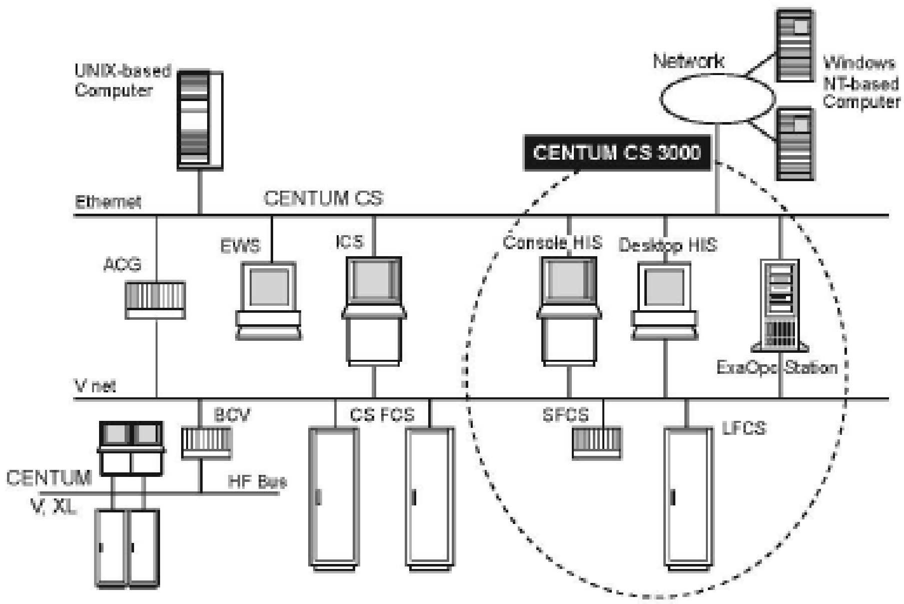


**Fig.4.1 System Configuration of CENTUM CS 3000**

### 4.3 History of Centum

Twenty-four years have passed since the CENTUM was rolled out as the world's first DCS in 1975. Up until now there have been several model changes. The first CENTUM had built- in microprocessors which at the time had begun to gather public attention as a technology offering great promise, and established the basic architecture of the CENTUM series in which the human interface and controllers are separated from one another and connected on a control bus. The first CENTUM introduced a new scheme, process operation and monitoring via CRTs and keyboards, to the world of process control. Present DCSs have inherited the basic architecture established by the CENTUM.

As microprocessors advanced from 16-bit design to 32-bit design, Yokogawa released the CENTUM V in 1983 and the CENTUM-XL in 1988. Although at that time it was acknowl- edged that customers were dissatisfied with the fact that DCSs were closed systems, Yokogawa was focusing on incorporating into the CENTUM original devices and developing original oper- ating systems and other software in order to gain better perfor- mance, by improving real-time controllability of controllers, in- creasing application capacity, and reducing the display retrieval time for the human interface. Each EOPS operator station, the human interface of the CENTUM-XL, was composed of up to 4 CRTs with 32-bit built-in processor, representing the best perfor- mance in those days.

After the CENTUM V, the market moved towards unifying the operating system and other software, and UNI X was gathering public attention. In response to this trend, UNIX was employed as the operating system of the ENGS engineering workstation, which was used for system generation and modification in the CENTUM-XL. Furthermore, the debut of the CENTUM CS in 1993 overthrew the common sense of those days by employing UNIX as the operating system of ICS human interface stations in addition to the engineering workstation. This means that the operating system was unified through all stations except for control stations. In response to the dissatisfaction with the fact that DCSs were "closed" systems, the employment of UNIX enabled DCSs, made it possible to exchange data with external systems over a LAN and Ethernet.

In recent years in the field of IT, Microsoft Windows has overtaken UNIX and greatly changed the world of computers. Popular IBM PC/AT-compatible machines were chosen as standard hardware specifications and Windows strove to present a more open architecture than UNIX could ever have done. The CENTUM CS 3000 was developed under such conditions of change in the field of IT.

### 4.4 System Conf1guration

The scale of the CENTUM CS 3000 is the same as the CENTUM CS, as shown below:

Maximum number of domains: 16

Maximum number of stations :64 per domain Maximum number of stations in total: 256

Maximum number of tags :100,000

#### 4.4.1 Operator Stations

In the CENTUM CS 3000, operator stations are generally referred to as human interface stations (HISs in short). The adoption of Windows NT asthe operating system means that each HIS can run system generation functions and other general- purpose business applications such as Microsoft Excel as well as performing operation and monitoring functions. As shown in Table 1, two types of hardware platforms can be used for HIS, thus allowing the machine which is most suitable for each user to be chosen.

**Table 4.1 Two Types of Hardware Platforms for HIS**

| | |
|---|---|
| General-purpose PC | Tue user can choose the PC model with the highest cost- **performance at the time when the user purchases a** CEN- TUM CS 3000 system. Higher CPU performance shortens the time taken by the operation and monitoring functions to **retrieve windows in response to user requests.** |
| Console | Console type, industrial PC supplied by Yokogawa has **touch operations with a similar feel to those of the user in-** terface of earlier CENTUMs. |

**4.4.2 Control Stations**

Control stations in the CENTUM CS 3000 are generally referred to as field control stations (FCSs). FCSs are the core of each system and are necessary to control a plant continuously for 24 hours a day, 365 days a year. Although in order to obtain an open interface, Windows NT is used as the operating system of system components for operation and monitoring, a Yokogawa original operating system is still used for FCSs in the CENTUM CS 3000. This is because FCSs must demonstrate high reliability for continuous 24-hour based operation.

There are two types of FCSs for the CENTUM CS 3000, as shown in Table 2. Each uses the hardware and programs that have been field-proven in the CENTUM CS and CENTUM CS 1000, ensuring high reliability.

**4.4.3 Control Bus**

The control bus is as important for control as FCSs. Vnet ( 10 Mbps, token passing method), the control bus that has already been field-proven with the CENTUM CS, is also employed as the control bus for the CENTUM CS 3000. Vnet is a dual-redundant bus standard.

**4.4.4 Information Network**

In the CENTUM CS, the information network was Yokogawa's original Enet. While, in the CENTUM CS 3000, the more commonly used Ethernet is employed as its information network with the aim of developing the open system, thus allowing CENTUM CS 3000 systems to be connected to the user 's intranet.

**Table 4.2 Two Types of FCSs**

| | |
|---|---|
| Standard FCS (LFCS) | Capacity: Large, the same capacity as that of the FCS of the CENTUM CS Hardware: It uses the field-proven hardware of the FCS of the CENTUM CS Control program: It uses the same control program as the FCS of the CENTUM CS |
| Compact FCS (SFCS) | Capacity: Small, the same capacity as that of the PFCS of the CENTUM CS Hardware: It uses the same hardware as the PFCS of the CENTIJM CS Control program. It uses the same control program as the PFCS of the CENTUM CS |

### 4.4.5 Communication Components on the Control Bus

Like the CENTUM CS, the CENTUM CS 3000 is designed to control a large-scale plant. For this purpose, the following communication components are connected to the control bus:

- ACG: Provides an Ethernet port for supervisory computers and supports the TCP/IP protocol; also used for connecting the Vnet to a large area network.
- BCV-V, BCV-H, BCV-L: Gateway units used to connect Vnet, HF-bus, and HL-bus to the Vnet of the CENTM CS 3000, respectively. The BCV-Vs are used to connect CENTUM CS 3000's domains with one another when configuring a large-scale system. The BCV-H and BCV-L are used to connect existing CENTUM-XL and (XL systems to the CENTUM CS 3000.

### 4.4.6 Field Network

Recently, activities to standardize the network of field sensors and actuators have increased. Representative field networks that have been standardized in the sector of process automation include Foundation™ Fieldbus (mainly promoted in the US and Japan) and PROFIBUS (mainly in Europe). The CENTUM CS 3000 supports these two field networks.

## 4.5 Function Conf1guration

### 4.5.1 Operation and Monitoring Functions

The leading-edge human interface functions developed for the CENTUM CS 1000 system for medium- and small-scale plants have been inherited, and functions required for a large- scale system (as in the CENTUM CS) have been added to the CENTUM CS 3000. The CENTUM CS 3000 does not merely use Windows NT but makes full use of the operability of the Windows operating system which has with the spread of Windows PCs become common knowledge. The CENTUM CS 3000's operation and monitoring functions allow the user to choose the display mode from two. The window mode allows windows of other Windows applications to be displayed on the same screen at the same time as operation and monitoring windows. The full-screen mode displays operation and monitoring windows in the full screen so as to allow operators who are accustomed to the display panels of the CENTUM CS or earlier systems, to experience a sense of familiarity.

The following new functions have also been developed:

- Long-term data archive function
- Enhanced graphics functions
- Graphic containers
- Assignment of generic names of process data
- Gradations

### 4.5.2 Control Functions

The present system utilizes the same hardware and control program as earlier CENTUMs. In the CENTUM CS 3000, however, the database structures are changed to a fixed-word-length database to speed up on-line maintenance. The reading functions, basic functions and extensive subsystem communication functions of the CENTUM CS's FCS are inherited. In addition to these, the CENTUM CS 3000's FCS supports communication with Foundation™ Fieldbus. An Ethernet card was developed for the PFCS, a compact FCS, to allow data (digital, analog data and messages) in PLCs to be exchanged via Ethernet and to be handled as tag data in the CENTUM CS 3000.

### 4.5.3 System Generation Functions

The CENTUM CS 3000's system generation functions provide the most powerful engineering environment in the history of the CENTUM series.

- Virtual Test: Yokogawa's original function to test the functions of field control stations allows the carrying out of engineering ranging from system generation to debugging to be accomplished on a PC.
- Divided Engineering: Facilitates engineering for expansion and modification of the existing system. Independently generated projects can be integrated into one large-scale system.
- Quick Online Maintenance: The realization of speedy online maintenance through the use of a fixed-word-length database. File Import/Export: Engineering data can be imported and exported from/to files of popular Windows NT-based applications such as Microsoft Excel.
- Graphic Debugging Function: Functional check of graphic windows can be performed without an FCS and HIS. Decreased Setting Items in Builders: Specifications that normally do not need to be set are hidden as advanced settings and set at the default values.

### 4.5.4 Communication Functions

- OPC:
  In the era of UNIX, it was reported that Ethernet and the TCP/ I P protocol standardized supervisory communication. Nevertheless, because the interface for the application layer had not been standardized the specifications of communication between a computer and a DCS varied between vendors. The OPC employed by the CENTUM CS 3000 is becoming a de facto standard in the process automation industry. The OPC server in a CENTUM CS 3000 system supplies almost all data inside the system to supervisory computers. Yokogawa is adapting MES*2 software applications to the OPC technology.
- ActiveX Controls:
  ActiveX is a technology that enables software components to interact with one another in a networked environment, regardless of the language in which the components were created. ActiveX controls are reusable software components that incorporate ActiveX technology and can be used in different machines, because they are machine-independent objects. Hence, a window configured by ActiveX controls can work on a UNIX-based supervisory computer as well as on a Windows NT-based HIS. In other words, such a window can be shared between an HIS and other computers. An HIS of the CENTUM CS 3000 allows ActiveX controls to be embedded in a graphic window to add specialized functionality that could only be achieved by the so-called computer windows in earlier CENTUM systems.
- Field bus:
  The "seamless enhancement" feature of FouNDATioN™ Fieldbus was adopted, enabling the seamless connections of control flmctions, unification of operation and monitoring flmctions, integration of engineering functions as well as the enhancement of functions to improve operability and flmctionality. Even when Fieldbus devices are mixed with conventional analog input/output signals, the system can be built without paying special attention to fieldbuses. The device management function reduces the man-hours required for maintenance, thus resulting in the reduction of the total cost of ownership (TCO).
- General-purpose PLC conununication
  By installing a newly developed Ethernet card and running a user C application inside a compact FCS (PFCS), data can be acquired from the PLCs of various vendors.

### 4.5.5 Batch Control Functions

Batch control had not until recently been standardized because batch processes are applied to diverse industrial sectors, and the product types handled and processes themselves are complex. In the struggle to standardize batch control the Instrument Society of America (ISA) formed ISAISP88, and issued S88.01, the specifications for batch models and terminology, in 1995. These specifications were adopted as an IEC standard in 1997. We have developed CS Batch 3000 as a batch control software package for the CENTUM CS 3000 that is compliant to IEC/ISA standards. For use with CS Batch 3000, we also prepared batch templates incorporating our sound expertise of batch applications, thus allowing efficient startup and cost reductions of a batch control-oriented system.

## V. LAMBDA TUNING FOR LABORATORY SURGE DRUM

The surge drum is the one of the important process unit connected in between two different process units, which enables a smooth flow of liquids. Hence its control improves overall efficiency of the plant. The lambda tuning rule, which provides optimum PID controller settings for surge drum level is implemented using Yokogawa centum CS3000 to control laboratory scale surge drum.

### 5.1 Lambda Tuning Rules

The Lambda tuning rules, offer a robust alternative to tuning rules aiming for speed, like Ziegler-Nichols, Cohen-Coon, etc. Although the Lambda and IMC rules are derived differently, both produce the same rules for a PI controller on a self-regulating process. While the Ziegler-Nichols and Cohen-Coon tuning rules aim for quarter-amplitude damping, the Lambda tuning rules aim for a first-order lag plus dead time response to a set point change. The Lambda tuning rules offer the following advantages: The process variable will not overshoot its set point after a disturbance or set point change.

The Lambda tuning rules are much less sensitive to any errors made when determining the process dead time through step tests. This problem is common with lag-dominant processes, because it is easy to under- or over-estimate the relatively short process dead time. Ziegler-Nichols and Cohen-Coon tuning rules can give really bad results when the dead time is measured incorrectly. The tuning is very robust, meaning that the control loop will remain stable even if the process characteristics change dramatically from the ones used for tuning.

A Lambda-tuned control loop absorbs a disturbance better, and passes less of it on to the rest of the process. This is a very attractive characteristic for using Lambda tuning in highly interactive processes. Control loops on paper-making machines are commonly tuned using the Lambda tuning rules to prevent the entire machine from oscillating due to process interactions and feedback control. The user can specify the desired response time (actually the closed loop time constant) for the control loop. This provides one tuning factor that can be used to speed up and slow down the loop response.

Unfortunately, the Lambda tuning rules have a drawback too. They set the controller's integral time equal to the process time constant. If a process has a very long time constant, the controller will consequently have a very long integral time. Long integral times make recovery from disturbances very slow.

It is up to the controls practitioner, to decide if the benefits of Lambda tuning outweigh the one drawback. This decision must take into account the purpose of the loop in the process, the control performance objective, the typical size of process disturbances, and the impact of deviations from set point.

Below are the Lambda tuning rules for a PI controller. Although Lambda / IMC tuning rules have also been derived for PID controllers, there is little point in using derivative control in a Lambda-tuned controller. Derivative control should be used if a fast loop response is required, and should therefore be used in conjunction with a fast tuning rule (like Cohen Coon). Lambda tuning is not appropriate for obtaining a fast loop response. If speed is the objective, use another tuning rule.

To apply the Lambda tuning rules for a self-regulating process, follow the steps below.

### 5.1.1 Do a step-test and determine the process characteristics

1. Place the controller in manual and wait for the process to settle out.
2. Make a step change in the controller output (CO) of a few percent and wait for the process variable (PV) to settle out. The size of this step should be large enough that the PV moves well clear of the process noise/disturbance level. A total movement of five times the noise/disturbances on the process variable should be sufficient. Refer Fig.5.1.
3. Calculate the process characteristics as follows:

   Process Gain ($G_p$)

   Convert the total change in PV to a percentage of the measurement span.

   $G_p = \frac{\text{change in PV [in \%]}}{\text{change in CO [in \%]}}$
4. Dead Time ($t_d$)

   Note: Make this measurement in the same time-units your controller's integral mode uses. E.g. if the controller's integral time is in minutes, use minutes for this measurement.

   $t_d$ = time difference between the change in CO and the intersection of the tangential line and the original PV level
5. Time constant ($\tau$)

   Calculate the value of the PV at 63% of its total change. On the PV reaction curve, find the time value at which the PV reaches this level.

   $\tau$ = time difference between intersection at the end of dead time, and the PV reaching 63% of its total change

   Note: Make this measurement in the same time-units your controller's integral mode uses. E.g. if your controller's integral time is in minutes, use minutes for this measurement.

### 5.1.2 Pick a desired closed loop time constant ($\tau_{cl}$) for the control loop

A large value for $\tau_{cl}$ will result in a slow control loop, and a small $\tau_{cl}$ value will result in a faster control loop. Generally, the value for $\tau_{cl}$ should be set between one and three times the value of $\tau$.Use $\boldsymbol{\tau_{cl}}$ = 3 x $\tau$ to obtain a very stable control loop. If you set taucl to be shorter than $\tau$, the advantages of Lambda tuning listed above soon disappear.

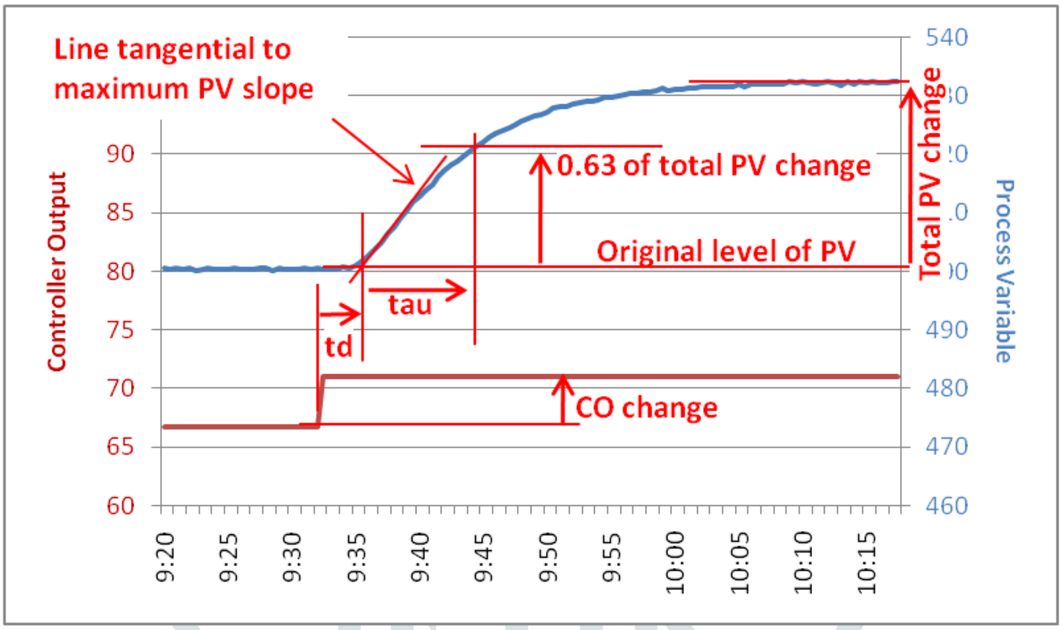


**Fig.5.1 Step test for Lambda Tuning**

### 5.1.3 Calculate PID controller settings using the equations below

Controller Gain ($K_C$)

$$K_C = \frac{\tau}{G_p(\tau_{cl} + t_d)}$$

Integral Time ($T_i$)

$$T_i = \tau$$

Derivative Time (Td)

$$t_d = 0$$

## VI. IMPLEMENTATION OF SURGE DRUM LEVEL CONTROL STRATEGY IN CENTUM CS3000

This section discusses the result obtained during the operation of surge drum controlled by YOKOGAWA Centum CS3000 through various screen shots obtained from the system monitor. The Fig.5.2 show the laboratory surge drum setup interfaced with the DCS system. A capacitive level transmitter is used to measure the level variation in the surge drum. The level transmitter is wired to the analogue input module of the DCS, which accepts 4-20 mA signal. The controller output through the output module of the DCS is wired to I to P converter. 3 to 15 Psi from the converter is connected to the pneumatic actuator of the control valve. The control valve then manipulates the outflow of the surge drum there by the controlling level at a steady nominal value irrespective any change in the feed flow to the drum.

**Fig.5.2 Laboratory Surge drum setup**

**6.1 Open loop Test**

To implement control strategy and thereby to tune the PI controller settings, an open loop model of the surge drum is to be obtained. from the "face plate" tool of the DCS, the controller is initially kept in the manual mode. The controller output is altered to maintain level in the surge drum at a nominal operating value. The controller output is changed suddenly from 50% to 70%. The decrease in the level of the surge drum is monitored using "trend" window. The trend shows a self-regulatory response which is presented in Fig.5.2

**6.1.1 Estimation of Process parameters**

The procedure to find the value of gain '$K_p$', time constant , '$\tau$', dead time '$t_d$' are as follows:

Process Gain ($K_p$) computation:

Convert the total change in PV to a percentage of the measurement span.

$$K_p = \frac{\text{change in process variable [in \%]}}{\text{change in controller output [in \%]}}$$

Time Constant ($\tau$)

$\tau = 1.5(t_2 - t_1)$

Dead time ($t_d$)

$t_d = t_2 - \tau$

Where,

$t_1$ =28.3 % of steady state value

$t_2$ =63.2 % of steady state value

Calculate the value of the PV at 63% of its total change. On the PV reaction curve, find the time value at which the PV reaches this level

$\tau$ = time difference between intersection at the end of dead time, and the PV reaching 63% of its total change

The Fig 5.3 , Fig.5.4 and Fig.5.5 shows the screen shot of the three different windows like face plate, tuning window and trend window and the various steps involved in the estimation of process parameters. The process parameters are calculated from the trend using tools within trend window.

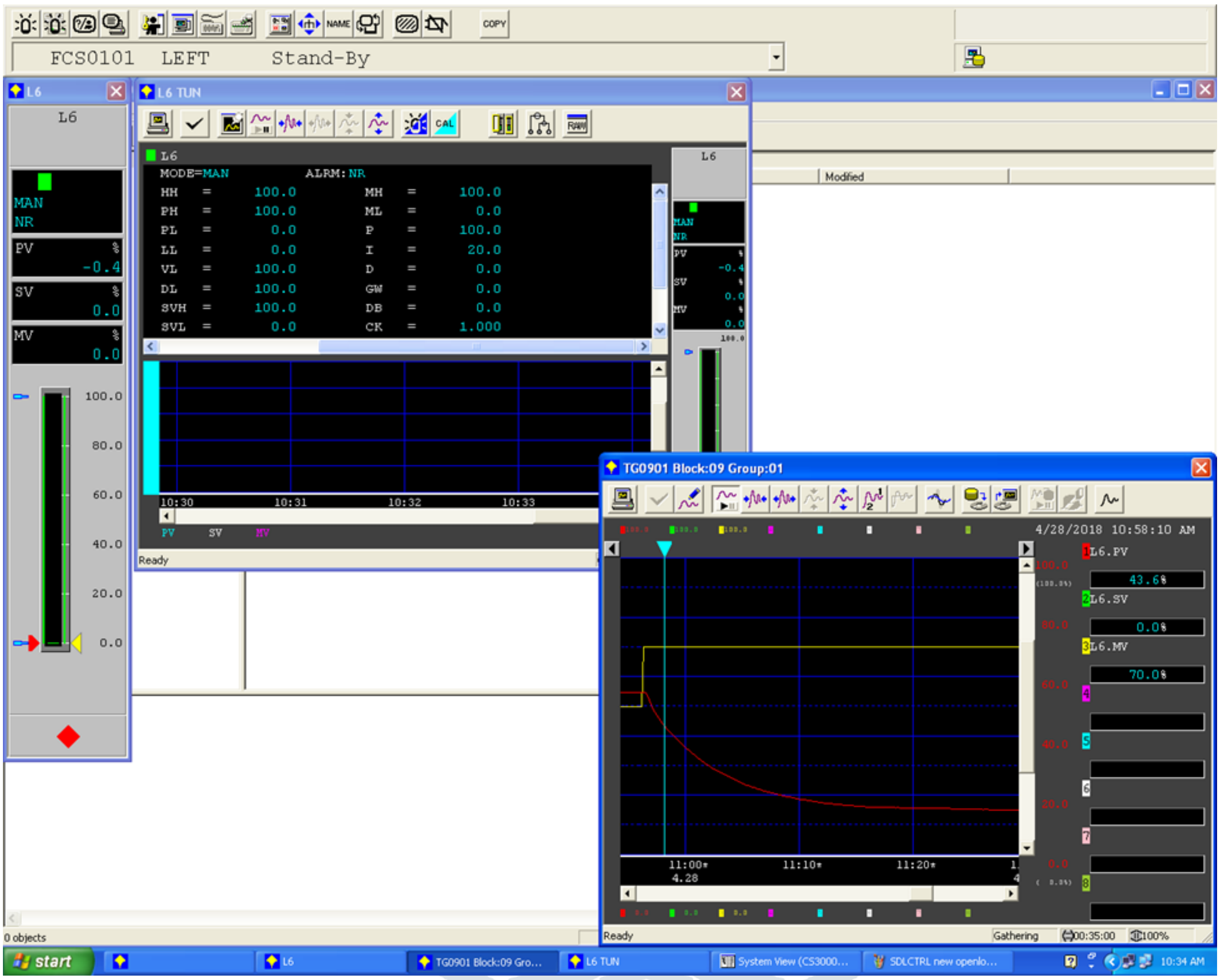


**Fig. 5.3 DCS display screen showing Open loop step response for MV change from 50%-70%**

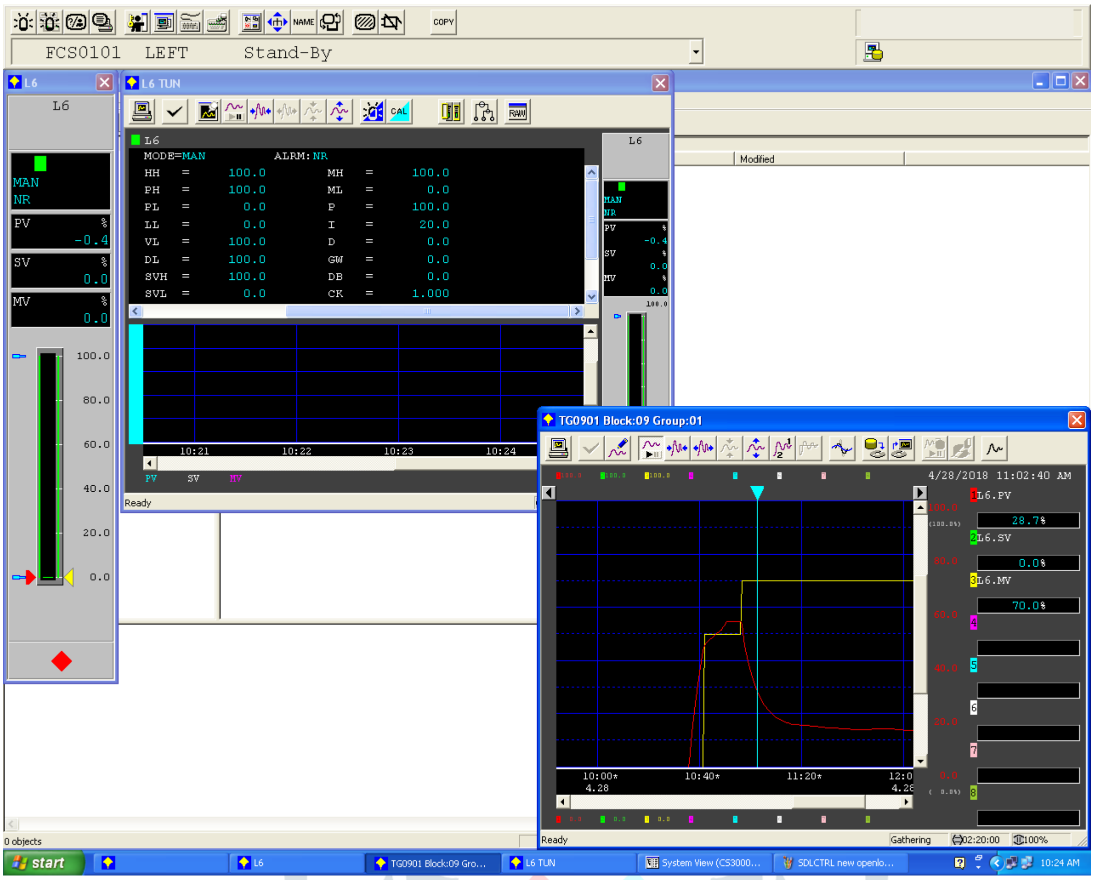


Fig.5.4 DCS display screen showing Computation of $t_1$ from Open Loop Response

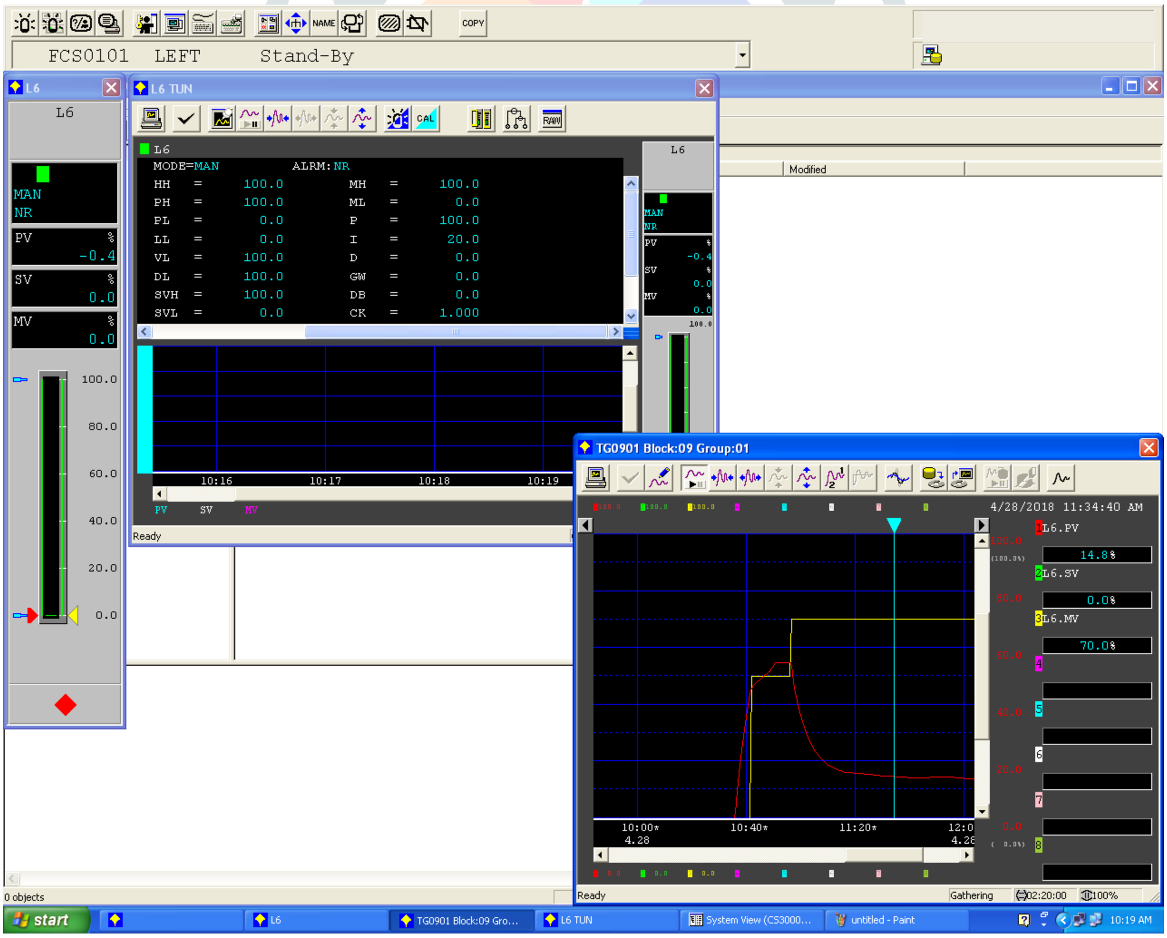


Fig.5.5 DCS display screen showing Computation of $t_2$ from Open Loop Response

### 6.2 Closed loop responses

The closed loop operation of the surge drum is performed by DCS by feeding controller settings obtained through Lambda tuning technique. Initially, the surge drum level is brought to the nominal operating values by manipulating valve position in manual mode, adjusted from the face plate tool of DCS. The closed loop response is obtained by putting DCS in auto mode through face plate window. The trends of PV, SV and MV are represented in different colours for easy identification.

#### 6.2.1 Drum level control for various values of %PB and $T_i$

The closed loop responses for surge drum control is obtained for various values of controller gains. The Fig.5.6 shows the DCS display screen showing the closed loop servo response for the value of %PB=100 and $T_i$=20 min.

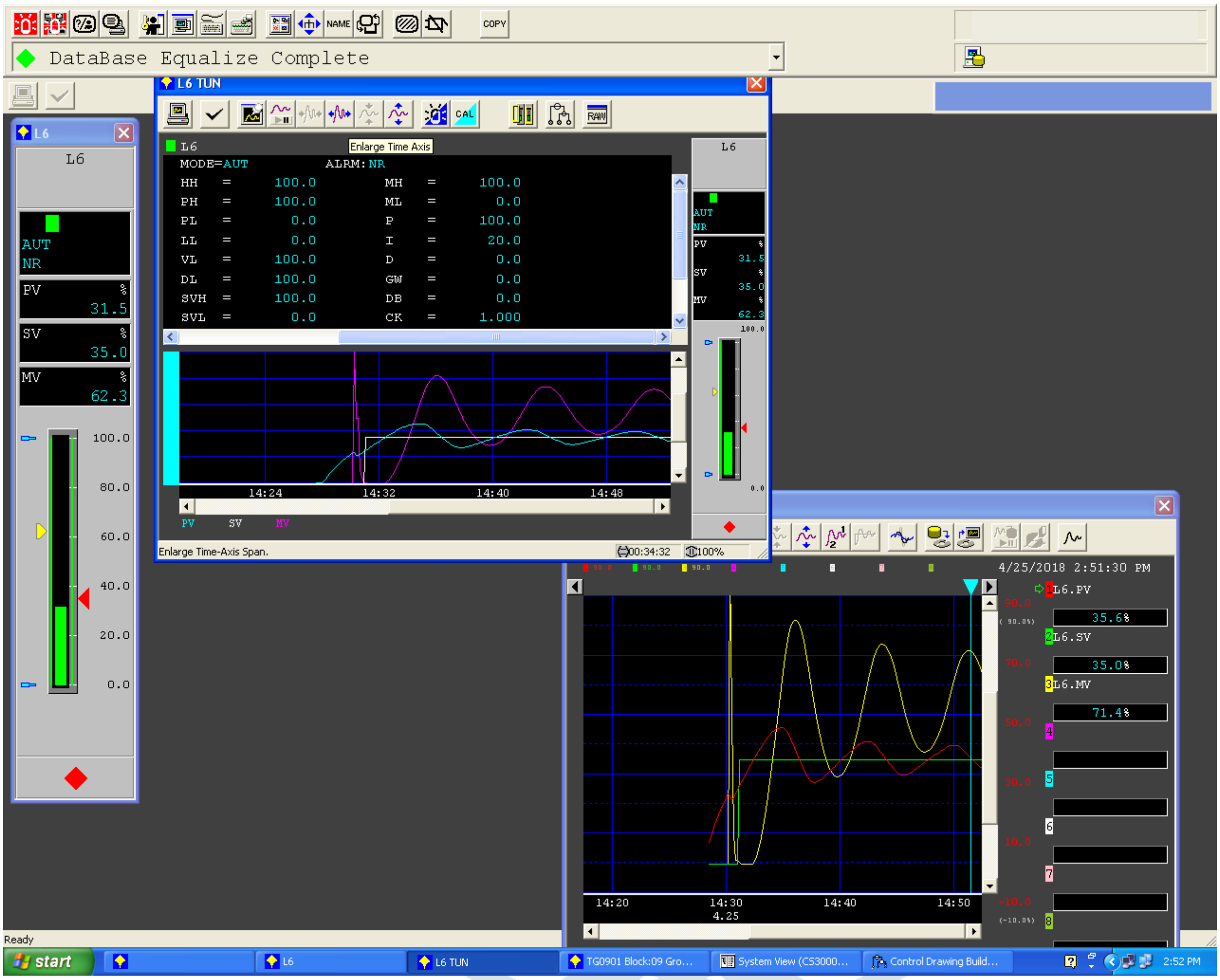


**Fig.5.6 DCS display screen showing the closed loop servo response for %PB=100 and $T_i$ =20 min**

The setpoint of the surge drum is varied around the operating point and the setpoint tracking feature is assessed for different values of controller constants and is shown in the Fig.5.7

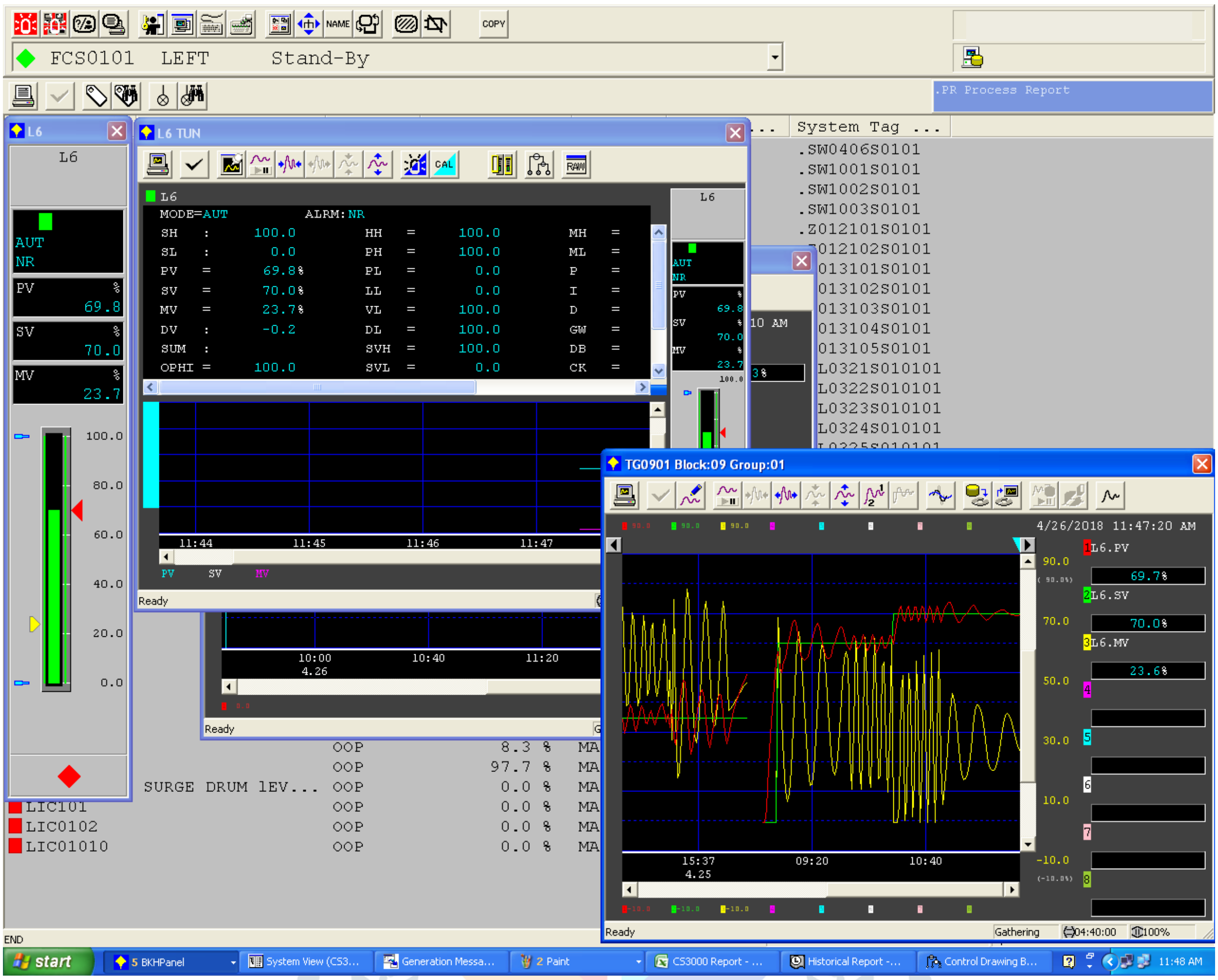

**Fig.5.7 Closed loop servo tracking response of surge drum level for %PB=30 & $T_i$=70min**

The regulatory behaviour of the surge drum level control is studied by bleeding the surge drum suddenly by means of bleed valve, which is a gate valve manually. The Fig 5.8 shows the regulatory behaviour of the surge drum level control for the value of controller constants computed from the Lambda tuning rule.

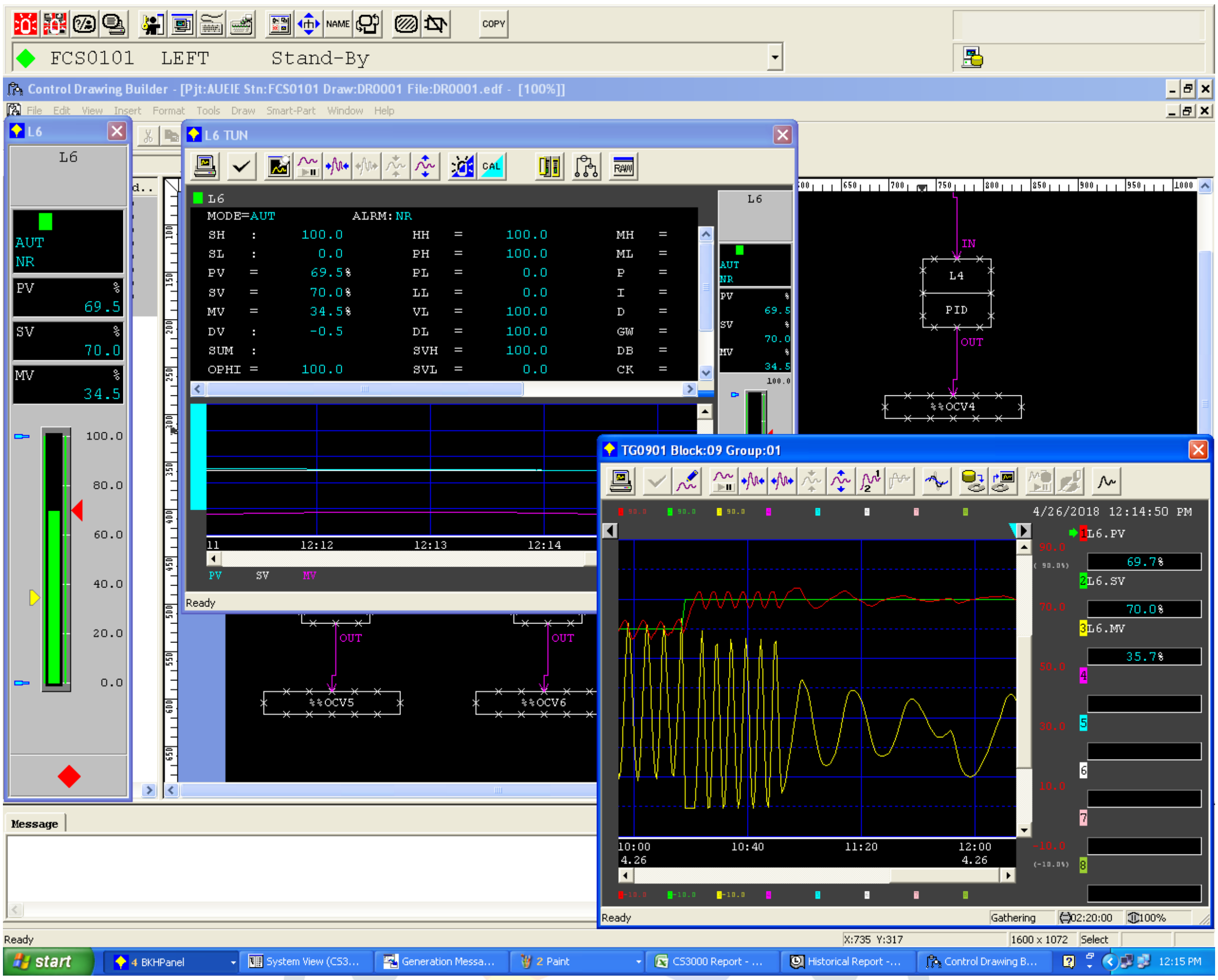


Fig.5.8 Regulatory response of surge drum level for %PB=30 & $T_i$=70

## VII. CONCLUSION

The surge drum is one of the important process unit, guarantees a smooth flow of feed and product in and out of the reactors in refineries and petro chemical industries. Surge tank in the hydro power plant prevents water hammer and related issues in the turbine and penstocks. The control of surge drum level is totally a different one when compared to the storage tank level control or any other vessel level control. A tuning strategy like lambda tuning provides better result compared to conventional tuning rules like Ziegler- Nichols. This paper demonstrated the implementation of control strategy for laboratory scale surge drum using Yokogawa Centum CS3000 DCS.

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