STATE OIL COMPANY OF AZERBAIJAN REPUBLIC

BAKU HIGHER OIL SCHOOL

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Bachelor's Thesis

Title: **Design of Level Control Loop by Control Valve at BHOS Emerson Test Rig**

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Abstract

Level control loops are widespread and necessary in the industry to monitor and control the process properly, and to ensure the safety and efficiency of the plant. If the level of the substance is not properly measured or maintained correctly, it can result in production loss, the damage to the equipment and process. Therefore, control loops will always carry out the following three actions in order to avoid undesirable situations: measurement, comparison, and modification.

In order to maintain the stability of the system and perform the mentioned tasks, level control loop technologies of BHOS test rig are selected according to the system requirements. This system comprises the needed components for automated control: the sensing device, the disturbance source, the controller, and the final control element (FCE). Firstly, the level transmitter measures tank level and sends a signal to the related level controller. Guided-Wave-Radar level/interface transmitter is selected as it has a long measuring range and less sensitivity to the disturbances. Then, the controller compares measured value with the desired value and transmits a control action to FCE. The best-suited algorithm for controlling the system is Proportional-Integral - PI control. If required, the controller can be tuned using Trial-and-Error approach. Lastly, the valve receives a control action and opens to allow some liquid to exit the tank. The globe valve is selected as it is most suitable for full-range flow control situations. In addition, the inlet pump speed can be altered and disturbance to the system can be created by altering the frequency of the Variable-Frequency-Drive.

As a result of technology review and design of the loop for the test rig, technical documentation used at various phases of the project will be created for the system. As a contribution to the future curriculum, lab work instructions will also be prepared based on the project.

Referat

Səviyyə tənzimləmə dövrələri sənayedə prosesi düzgün izləmək və nəzarət etmək, zavodun təhlükəsizliyini və səmərəliliyini təmin etmək üçün geniş yayılmışdır və zəruridir. Maddənin səviyyəsi düzgün ölçülməzsə və ya düzgün qorunmazsa, bu, istehsal itkisi, avadanlıq və prosesin zədələnməsi ilə nəticələnə bilər. Buna görə də, nəzarət dövrələri arzuolunmaz halların qarşısını almaq üçün həmişə aşağıdakı üç hərəkəti yerinə yetirəcək: ölçmə, müqayisə və tənzimləmə.

Sistemin dayanıqlığını qorumaq və qeyd olunan vəzifələri yerinə yetirmək üçün BANM-ın Emerson sınaq qurğusunun səviyyəyə nəzarət dövrə texnologiyaları sistem tələblərinə uyğun olaraq seçilir. Bu sistem avtomatlaşdırılmış idarəetmə üçün lazım olan qeyd edilən komponentlərdən ibarətdir: sensor cihaz, narahatlıq mənbəyi, kontroller və son idarəetmə elementi. İlk öncə səviyyə transmitteri çən səviyyəsini ölçür və müvafiq səviyyə kontrollerinə siqnal göndərir. Güdümlü-Dalğa-Radar səviyyə və interfeys transmitteri geniş ölçmə diapazonuna və narahatlığa daha az həssas olduğuna görə seçilmişdir. Sonra kontroller ölçülmüş dəyəri arzu edilən dəyərlə müqayisə edir və nəzarət hərəkətini FCE-yə ötürür. Sistemin idarə edilməsi üçün ən uyğun alqoritm Proporsional-İnteqral - PI nəzarətidir. Lazım gələrsə, kontroller Sınaq və Səhv metodundan istifadə etməklə sazlana bilər. Sonda klapan nəzarət hərəkəti qəbul edir və mayenin çəndən çıxması üçün açılır. Qlobus klapan tam diapazonlu axın nəzarəti vəziyyətləri üçün ən uyğun olduğuna görə seçilmişdir. Bundan əlavə Dəyişən Tezlik Sürücüsünün tezliyini dəyişdirməklə giriş nasosunun sürəti dəyişdirilə və sistemdə narahatlıq yaradıla bilər.

Texnologiyanın nəzərdən keçirilməsi və sınaq qurğusu üçün dövrənin dizaynı nəticəsində sistem üçün layihənin müxtəlif mərhələlərində istifadə olunan texniki sənədlər yaradılacaq. Gələcək kurrikuluma qatqı olaraq layihə əsasında laboratoriya işi təlimatları da hazırlanacaqdır.

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Introduction

Level control systems are widespread in industry as they are crucial for ensuring the safety and profitability of plant processes. Principally, the primary objective of level measurement is to determine the location of the surface of a liquid, solid, slurry, or the interface between two liquids in tanks, silos, or reactors. In addition, level systems are essential for safety, detecting leaks, and preventing overfilling. If the amount of a liquid, solid, or liquefied gas is not properly monitored and maintained, it might seriously harm equipment and lead to an unwanted change in product quality or production loss.

In a variety of industries and applications, control loops are established to keep a process variable at a specified value - the set point. They are essential for maintaining the system's stability and continually generating the intended result. This system includes the sensing device, the controller, and final control elements (FCE), all of which are necessary for automated control.

In order to obtain a proper, safe, and accurate level measurement, measuring equipment must be chosen based on an evaluation of the technologies and suppliers, as well as the characteristics of the given system. Level sensors can involve a contact or non-contact measuring principles. The temperature or pressure of the process material may alter the reading of the sensor, deteriorate it, or cause other additional complications.

The crucial loop component – a controller reads sensor signals and decides controller action by comparing that reading with the desired setpoint. The PID Algorithm is a typical kind of feedback control in which the combination of integral and derivative controls reduces or eliminates the offset, and the involvement of proportional control increases the response time. Using this approach or minor modifications, the majority of these feedback loops can be successfully controlled.

FCEs, that obtain the controller action, are the final devices alter process variable to target output. There are various common FCEs of the control system, such as a control valve, Variable Frequency Drive, or solenoid valve. Although VFDs have economic benefits, they will not function correctly at extremely low speeds. In order to obtain a wide variety of system speeds, a control valve can be introduced into the control system. The chosen control valve modifies the fluid flow to substitute for the load disturbance and holds the process variable close to the intended set point.

Good technical documentation is the most valuable asset in managing a facility. There are several types of documentation, ranging from complicated schematics to basic layout drawings. In addition, it contains part listings, the specifications of operation, order data, preventative maintenance methods, configurations, training manuals, and any other useful paperwork. P&IDs, loop diagrams, and equipment manufacturer's documentation could be the most commonly utilized documents during maintenance operations. If the process or its controls undergo any modifications, the appropriate P&ID and loop diagrams are automatically altered.

1. Overview of the technology

Level measurement is used in a vast array of applications and might entail the measurement of slurries or microscopic granules as well as liquids. Some processes require level to be measured with a high degree of precision, while others require simply an approximation of level. There is a vast selection of devices available to fulfill these diverse requirements.

The cost of simple equipment like dipsticks and float systems is quite reasonable. Although they only provide limited measurement precision, they are more than enough for applications and are widely used. For applications requiring a higher accuracy, a number of devices with increased precision are also available. Pressure-gauge, ultrasonic, radar, and radiation devices are among the often-used equipment that provide accurate measurements. There are also a variety of gadgets that are utilized less frequently.

1.1. Level measurement

Continuous and Single-Point measurement

There are several variants of liquid sensing devices, and they may be categorized into two primary groups. These two categories comprise sensors for single-point detection of liquid levels and sensors for continuous sensing of liquid levels. Different processes require the advantages of a continuous detection method, while others may profit more from point level detection.

Single Point Measurement

A sensor made for point-level detection may detect the presence of liquid at a specific location within a tank. Typically, this is meant for procedures requiring management of low or high levels. The majority of the time, they operate as a switch to activate a feature whenever the tank level reaches a specified level, either by rising or falling. This may be to activate a device or to sound an alert. The sensing device detects once the liquid has passed the necessary level and works as a switch to initiate the appropriate reaction.

Limit level monitoring is utilized to guarantee that monitored substances do not exceed or drop below a predetermined threshold. This method of measuring helps prevent overfilling of containers and pump failure. The primary purpose of level sensors is fast and accurate measurement of the data. For point level measurement, sensors such as Single- or Multi-point level switches, Mechanical Floats and Vibrating-Tuning Fork switches are employed.

Figure 1.1. Point Level Measurement devices

Continuous Measurement

Continuous liquid level measuring sensors are developed to detect the liquid level at all points within a tank or container. This means that input is delivered independent of liquid level or container range. This is advantageous for procedures in which it is constantly essential to monitor the level of the liquid, and for the processes requiring more precision.

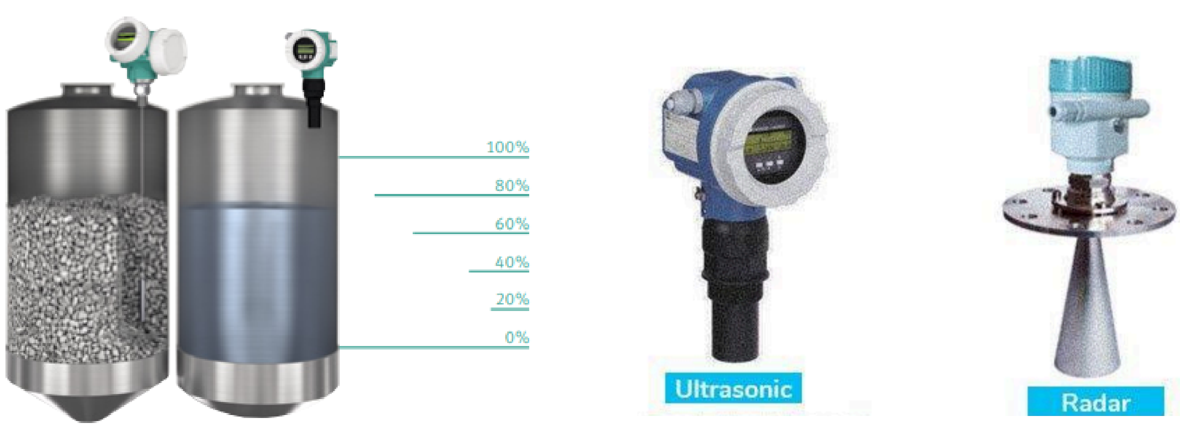


Figure 1.2. Continuous Level Measurement devices

Using continuous detection, the media fill level is always checked. Continuous level monitoring contains a range of vital information that enables precise process management, such as the precise rate at which materials are used, information related balance, and loss control. Radar, Guided-Wave-Radar, Ultrasonic and Magnetic sensors are the examples for continuous level measurements.

Non-contact level measurement

When selecting contact-type sensors, one should always take into account if whether it is a corrosive material and could potentially destroy the measuring device; whether that is volatile or a contact sensor could end up creating a hazardous condition; whether temperature, pressure, as well agitation of the process fluid might impact the reading or malfunction the sensor; and any other potentially problematic circumstance.

In non-contact measurements, no component of the measuring system makes direct contact with the object being measured. They employ more complex measurement concepts that would not necessitate physical touch with the material being measured. This increases their cost, but also their adaptability.

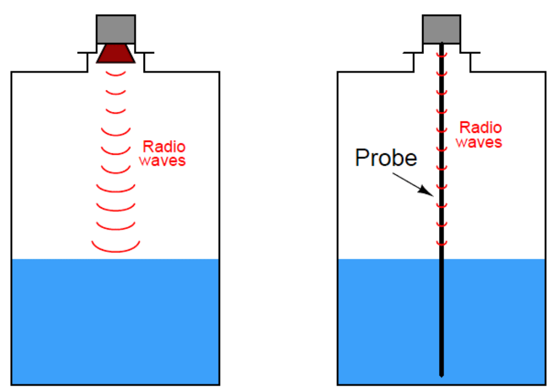


Figure 1.3. Non-contacting and Contacting Level Measurement

Beginning with the basic, the three primary types are as follows:

Ultrasonic level sensors

In ultrasonic sensors, the time it takes for a sound wave to return to the sender is used as a measure of distance. The transit time may be computed since the sound speed is known. These sensors are non-contacting, robust, and accurate; there are no moving components, and they are insensitive to changes in density, contact, or conductivity.

Measuring principle

A block schematic of a typical ultrasonic level measuring system can be seen in Figure 1.4. The transmitter circuit generates the sound waves, and the transducer transmits them. The substance or level measured reflects these sound waves. The sound wave that is received by the transducer is converted to electrical signal. In order to shape the wave, a receiver/amplifier circuit amplifies this signal. The operations of the measuring system are synchronized using a timing generator. The time elapsed between sending a signal and receiving an echo is recorded by the device. The distance between these transducers and level being sensed is proportional to the time elapsed.

Limitations

- The foam may absorb the signal, hence it cannot be utilized for foam
- In a vacuum, it will not function.
- Several variables, including instrument precision, vapor concentration, temperature, humidity, and other gases or vapors pressure, may influence the overall performance.

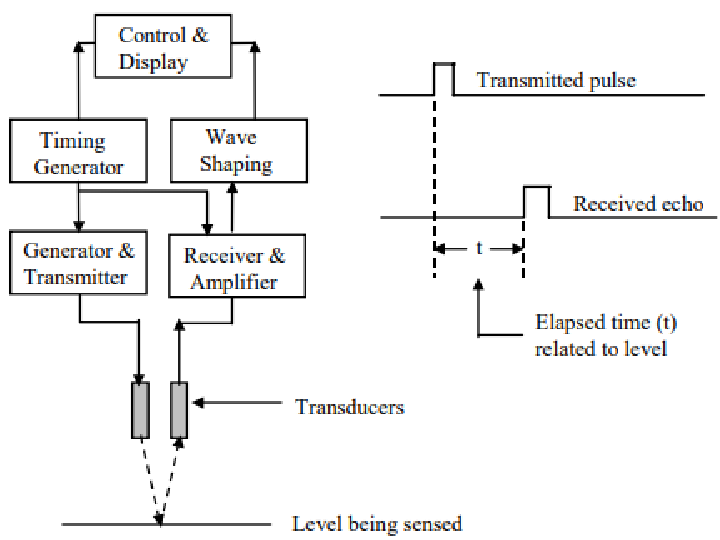


Figure 1.4. Block diagram of ultrasonic measuring system

Radar level sensors

Radar devices function by sending microwaves, which have high frequency – GHz, and tracking their return journey to a level surface. In this regard, they are comparable to ultrasonic measuring devices. Nevertheless, radar has a special advantage over ultrasonic due to sound intrinsic restrictions. For instance, vapors are a common source of mistake in ultrasonic measurement since they alter the speed and intensity of propagation.

As illustrated in Figure 1.5, there are two types of radar level instruments: non-contacting and guided wave. In the non-contacting form seen in Figure 1.5 a, when the radar pulse is delivered into the air, it rapidly weakens and disperses. The liquid surface reflects the signal back to the device. The intensity of reflected pulse is exactly proportional to the liquid's dielectric constant. Hydrocarbon fluids, which have lower dielectric constants, reflect relatively little of the signal. On its return to the device, this weak signal loses further energy until the intensity of the signal received is less than one percent of its initial strength. By absorbing the radar signal, liquid turbulence and certain foams will further disrupt the measurement.

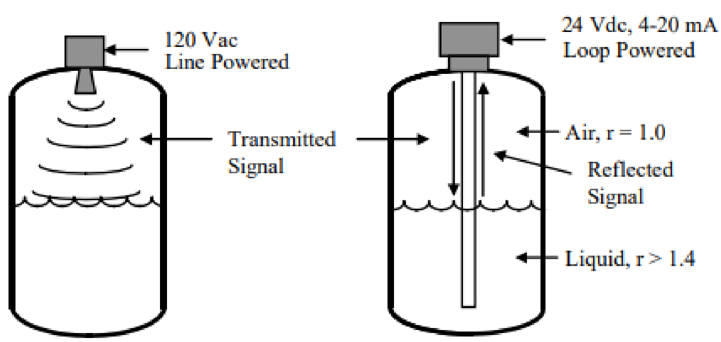


Figure 1.5. Block diagram of radar measurement system a) Non-contact b) Guided-wave

Limitations

The applications for radar instruments are quite particular. Solids should not be measured by radar due to the reflection of weak signal.

Advantages

- Used for challenging "hard-to-handle" situations and processes
- Offers high accuracy
- Does not have a contact with the medium measured
- Identify any obstacles in the material.

Applications

This measuring concept offers non-contact, continuous level monitoring for liquids, solids, and powders at high temperature/pressure, vacuum, vapor, and violent and poisonous substances. Typically, radar level measuring system is employed when temperature and/or pressure are problematic.

Nuclear level sensors

Because nuclear radiation devices can see through tank walls, they may be installed externally on process equipment. This lowers installation and repair expenses.

Figure 1.6 illustrates two common nuclear level sensors. The nuclear level device depicted in Figure 1.6 a is comprised of a single lower-level gamma-ray generator on one side and a radiation detector on the opposite side of the tank. As seen in Figure 1.6 b, the level may be determined with more precision by putting multiple gamma sources at various heights above the tank. Since the substance in the tank has distinct transmissibility properties than air, the sensor can generate an output signal that is proportionate to the material level in the tank or container.

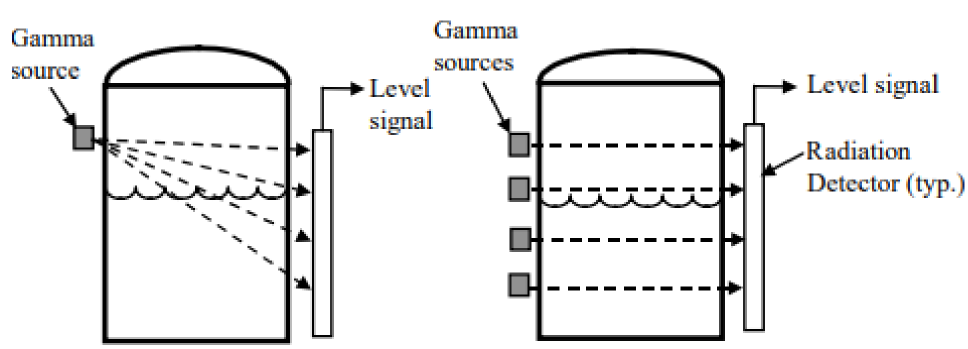


Figure 1.6. Nuclear level sensors a) Single-gamma source b) Multiple-gamma sources

1.2. PID controller

A Closed-Loop Control System

It is a system in which the outcome affects input quantity, so that it modified itself in response to the output produced. It may be characterized as a system with a feedback loop or a control system that generates output using a feedback signal. This system's stability can be regulated through a feedback mechanism. Any open-loop control system may be converted to a closed loop by incorporating a feedback mechanism.

The four basic components of a process control are process, measurement, evaluation, and control. Figure 1.7 demonstrates a relationship block diagram of these components. Additionally, the figure depicts the disturbances that enter or influence the process. If there were no disruptions to a process, the control system would be unnecessary. Figure 1.7 also depicts the process input & output as well as the control setpoint.

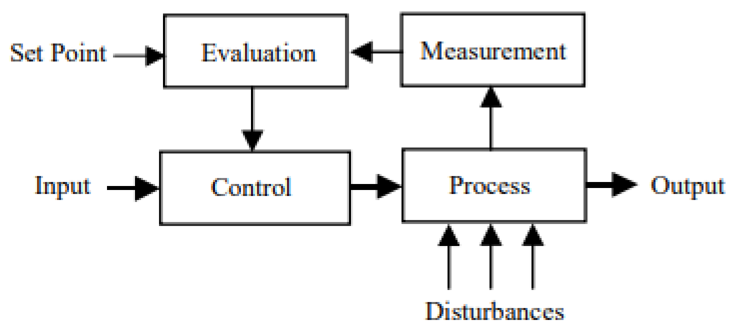


Figure 1.7. Four main elements of a control system

To control a process dynamic variable, it is necessary to know information about the variable or entity itself. By measuring the variable, this information is acquired. The term measurement involves the transformation of a process variable to a digital or analogue signal that may be utilized by the system. The equipment that takes initial measurement is referred to as a sensor or an instrument. Pressure, Temperature, Level, Flow, as well as position, and speed are typical units of measurement. The outcome of every measurement is the transformation of a dynamic variable to proportional data required by other components in the process or sequence.

In the assessment phase of the process sequence, the measured value is compared to the target value or a setpoint, and the degree of corrective measures required to maintain appropriate control is decided. This assessment is performed via a controller. The FCE in a loop is the device that takes an input from the controller and performs a proportional action on the process in response. Typically, this control element will be a control valve that modifies the process fluid flow. As the control elements, devices such as electric motors, pumps, and dampers may also be utilized.

PID controllers are the most popular control algorithm. Using this approach or minor modifications, the majority of these feedback loops can be successfully controlled. PID Algorithm is a typical kind of feedback control in which the combination of integral and derivative terms offers a lowered or zero offset, and the integration of P control gives a faster response. The integral component of PID controllers removes the offset, which is a significant drawback of the P-Only controller. In addition, the integral control of the PID controller evaluates how long process variable has deviated from the target setpoint, whereas the proportional term simply analyzes the present inaccuracy. The derivative control in the following PID equation considers the rate of change of error or PV at the present time. PID algorithm is characterized by the following:

where u represents controller signal while e represents an error. Controller signal includes three modes: P-mode, I-term (integration of error), and D-term (derivative of error). Controller parameters are K - proportional gain, Ti - integral time, and Td - derivative time.

Proportional term

The easiest approach to linear control is defined by a constant connection of input and output of controller. Variable P-mode parameter Kc can also be referred as proportional gain. Generally, it can be represented as a function of PB - per cent proportional band, that is inversely proportional to proportional gain, as demonstrated:

$$Kc = 100 / PB$$

The proportional control is only responsive at the present moment. It cannot assess the past history error, or potential effects of error trends. This term just reacts to the current amount of error. Moreover, it reacts proportionally to all the faults almost in same way. The primary constraint of proportional control is its inability to keep controlled variable near desired setpoint.

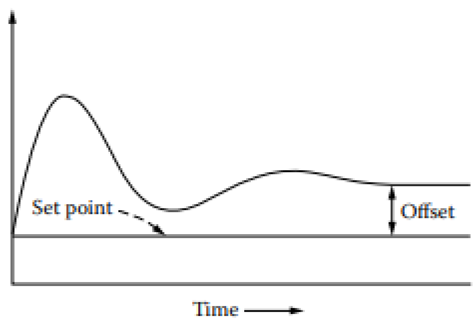
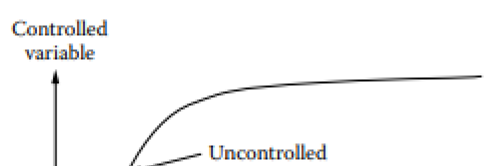


Figure 1.8. Proportional mode

Integral term

It is known as reset mode upon a change in load, this mode resets control variable to desired setpoint and removes undesired offset, whereas a proportional mode cannot. It has been implemented to remove the offset that standard proportional control cannot reduce. As P-mode disregards the error's prior history, offset will arise from proportionate action. In contrast, I-mode removes offset by continually integrating the region under error curve while continuously analyzing complete previous error history.

Figure 1.9 depicts the uncontrolled process variable behavior to a load change under Proportional, Integral, and PI actions.



Derivative term

The P-term evaluates current value of system error, meanwhile the I-term considers error's previous history, whereas the derivative action predicts the future trends of the error and responds accordingly. It is not sufficient for huge processes to react to such error after this has established, as these vast processes inertia makes a prevention, or correction of a trend exceedingly tough once already formed. Goals of the D-mode are to forecast errors prior to their occurrence in system and take preventative measures.

In order to limit the ultimate deviation, rate action uses a predictive technique, which delivers a large initial control output. Figure 1.10 illustrates the usual open-loop response. It is clear that the derivative mode provides a significant, immediate control signal that restricts deviation. After this step, proportionate action is taken.

When SP is constant, the derivation of e(t) is equal to negative derivation of PV, as e(t) = SP – PV. Thus, derivation of e(t) becomes proportional to derivation of PV for all periods unless setpoint changes. Derivative on error creates derivative kick at the controller output as the desired SP concurrently shifts. After the setpoint is modified, error value fluctuates abruptly, resulting in an undesirable control output known as derivative kick. As shown in Figure 1.11, when measurements on both PV (PV derivation) and error (error derivation) are examined, the difference seems to be that the derivative kick emerged in measurements on error.

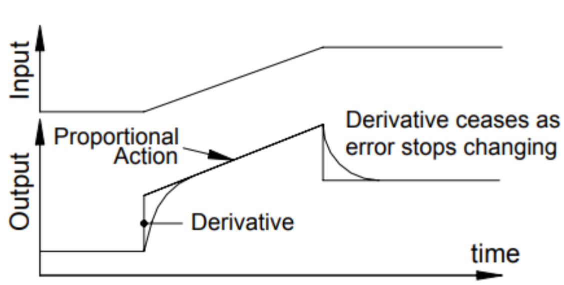


Figure 1.10. Open-Loop Response of Proportional & Derivative Terms

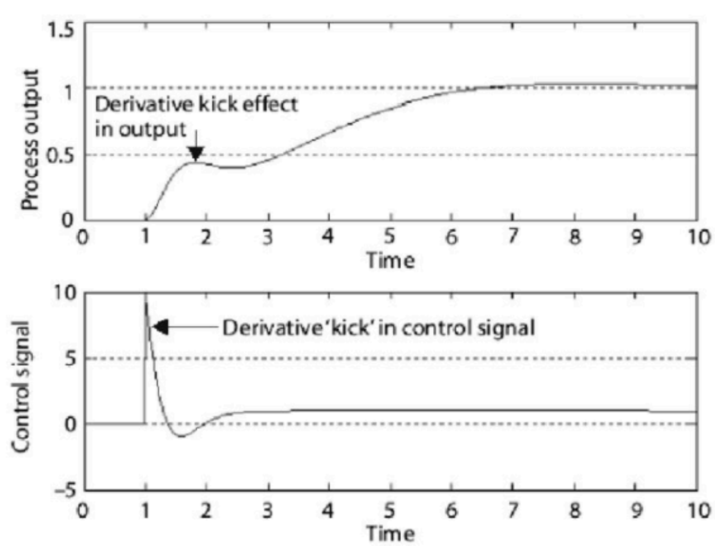


Figure 1.11. Derivative kick

1.3. Variable Frequency Drives

It is a device that regulates the voltage or frequency provided to a motor, hence regulating the motor speed and the system it is operating. By satisfying process requirements, the system's performance is enhanced.

A VFD may vary induction motor's speed or torque. Hence, it allows speed control of process across a continuous range. AC induction motors or motors with a constant speed suit the majority of systems. In these systems and applications, flow and pressure are regulated by control devices like dampers and valves. As a result of their throttling function, these devices typically produce inefficient operation and power losses.

It is frequently desirable for a motor to run at multiple separate speeds, or at varying speeds. Frequently, the traditional control components can be replaced with varying speed operation utilizing a VFD.

The feature of a VFD is to vary motor speed to meet the needs of a driven load. The outcomes are improved process control and decreased energy use. VFD technologies are quite costly, but they offer an exceptional level of control over industrial processes. In most circumstances, the decrease in energy expenses resulting from the VFD installation is sufficient to balance, if not entirely cover, the high initial costs. In the selection process , the application nature, the cost, and the operating environment are of utmost importance.

VFDs have several standard applications as process controls that are uncommon for other forms of variable speed control systems. VFDs are ideally suited to centrifugal loads when energy conservation is the primary aim. As a result of its adaptability in automatic process control systems, it is also widely used for continuous torque loads. Before selecting a VFD, the process must be extensively studied to determine its compatibility with the VFD.

Primary elements of VFDs

Most of them have three fundamental components:

- A rectifier transforms the fixed frequency ac to dc input voltage.
- An inverter converts rectified dc voltage to an ac output voltage with adjustable frequency.
- The dc bus links the rectifier and inverter.

A series of controls guides the rectifier and inverter to generate the necessary ac frequency or voltage to fulfill the system's requirements at any given time.

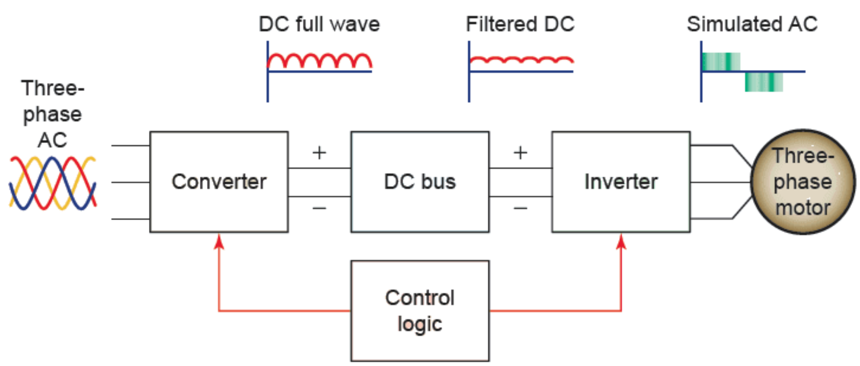


Figure 1.12. Components of VFD

VFD Operation

Pulse-Width Modulation is a technique used by electronic VFDs to alter the voltage or frequency of an induction motor. VFDs are the favored choice for variable speed systems since they are reasonably affordable and dependable. VFDs utilize the insulated-gate-bipolar transistors as power semiconductors. With PWM, the motor's speed and torque characteristics may be modified to fit the required load.

A microprocessor controls the entire procedure and monitors the following:

- Input voltage supply
- Setpoint of the speed
- Voltage of the DC link
- Output current and voltage to guarantee motor operating within specified limits.

The AC input voltage is converted to DC using a rectifier as the first stage in the PWM technique. Filter capacitors smooth out voltage waves in DC power. The DC

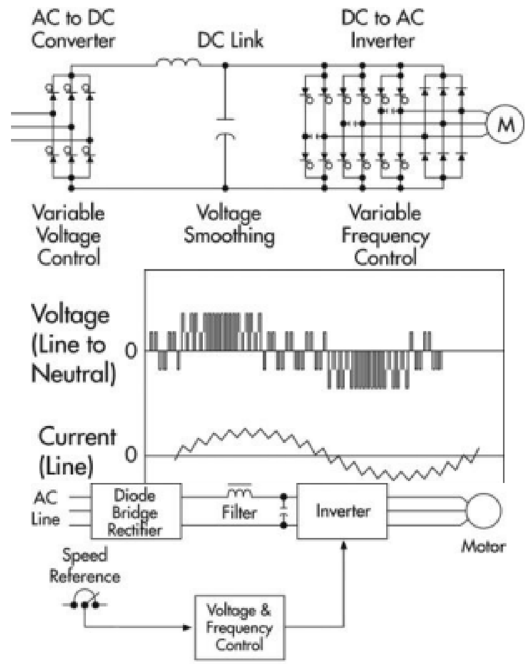


Figure 1.13. Schematic of a usual PWM VFD

bus link is a term used to describe this part of the device. DC voltage is then transformed back to AC. PWM is common technique utilized to convert power-electronic components like IGBT power transistors. High-rate switching of output voltage causes the pulse width, or on-time, to be adjusted to approximate the sinusoidal waveform.

In most cases, the fundamental drive applications, reference for speed is a setpoint. Process controllers, like PLCs, are used to give the reference in increasingly complex applications.

1.4. Control Valves

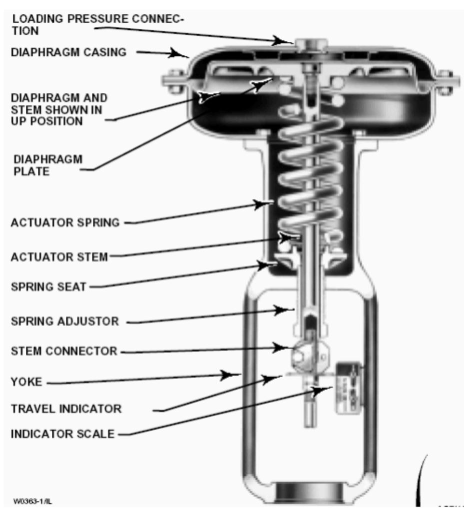
Control valves are the most prevalent part of final control in process control industries. It controls a fluid flow, including water, gas, or steam for the compensation of the disturbance load and maintaining the controlled process variable as near to the intended set point as possible.

The primary components of a control valve are the Actuator and the Valve Body Assembly. The valve body offers a variable entrance for the flow of process medium through it, while the actuator provides a force or motion to the valve in order to open or close it.

Actuators

This pneumatic device provides force or motion for opening and closing a valve. With a rise of pneumatic pressure applied, they are intended to make the valve move in the direction of opening or closing. These types of actuators are addressed as Fail-Open or Air-To-Close or Direct-Acting Actuators and Fail-Close or Air-To-Open or Reverse-Acting. A positioner is connected to the actuator to provide air pressure according to the control input to identify an actuator position.

Positioners



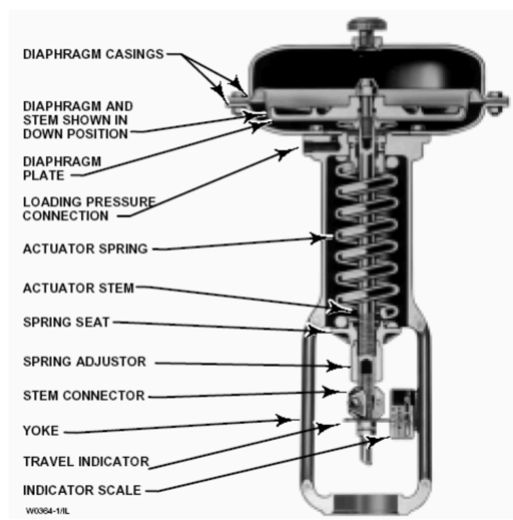


Figure 1.14. a) Direct-Acting Actuator b) Reverse-Acting Actuator

A positioner is required for pneumatically controlled valves to convert a control action from a controller into valve travel. It receives a pneumatic signal - typically 3 to 15 psig and interprets this into a desired valve position to provide the valve actuator with the necessary air pressure to change the valve to the desired position. The I/P converter - current to pressure converter is utilized to convert the 4-20mA signal from the controller into 3 - 15 psig air pressure in order to transmit a pneumatic signal to the positioner for the positioning of the valve.

Valve Body Assembly

The Figure 1.15 below depicts the basic body assembly of the control valve. This consists of the bonnet assembly, the bottom flange, and the valve trim. The trim contains the valve plug – closure member, which can open, close, or partly obstruct one or more ports. Connecting the actuator stem to the closing member is the valve stem.

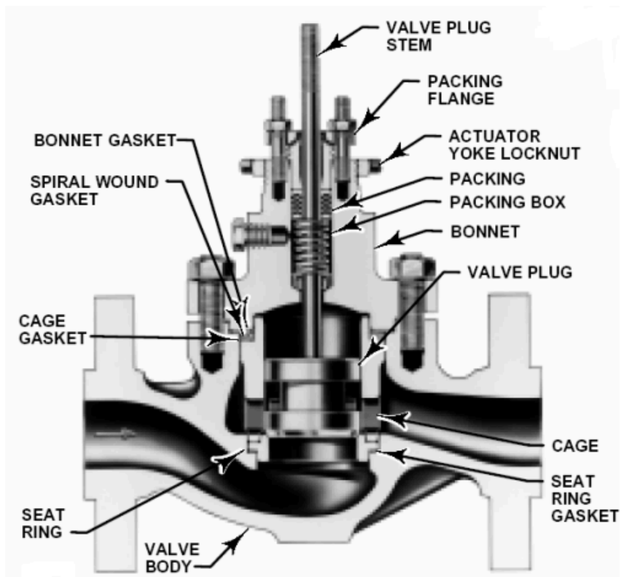


Figure 1.15. Valve Body

According to the needed flow characteristics, the shape of the cage's plug or window opening is designed. Typically, three types of *flow characteristics* are used:

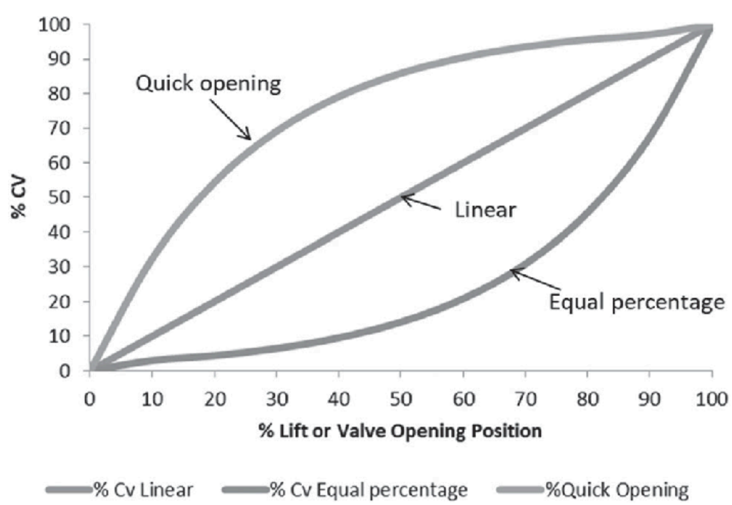


Figure 1.16. Flow Characteristics Curve of Valve

- **Linear**: This type of flow characteristics results in a flow rate that is precisely dependent on valve plug travel across the whole travel range. For example, flow rate is 25 percent of maximum amount of flow at 25 percent of rated trip. Changes in flow rate are proportional to the movement of the valve plug. Typically, linear valves are required for liquid level and flow control applications that need constant gain.
- **Quick-Opening**: At low trips, a quick-opening type of the valve gives the highest change in flow rate. The curve is essentially linear during the 40 percent of the valve plug's travel firstly, after which there is a negligible flow rate increase as the trip nears the fully open position. This type of the valves is extensively applied on the on/off applications in which a high flow rate must be achieved rapidly as the valve opens. They are typically employed in applications involving relief valves.
- **Equal-Percentage**: This type enables accurate throttle control in the lower section of travel range of the valve and quickly rising capability as the valve plug approaches the fully open position. These valves are applied on applications in which the intake pressure falls as the flow rate increases. This is a typical occurrence in physical systems, hence equal-percentage is utilized often.

Types of valves

There are various shapes and mechanisms for the components that adjust the flow via the valve:

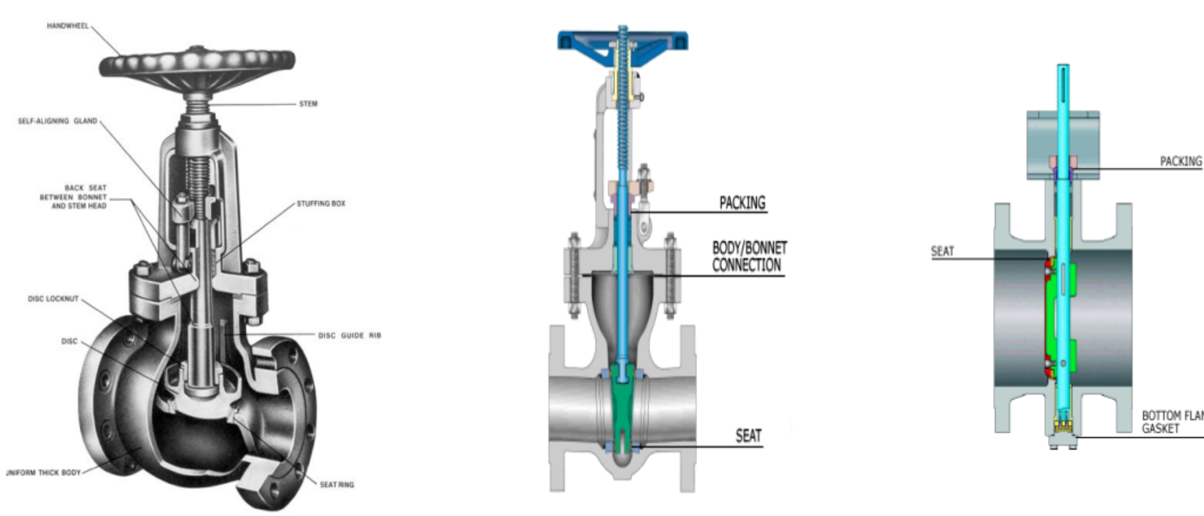


Figure 1.17. Valve types: a) Globe; b) Gate; c) Butterfly

Globe type

They derive their name from their spherical bodies. The two sections of the body are divided by a baffle that forms a seat upon which a moveable plug may be used to manage the flow. The plug is attached to a stem that is controlled by an actuator or a manual wheal.

They are utilized in applications demanding frequent throttling and operation. As this baffle limits flow, it is not advised in situations where unrestricted flow is essential.

Ball type

It opens by spinning a stem connected to a ball located within the valve. The ball's center has a hole or port, such that when the port is aligned with both valve endpoints, flow will proceed. The hole is orthogonal to the valve endings and flow is prevented when the valve is closed. Even after many years of inactivity, ball valves are often capable of achieving complete shut-off. Consequently, they are a suitable option for applications involving cutoff. They do not provide the precise control that may be required in throttle applications, but they are occasionally applied for this purpose.

Gate type

It opens by removing a circular or rectangular gate/wedge from the fluid's flow. The flat sealed sides between both the seats and gate are a defining characteristic of this valve. The gate sides may be either wedge-shaped or parallel. They are constructed to open or seal completely. When the usual gate valve is completely open, the flow route is unobstructed, resulting in a quite-low friction loss.

Butterfly type

It is a type of valve which utilizes a round disc or vane as its shutoff function. Utilized to regulate the liquid flow through a pipe system, they have a rapid opening/closing mechanism with a quarter-turn rotation. Typically, they pivot on axes that are perpendicular to the flow direction within the flow chamber. Unlike ball type valves, butterfly type does not contain fluid-trapping chambers in case of valve closing. They are extensively applied as throttling devices, regulating the flow levels in three positions: completely closed, completely open, and partially open. They are located on spindle which enables for unidirectional flow and are able to regulate diverse air, fluid, and solids currents.

Control valve calibration

Valve calibration refers to the adjustment of the location of the valve in relation to the pneumatic pressure signal. This calibration is actually conducted on the valve positioner. Firstly, all shown air connections in the diagram below must be established. In addition, I/P converted must be calibrated in advance. Then, specified settings must be adjusted in the positioner and I/P air pressure supply using Air Filter-Regulators.

Calibration procedure: top cover of the positioner is opened. The feedback link between the stem and the positioner is checked to be properly tight. After ensuring, controller output is set for 0 percent of valve position, for example - 4mA for Fail-Close or 20mA for Fail-Open actuator. The valve position is examined on indicator. If any deviations are discovered, the linkage screw is slided slightly into the correct direction. So, the valve will begin to move, the linkage is adjusted for 0 percent of the valve position. Then, controller output is set for 100 percent of opening, valve position is examined again, the screw linkage is adjusted if necessary. Later, intermediate positions must be checked too.

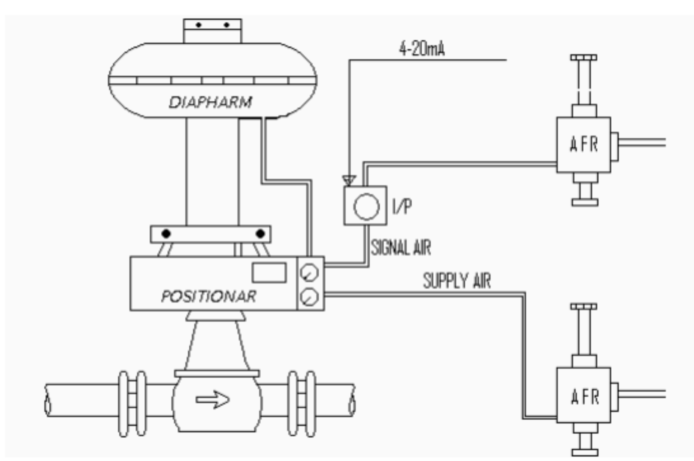


Figure 1.18. Control valve calibration

2. Key features of the used devices

2.1. Rosemount 5300 Radar Level Transmitter

In the radar business, the Rosemount 5300 is the most widely used guided wave radar. According to its strong design and diagnostic capabilities, it is built for the end user. A wide range of options are available to help you get better outcomes, stay safe and streamline your procedures. It is also SIL 2 certified.

A top-down measuring device, guided-wave radar uses a metal probe to emit low-energy microwave pulses that are reflected by the surface. As soon as the probe touches a different dielectric constant, it registers an abnormal reading. Net level or interface is calculated from the time differential of transmitted and returned pulses.

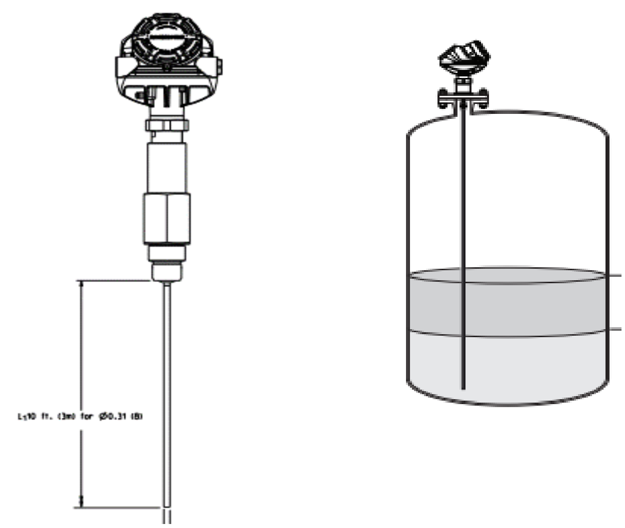


Figure 2.1. Rigid Single-Lead Probe type Rosemount 5302

Special characteristics

GWR delivers precise and trustworthy level and interface measures and may be utilized in a wide range of applications. It is a direct measurement from the top to down, as it determines the length to the surface. GWR is applicable for liquids, slurries, and certain solids. No adjustment is required for changes in the fluid's density, dielectric, or conductivity, which is a fundamental benefit of radar. Pressure, temperature, and the vast majority of vapor space variables have little effect on the precision of radar observations. Furthermore, radar devices include no moving parts, requiring minimum maintenance. GWR is simple to install and may readily replace other technologies, like as displacement and capacitance, while liquid is still present in the tank.

Key parts

The device comprises a stainless-steel or aluminum enclosure that contains modern electronics and signal processing software. The radar circuitry generates an electromagnetic pulse that the probe guides. Various types of probes are offered for different systems: rigid or flexible twin lead, rigid or flexible single lead, coaxial, and so on.

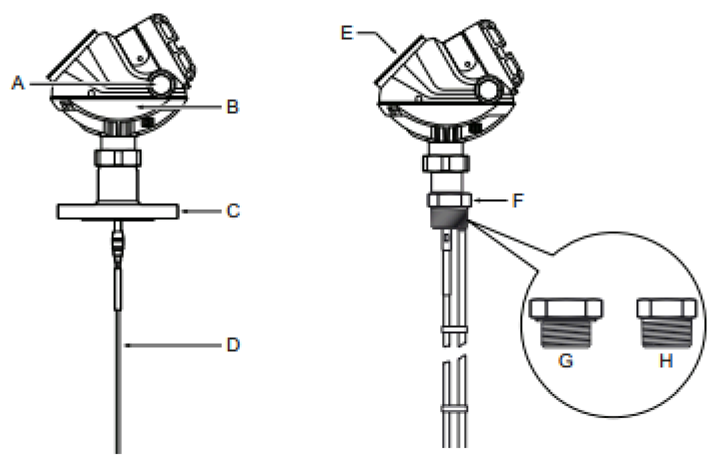


Figure 2.2. A) Cable entry B) Electronics C) Flanged Process Connections D) A Probe E) Dual enclosure F) Threaded Process Connections G) NPT

Model Code - 5302HA2S1E4AM00140RCNA

The following table illustrates how the model code for the 5300 series of Rosemount are generated. The model number and decoded components are presented in the table:

Table 2.1. Encoding of Model numbers

Code	Function	Description	
5302	Model	Guided-Wave-Radar Level and Interface Transmitter	
H	Output signal	4-20 mA with HART communication	
A	Material of housing	Polyurethane-covered Aluminum	
2	Cable threads	M20 x 1.5 adapter (1 adapter and 1 plug provided)	
S	Operating temperature and pressure	Design and operating temperature: -40 to 302 °F (-40 to 150 °C)	Design and operating pressure: -15 to 754 psig (-1 to 52 bar)
1	Construction material	316/316L/EN 1.4404	
E	O-ring Sealing material	Ethylene Propylene (EPDM)	
4A	Probe type	Rigid Single-Lead (8 mm)	
M	Units of Probe length	Meters or centimeters (metric)	
001	Total probe length (feet or m)	0-164 ft. or 0-50 m	
40	Total probe length (inch or cm)	0 - 11 in. or 0-99 cm	
RC	Process connection - size / type	2-in. NPT thread	
NA	Certifications for Hazardous locations	No Certifications for Hazardous Locations	

Configuration

The device is powered from system loop and utilizes same cables for power supply and signal output. An output signal is a 4-20 mA analog signal with a digital Modbus, HART, or FOUNDATION™ signal.

With an addition of HART Tri-Loop™ may be transformed into extra three 4-20 mA analog signals.

Furthermore, transmitter may be linked to an Indicator with 4-20 mA/HART signal or provided with an internal display.

Utilizing a portable communicator, or a computer equipped with Rosemount Radar Master software, the transmitter may be programmed with ease. Rosemount 5300 transmitters are also configurable with AMS Suite and DeltaV™ software.

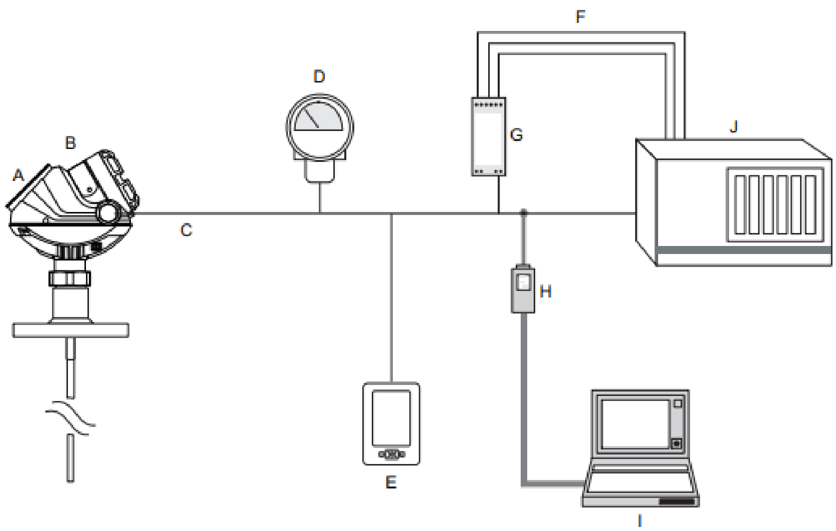


Figure 2.3. System Architecture of HART

A. Integral display B. Rosemount 5300 transmitter C. 4-20 mA/HART

D. Rosemount 751 Field-Signal Indicator E. Handheld communicator F. 3 x 4-20 mA

G. Rosemount 333 HART Tri-Loop H. HART modem I. Rosemount Radar Master or AMS Suite J. DCS

2.2. Fisher™ easy-e™ EZ Control Valve

Globe-shaped Fisher EZ valves have integral connections, guidance, and quick-open trim. These valves are utilized in chemical or petrochemical systems, as well as in applications require control of non-lubricating, sticky, or other difficult-to-manage fluids. Wide varieties of fluids can be throttled or shut off with these valves. The globe-shaped, single-port body has a quick-open trim, and a post-guided valve plug.

Figure 2.4. FIELDVUE DVC6200 Mounted on 657 Diaphragm Actuator and easy-e EZ Valve

Special characteristics

- Interchangeable, limited-capacity, and full-scale trims to fulfill varying process flow requirements
- Quick-open trim with a secured seat ring decreases the time required for disassembly.
- Low-flow specifications can be met using limited-capacity trim or Micro-Flow, or Micro-Form valve plugs.
- Streamlined flow paths offer higher capacity than the majority of globe type valves with the same size.

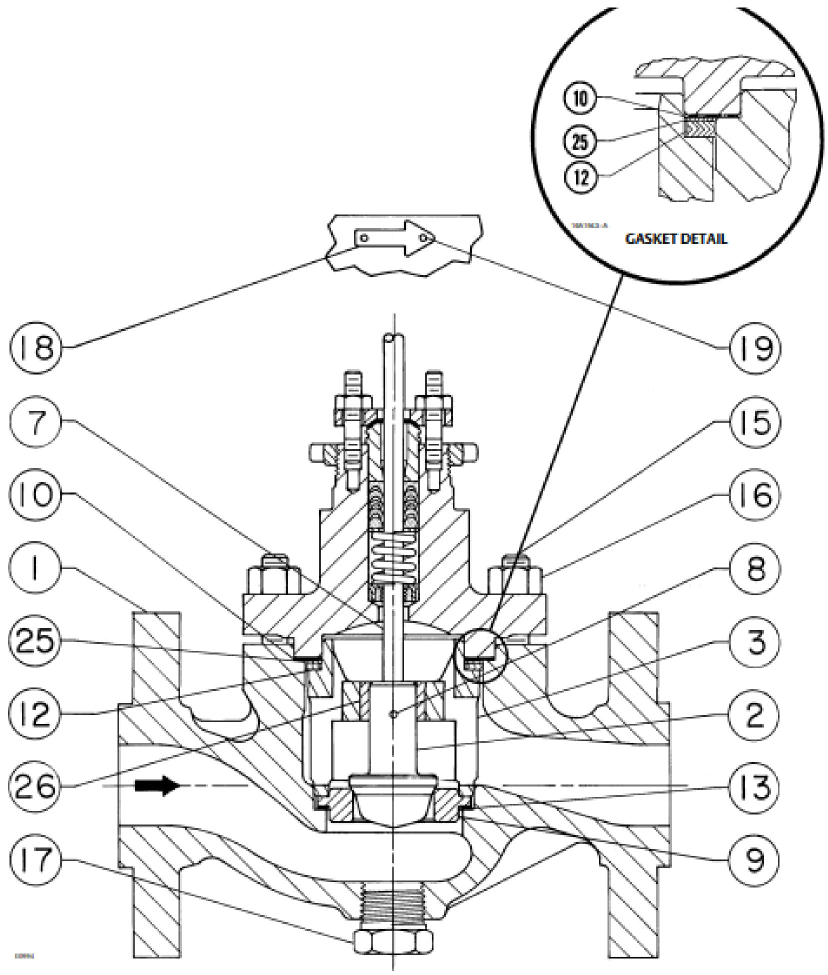


Figure 2.5. Components

1 Valve Body 2 Valve Plug 3 Seat-Ring Retainer 7 Stem 8 Pin 9 Seat Ring 10 Bonnet Gasket 12 Spiral-Wound Gasket 13 Seat-Ring Gasket 15 Stud Bolt 16 Nut 17 Pipe Plug 18 A Flow Arrow 19 A Drive Screw 25 A Shim

Fisher™ 657 & 667 Diaphragm Actuators

These Fisher spring-opposed actuators move the plug according to varied pneumatic signals from the controllers or valve positioner that are implemented to the diaphragm. The tension of the actuators spring determines the zero position of the actuator. Both the rate and quantity of actuator available spring determine the span. The 667 actuator is reverse-acting while the 657 is direct-acting. They are developed to supply automated control valves with dependable on/off or throttling functionality.

These heavily loaded actuators include a spring-return action as well as a variety of operating choices and actuator-mounted accessories. The actuator can be applied either with or without a positioner for on-off or throttling operation.

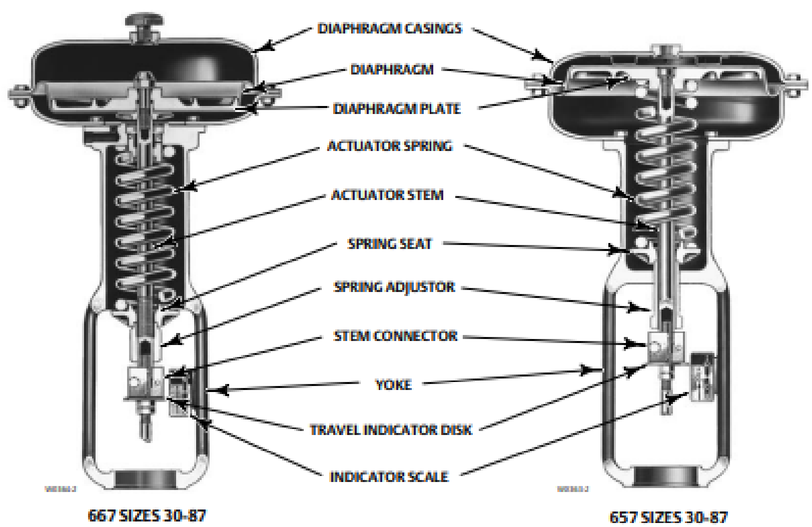


Figure 2.6. Components of Actuator

Special Characteristics

- High-Thrust Capacity— The shaped diaphragm provides for maximal thrust for the given size.
- Remarkable Linearity Among a Load Pressure and Travel — A shaped diaphragm moves in a wide diaphragm shell, limiting area change during the course of its trip.

- A shallower casing on the pressure side reduces the volume upon this surface, hence lowering response time.

Fisher™ FIELDVUE™ DVC6200

It is a HART communication device transforms a two-wire 4-20 mA signal to a pneumatic actuator output. This device may be adapted easily to replace analog positioners on the majority of Fisher and non-Fisher pneumatic actuators. It is intended to replace pneumatic or electro-pneumatic positioners.

Figure 2.7. DVC6200

The DVC6200 is microprocessor-based current-to-pneumatic devices that communicate with each other over a serial bus interface. An additional feature of it is the HART communicating protocol, which provides quick access to information that is important to a process's success. Utilizing communicator at valve, junction box, a personal computer, or console of operator in the control room, or even from the process's primary component, the control valve, data may be gathered. Independent valve position feedback can be achieved by using separated circuitry, or switches integrated to system may be used as limit or alarm switch, depending on the application.

Many functions may be carried out with the DVC6200 using ValveLink or AMS software: Device Manager or Communicator. Messages, tags, descriptors, and revision levels may all be accessed to gather broad demographic data.

Special Characteristics

- Actuator Prevention against Overpressure

- Information may be accessible at any point along the loop due to the DVC6200's HART connectivity. Because to its adaptability, testing valves in difficult-to-reach places may be done with less risk of injury.
- The two-stage architecture of the positioner allows for rapid reaction to big step changes and accurate control of modest setpoint adjustments.

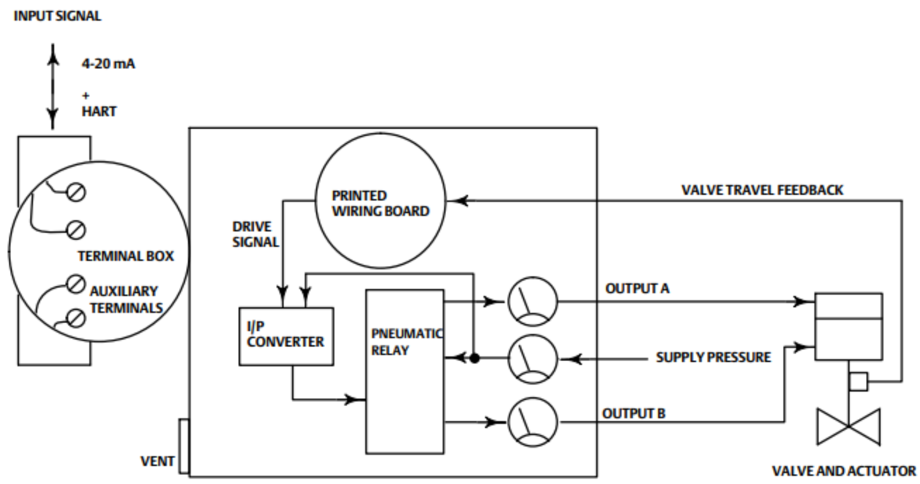


Figure 2.8. FIELDVUE DVC6200 Schematic

2.3. DeltaV Hardware & Software (Control Studio)

The DeltaV system enables users to build control systems those are simple to install, simple to operate, reliable, and safe. The system employs the following to achieve these objectives:

- Plug-and-play hardware setup technologies
- A collection of control modules that may be reused to facilitate initial configuration
- Dragging-and-droping techniques for facilitating configuration or customization.
- Compatible graphic interface analogous to the operating system Microsoft Windows
- Context-aware assistance and online free documentation
- Hardware/software techniques for assuring confidentiality and reliability in system
- Configuration Assistant guides throughout the process of the system customizing while also showing the basics

Software

DeltaV Control Studio

It facilitates the visualization, modification, and troubleshooting of control schemes. These strategies are viewable and editable in their set state. Each module inside the DeltaV system has its own control tag. To access a module online, the module's name is sufficient, not its physical address in controller. Each module is handled as a distinct entity within Control Studio. This allows the user to concentrate on a particular module without disrupting other modules which may be operating at same controller.

It recognizes several industrial standards, such as FBD (in order to continuously control) and Sequential-Function Charts SFC (in order to sequentially control). It is possible to combine components of various control languages in a common control module. After a module has been downloaded, its execution may be visually observed. If there are any necessary security permissions, the strategy may be debugged using the same graphical interface. Operation may be halted, a break may be specified point , and a variety of additional operations may be carried out.

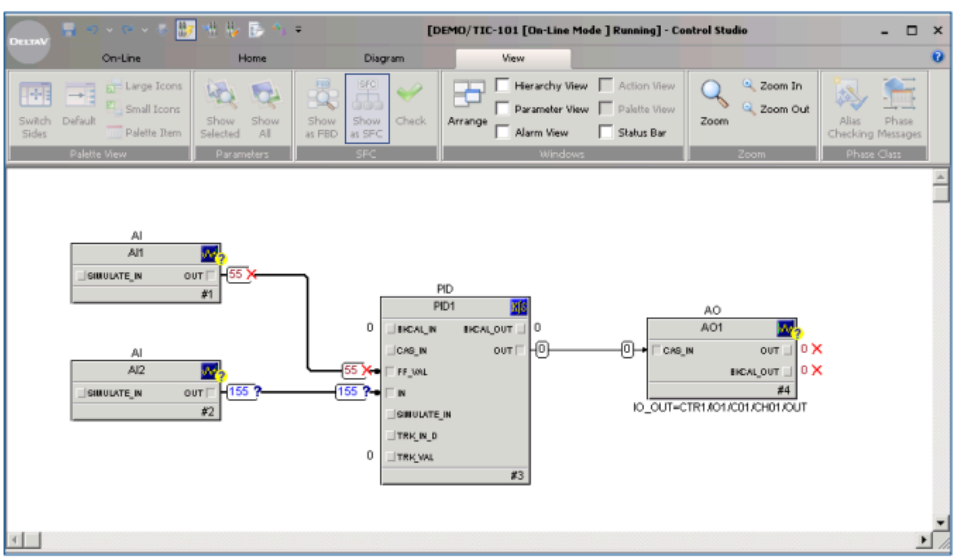


Figure 2.9. General view of Control Studio

DeltaV Explorer

It is a program like Windows Explorer in appearance that enables users to design system features , including areas, nodes, modules, or alerts, and inspect system's general structure and architecture. This application allows for a variety of uses, as follows:

- Creation, duplication, or relocation of modules
- Configuration of hardware components
- Defining alarm kinds and priority

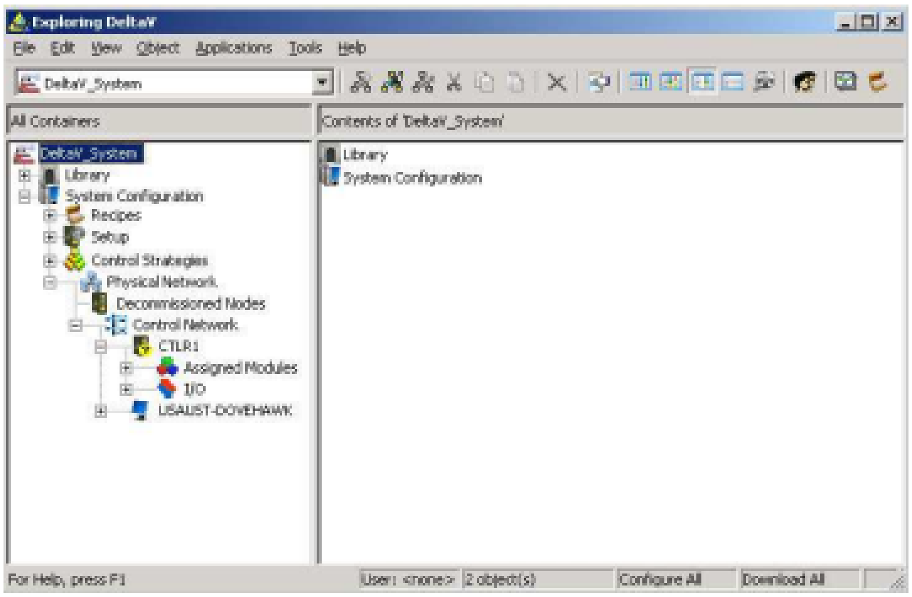


Figure 2.10. General view of DeltaV Explorer

AMS Device Manager

It is the industry's leading predictive analysis software solution for instrumentation processes, suggesting a unique tool for configuration, calibration, documentation, and diagnostics of the device and system. It helps the maintenance staff to effortlessly check the health condition of field devices and rectify possible faults before they escalate into costly difficulties.

Field devices can be configured, device configurations can be saved in the database, loop tests and calibrations can be conducted, system data can be imported/exported - all can be done easily using AMS with DeltaV.

This program boosts efficiency by identifying and diagnosing possible equipment faults prior to their influence on the process, hence decreasing wasteful and inefficient work. During configuration or maintenance of the devices, Device Dashboards provide engineers and maintenance employees with a standardized graphical interface. When unexpected operating circumstances arise, the updated user interface provides intuitive images to assist operators in making prompt and correct decisions.

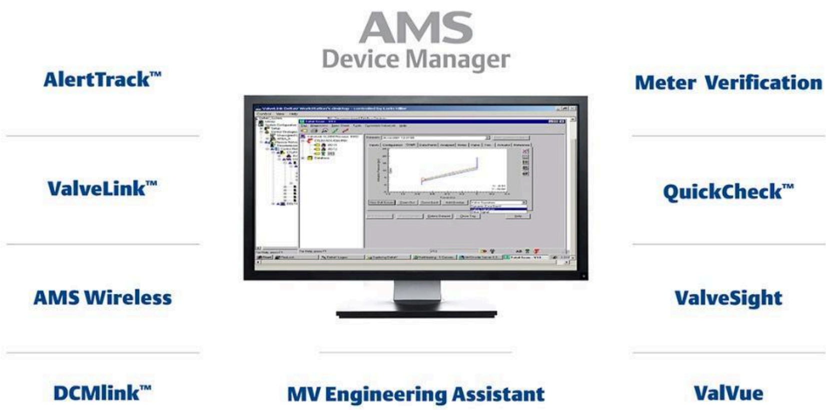


Figure 2.11. Applications of AMS Device Manager

Hardware

Multiple forms of I/O are available on the DeltaV, allowing for more adaptability to meet the needs:

- Electronic Marshalling permits the addition of a variety of I/O types when and where desired.
- Traditional I/O provides discrete or analog I/O cards with a high density.
- A variety of bus cards provide connections to fieldbus instruments employing a variety of bus technologies.

The system's hardware includes the following:

- At least one DeltaV workstation
- A control network for interconnecting nodes of system
- Power supply

- At least one DeltaV controller for local control, and data/communication management among Input/Output subsystem and a control network.
- At least one Input/Output subsystem per each system controller which handles data come from field devices

DeltaV™ S-series Traditional Input/Output

The compact subsystem enables flexible installation and is intended to withstand the harsh climatic conditions encountered in field deployments. Traditional I/O from the S-series is outfitted with a snap-in retaining device to facilitate speedy installation.

They may be inserted into any 64 slots available. All the wiring connection is routed with carriers or terminal blocks, allowing modules to be removed without having to disconnect any wires. It is an intelligent solution for process control applications because of its modularity, quick installation, expansion, and environmental resilience.

Figure 2.12. I/O Interface

The subsystem includes:

- Interface carrier on something that is mounted all input/output-related components
- Power supply bulk AC to 24V DC for all field equipment

- Various analog/discrete interfaces, each of which consists of I/O card encased with a commonly chosen format and an accompanying I/O terminal block that readily connect to the carrier.
- Cable extenders which facilitate carrier installation flexibility

AI card specifications and block diagram

Table 2.2. Specifications for AI Card, 8-channel, 4 to 20 mA, HART

Number of Channels	Eight
Input Sensor Types	4 to 20 mA (span), 2-wire and 4-wire
Full Signal Range	1 to 22.5 mA, with over range checking
Transmitter Power (2-wire)	13.5V minimum at 20 mA
Accuracy Over Temperature Range	0.1% of span
Repeatability	0.05% of span
Resolution	16-bit A/D converter
Calibration	None required
Optional Fuse	2.0 A
HART Communications Support	HART pass-through for AMS Device Manager. HART variable and status reporting for control functions
Hart Scan Time	600 – 800 ms per enabled channel

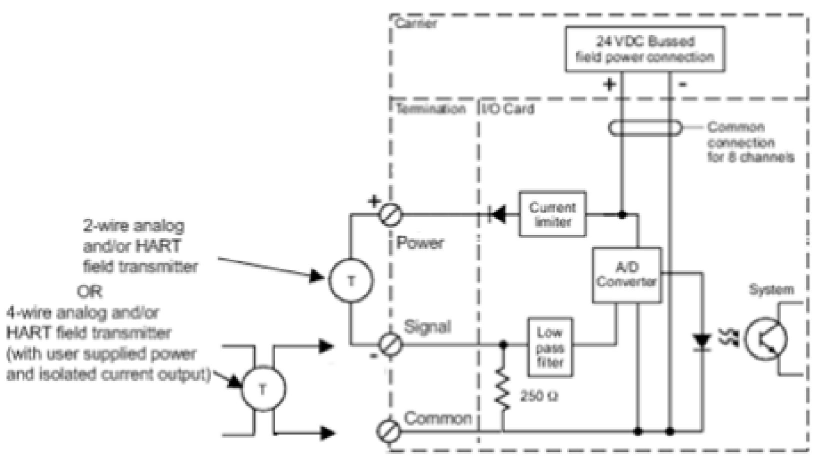


Figure 2.13. Schematic diagram for AI card, 8-channel, 4 to 20 mA, HART

AO card specifications and block diagram

Table 2.3. Specifications for AO Card, 8-channel, 4 to 20 mA, HART

Number of Channels	**Eight**
Device Types	4 to 20 mA
Full Signal Range	1 to 23 mA
Accuracy Over Temperature Range	0.25% of span (-40 to 60°C)
Resolution	14-bit D/A converter
Calibration	None required
Isolation	Each channel is optically isolated from the system and factory tested to 1500V DC.
Open-Loop Detection	Less than 0.70 mA
Optional Fuse	2.0 A
HART Communications Support	HART pass-through for AMS Device Manager. HART variable and status reporting for control functions.
Hart Scan Time	600 – 800 ms per enabled channel

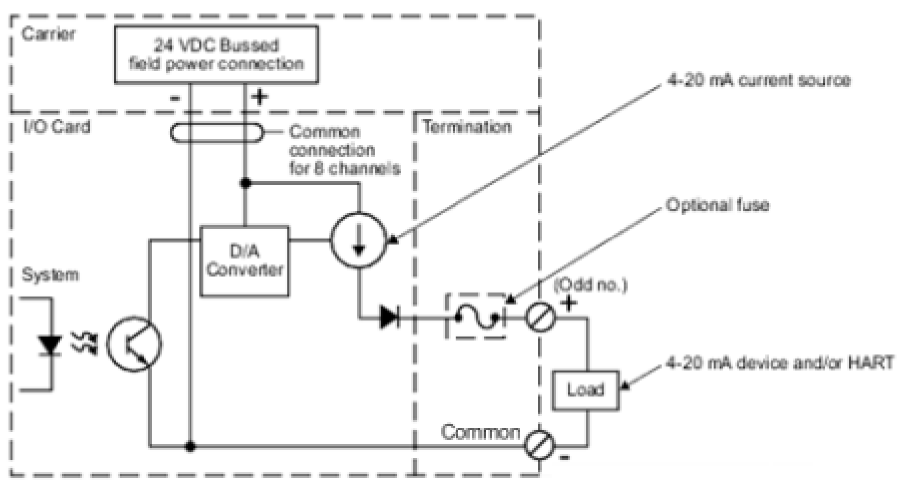


Figure 2.14. Schematic diagram for simplex AO card, 8-channel, 4 to *20 mA, HART*

2.4. Unidrive M200

It was developed for applications that demand flexible interaction with systems via sophisticated communication networks, fieldbuses, or sophisticated RFC-A motor control.

- SI-PROFINET, -PROFIBUS, and -DeviceNet are just a few of the industry-standard fieldbuses and extended I/O interfaces that may be used with the M200's SI interface.
- Allows RS485 networks to be connected to Modbus RTU networks using the AI-485 Adapter option.
- A LED keypad that is simple to use.
- On the drive's front, there is a handy parameter guide.

Model code - M200-022-00075 A 1.5 kW

Table 2.4. Encoding of Model numbers

Code	Function	Description
M200	Identification label	Unidrive M200
02	Frame Size	Electrical specification
2	Voltage Rating	200 V (200 – 240 ± 10 %)
00075	Current Rating	Heavy Duty current rating x 10
A	Drive Format	A - AC in AC out

Operating modes

Any of the following modes of operation can be used by the drive:

1. Open-loop mode
    - Open-loop vector mode
    - Fixed V/F
    - Square V/F

    Variable frequencies can be set for power to be applied to the motor through a drive. The drive's output frequency and the slip caused by mechanical load determine the motor's speed. Slip compensation can help the drive better regulate the motor's speed. V/F or open-loop vector mode affects performance at low speeds.

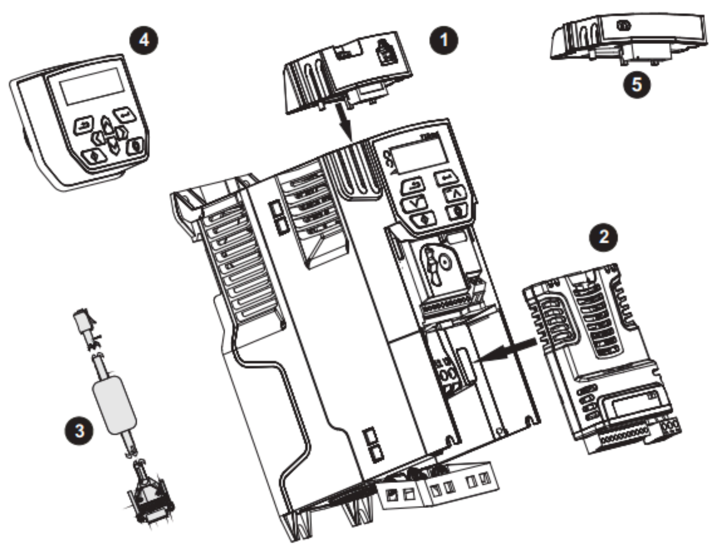
2. RFC - A

When used with induction motors, Rotor-Flux-Control is a form of closed-loop vector control that does not utilize position feedback.

- Absence of position-feedback device

It enables closed loop without requirement for position feedback by estimating the motor speed using current, voltage, and essential motor characteristics. It can reduce the usual instability related with open-loop control, for as when operating big motors with modest loads and low frequencies.

Components

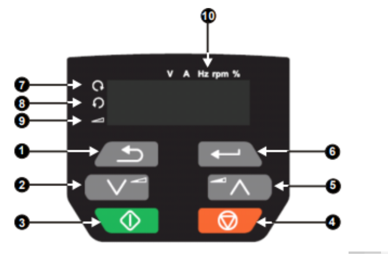


Keypad and display

Figure 2.15. Components of the drive

1.AI-485 adaptor 2. SI module 3. CT comms cable 4. LCD keypad 5. AI-Backup adapter module

It gives the user information on the drive's working state and trip codes, as well as the means for adjusting parameters, halting, and resuming the drive, and performing a drive reset. A 6-digit LED display serves as the keypad's display. The display indicates the current status of the drive, or the menu, and parameter number being modified. The option module must be installed for the Unidrive menu (S.mm.ppp) to be shown. Where S represents the slot number for the option module and mm.ppp is the internal menu & parameter number for the option module. In addition, the display features LED



indicators displaying units and status. When the drive is switched on, the screen will display the power up parameter provided by Parameter Exhibited upon Activation.

1. The Escape is utilized for leaving the parameter edit or view mode.
2. Down button can be utilized to pick specific parameters or to modify parameters.
3. Start button
4. Red Stop button is considered to pause and reload drive-in keypad mode. Additionally, it may be utilized for rebooting terminal mode.
5. Up can be utilized for choosing specific parameters or modify parameter values.
6. Enter is utilized for giving parameter display or edit mode, or to accept an edited parameter.
7. Run-forward indicator
8. Run-reverse indicator
9. Keypad-reference indicator

3. Project implementation

The primary purpose of the project are the development and configuration of a level control loop using a control valve at the BHOS test rig to track a set point of the level. The system showed in Figure 3.1 below consists of the measurement device, a controller, and a final control element (FCE), which are necessary for automated control in the system. The devices used in the control loop are “Radar Level Transmitter 5300” as a measuring device, “EZ control valve - 657 actuator- DVC6000” as a FCE - final control element with its actuator and positioner, “Hardware & Software of DeltaV” as a controlling system and “Unidrive M200 VFD” as a disturbance source.

As can be seen from the Figure 4.4 – P&ID of the system, there are two tanks with tag numbers “T101” and “T201” – their levels are controlled by a control valve with tag number “CV101”. Level transmitter with tag number “LT101” continuously measures the level in the tank “T101” and sends the measured value to the level controller “LIC101”. In addition, there are two level switches with tag numbers “LSH101” and “LSL101” to detect high and low levels in the same tank and to send the signal to the “LIC101”. By changing frequency of the motor using VFD “SC101”, the speed of pump “P101” is changed, and it creates a disturbance to the system. “LIC101” level controller makes a decision and sends a control action to the control valve “CV101”.

The scope of work is defined as follows:

- Assign I/O cards in the DeltaV Explorer
- Configure the function blocks and create a control strategy in Control Studio
- Start the operation after downloading to the controller
- Establish flow using VFD with constant rotational speed
- Record the tank level and position of the control valve readings when altering the level set point

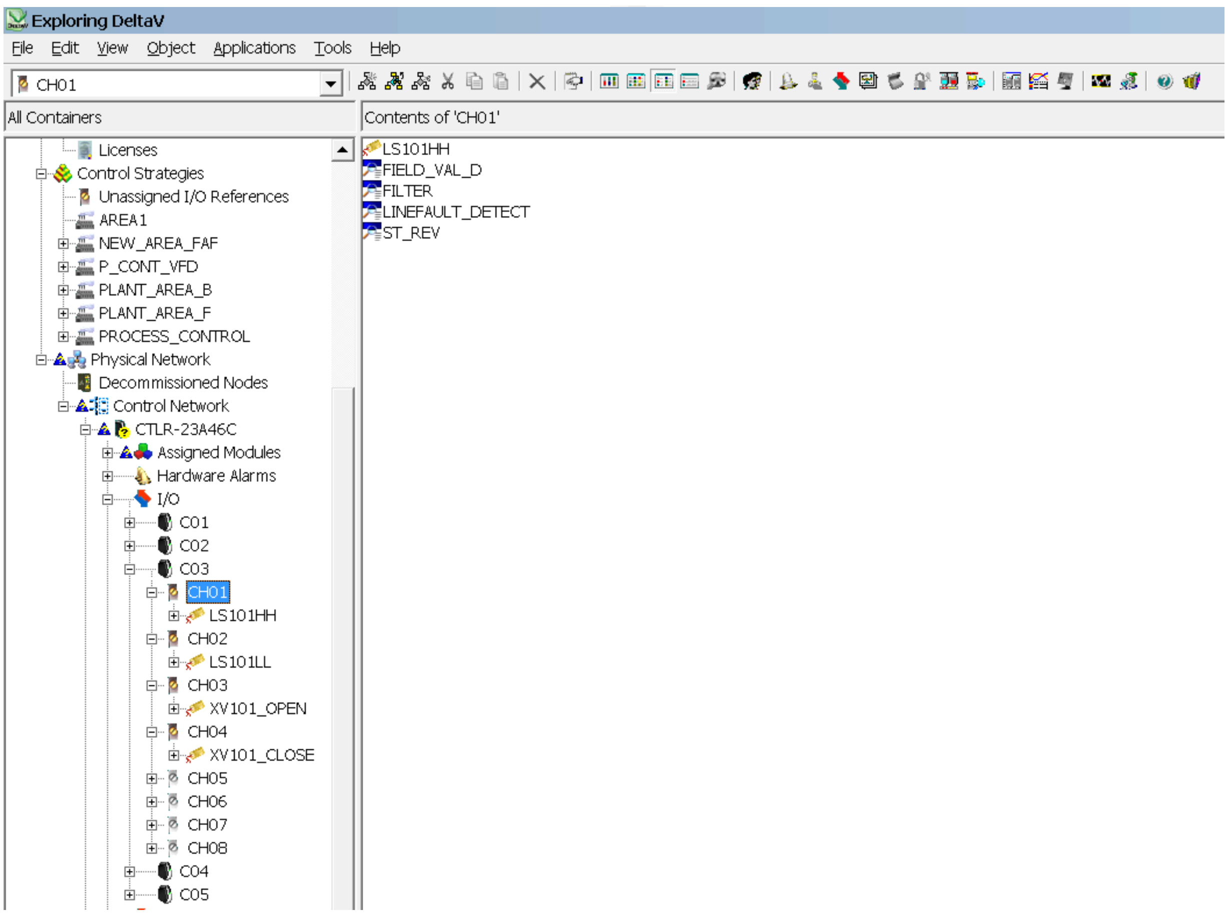
is necessary

3.1. Configuration of I/O cards

As can be seen from the Figure 3.2 that DeltaV Hardware consists of:

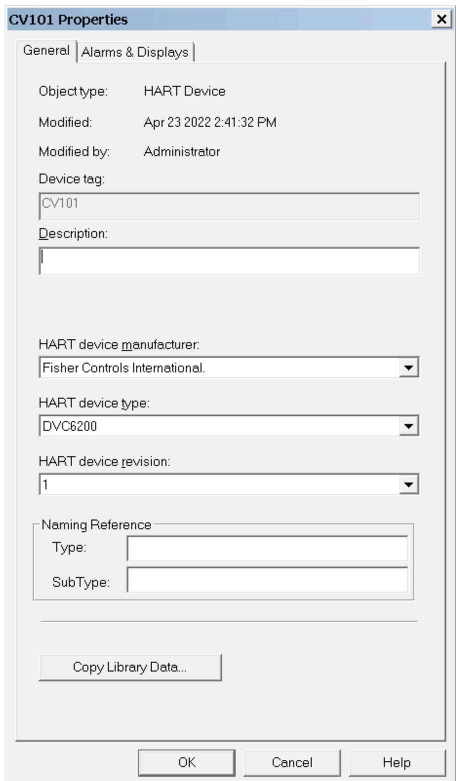
- System Power Supply
- SQ controller
- AI module, 8 channels
- AO module, 8 channels
- DI module, 8 channels
- DO module, 8 channels
- Serial module

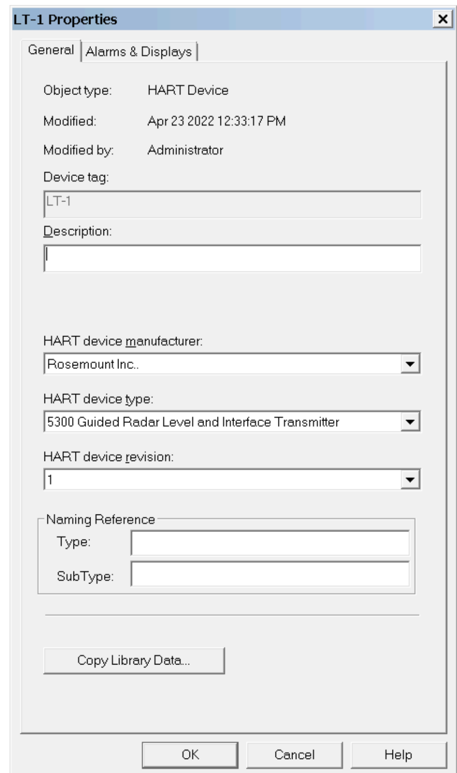
DeltaV Explorer allows the tags of field devices, sensors, and actuators to be assigned to an I/O card of the system as a part of the I/O configuration process. Radar transmitter is assigned as Analog input in the system while a positioner is connected as Analog output. In addition, vibration forks are connected to Discrete input module. The LEDs of the reserved channels are turned on as can be seen from the Figure 3.2.



General view of the DeltaV Explorer window and devices assigned to the I/O channels of the controller can be seen from the Figure 3.3.

By clicking one of the assigned devices and opening the properties, tag, manufacturer and type of the device can be checked:

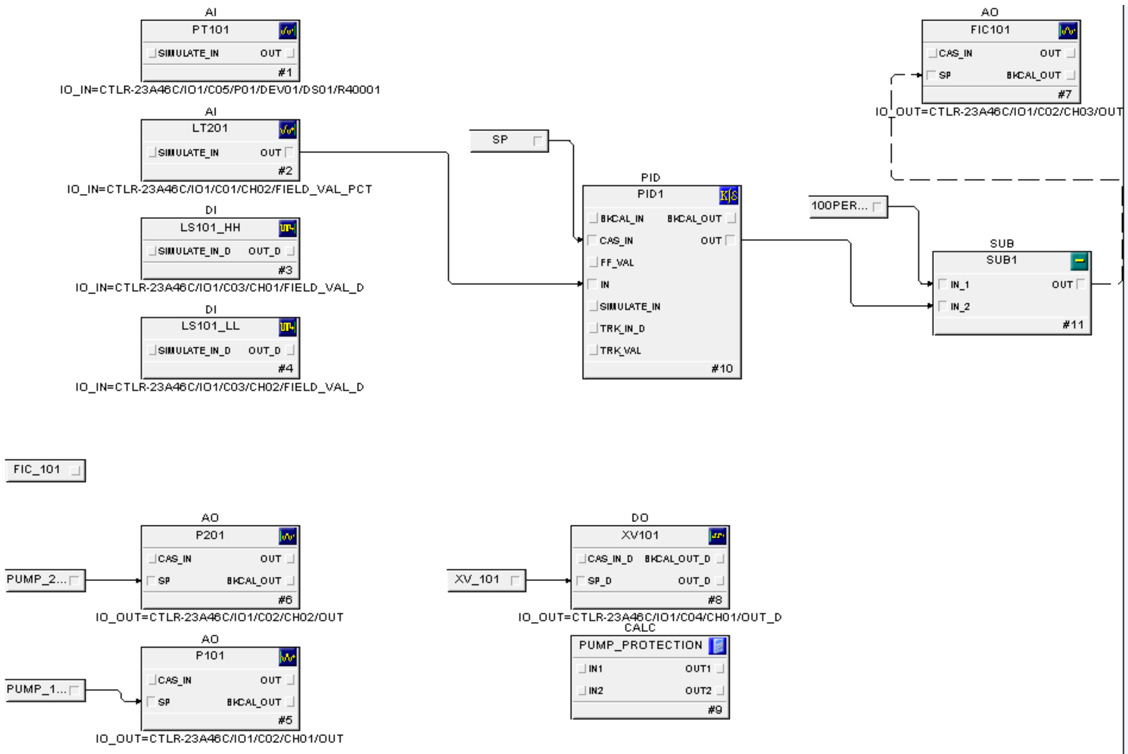




3.2. Control strategy

Modules are used to make up Control strategies at DeltaV software. The software has a pre-defined module templates library with fundamental properties. These library templates can be modified again or new modules with different features can be built from scratch. The new self-designed modules can also be uploaded to the template library, allowing to reuse them in the creation of own control strategy.

Control Studio is used to design and modify the individual modules and templates that make up the control strategy of the level control loop explained above. With this application a control module is graphically built by pulling items from a palette to the diagram. Then, items are wired to create an algorithm for the module. For continuous control, the control language FBD – Function Blocks Diagram is used to create the strategy.



As can be seen from the Figure 3.4 above – control strategy of the implemented level control loop in the test rig, level transmitter with tag number "LT101" continuously measures the level in the tank "T101" and sends the measured value to PID1 function block as an analog input. The "PID1" compares the received value with the given set point SP and calculates the error by subtracting the measured value from the SP. If there is any error, "PID1" sends a control action the control valve as an analog output. As there is a reverse action, subtraction block is used to subtract analog output of the controller PID1 from 100 to correct the action. In addition, there are two level switches with tag numbers "LS101_HH" and "LS101_LL" to detect high and low levels in the same tank. The signals sent from the switches are used in the Pump Protection function block. “XV101” on-off valve can be manually fully closed or opened in case of alarm situations.

The pumps’ speeds can be altered from the analog output blocks. The unit of the entered value is percent. It means if 100 % equals to the maximum value of the frequency in hertz while 0 % equals the minimum value.

The used tags in the diagram and their functions are listed below:

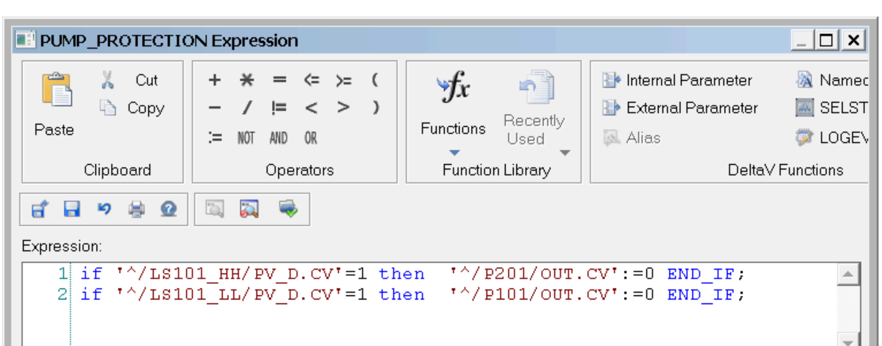
Table 2.5. Tag information

LT101	AI from Level Transmitter
LS101_HH	High-high alarm level switch
LS101_LL	Low-low alarm level switch
P101	Pump 1
P201	Pump 2
XV101	On-off valve
PID1	Controller
SP	Set point for level
FIC101	AO to the control valve

Explanation of some blocks are added below:

“PID1” function block: gets a measured value by the LT101 and compares it with the desired set point SP. Parameters of this block can be added for tuning from the “Parameters” part of the screen in the left side. This block sends a control action according to the entered parameters to the control valve.

“PUMP_PROTECTION” function block: is used to protect the pumps from dry running. Expression for the pump protection can be seen from the figure below:



3.3. PID Tuning

The PID is tuned using Trial and Error approach. Once a strong knowledge of PID parameters is obtained, this method is a reasonably straightforward technique. It progresses through the parameters proportional, integral, and derivative. Small adjustments are often made to an existing version of settings to enhance the response. For fresh PID loops, a safe and approximate first estimate is made:

- The P-control is implemented to boost response speed. Excessive P-action causes oscillation.
- The I-control is implemented in order to get the appropriate steady-state response. A stronger oscillating reaction over a prolonged duration is a disadvantage.
- The D-control is implemented to provide damping. The disadvantages include the likelihood of oscillation at a high frequency and the sensitivity to noise.

The advantages and disadvantages

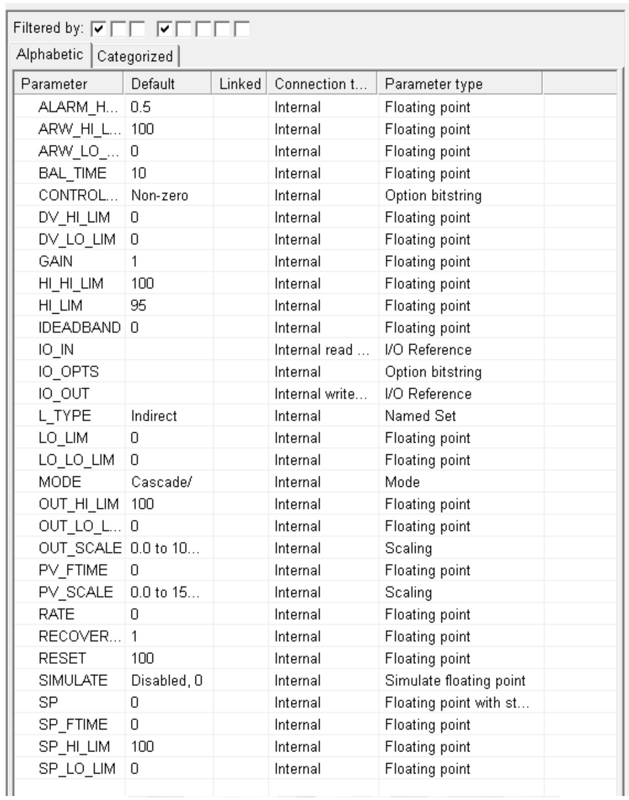
The advantages:

- It is a quick and simple method for achieving a satisfactory outcome.
- It takes an adaptive approach, meaning no assumptions can be made regarding the process.
- Minimal process skill is needed.

The disadvantages:

- It is time-consuming. Good performance requires much time to attain.
- It does not ensure a firm and stable resolution. This may pose a threat to the entire facility.

Gain for Proportional control, Reset time for Integral control and Rate for Derivative control can be added from “Parameters” part of PID1 block in the left side of the screen.



Filtered by:

Alphabetic | Categorized

Parameter	Default	Linked	Connection t...	Parameter type
ALARM_H...	0.5		Internal	Floating point
ARW_HI_L...	100		Internal	Floating point
ARW_LO_...	0		Internal	Floating point
BAL_TIME	10		Internal	Floating point
CONTROL...	Non-zero		Internal	Option bitstring
DV_HI_LIM	0		Internal	Floating point
DV_LO_LIM	0		Internal	Floating point
GAIN	1		Internal	Floating point
HI_HI_LIM	100		Internal	Floating point
HI_LIM	95		Internal	Floating point
IDEADBAND	0		Internal	Floating point
IO_IN			Internal read ...	I/O Reference
IO_OPTS			Internal	Option bitstring
IO_OUT			Internal write...	I/O Reference
L_TYPE	Indirect		Internal	Named Set
LO_LIM	0		Internal	Floating point
LO_LO_LIM	0		Internal	Floating point
MODE	Cascade/		Internal	Mode
OUT_HI_LIM	100		Internal	Floating point
OUT_LO_L...	0		Internal	Floating point
OUT_SCALE	0.0 to 10...		Internal	Scaling
PV_FTIME	0		Internal	Floating point
PV_SCALE	0.0 to 15...		Internal	Scaling
RATE	0		Internal	Floating point
RECOVER...	1		Internal	Floating point
RESET	100		Internal	Floating point
SIMULATE	Disabled, 0		Internal	Simulate floating point
SP	0		Internal	Floating point with st...
SP_FTIME	0		Internal	Floating point
SP_HI_LIM	100		Internal	Floating point
SP_LO_LIM	0		Internal	Floating point

4. Output Documents

Developing an output documentation, which is considered to track overall work, progress as well as the material/cost management, is the most crucial stage of the project. Various types of the documents are created according to the needs of work and used at various phases of its life cycle. Generally, these documents can be used for a variety of purposes, including the operation, as well as troubleshooting & maintenance. To execute and complete the work, multiple forms of documents listed below are created:

4.1. I/O List

The information provided in these documents should include the tag number, whether the loop is intrinsically safe or not, digital or analog, range, units, crucial or not, report input, and alarming priority.

№	Tag number	Instrument type	Service description	Location	I/O type	System
1	PT-101	Pressure transmitter	Measuring pressure on L-001	Field	WIRELESS HART SIGNAL	PCS
2	FT-101	Flow transmitter	Measuring flow on L-001	Field	AI	PCS
3	TT-101	Temperature Transmitter	Measuring temperature on L-001	Field	WIRELESS HART SIGNAL	PCS
4	CV-101	Control valve	Controlling flow on L-001	Field	AO	PCS
5	P-101	Pump	Discharging T-101	Field	AO	SIS
6	P-201	Pump	Discharging T-201	Field	AO	SIS
7	XV-101	On-off valve	Open/close L-002	Field	DO	SIS
8	LT-101	Level transmitter	Measuring level in T-101	Field	AI	PCS
9	LT-201	Level transmitter	Measuring level in T-201	Field	AI	SIS
10	LSL-101	Level switch	Alarming low level in T-101	Field	DI	SIS
11	LSH-101	Level switch	Alarming high level in T-101	Field	DI	SIS

Project Name: Design of Level Control Loop by Control Valve			**Date:** 14.05.2022	
Document type: I/O List **Engineer:** Mujgan Huseynli **Supervisor:** Erkin Ibrahimov				
PAGE SIZE	DRWN.	Mujgan Huseynli	07.05.2022	DWG. NO. / REV.
A3	CHKD.	Erkin Ibrahimov	14.05.2022	
	APVD.	Erkin Ibrahimov	14.05.2022	

4.2. Instrument Index

It is a document that contains am instrument devices list within a facility. It comprises all physical devices, such as field instruments, physical alarms and indicators, as well as pseudo instruments, often known as "soft tags" - DCS indication, alarm, and controller.

№	Tag number	Loop number	Instrument type	Status	Service description	Location	I/O type	System	Calibration		Eng. unit	Datasheet number	Manufacturer
1	PT-101	L-001	Pressure transmitter	New	Measuring pressure on L-001	On L-001	AI 4-20 mA	PCS	0	55	Bar	3051S2TG2A2A11X5A WA3WK1B4M5	Rosemount
2	FT 101	L-001	Flow transmitter	New	Measuring flow on L-001	On L-001	AI 4-20 mA	PCS	0	100	m^3/h	2400SIA11FMEZCZ	Micro Motion
3	TT	L-001	Temperature transmitter	New	Measuring temperature on L-001	On L-001	AI 4-20 mA	PCS	0	150	°C	648DX1D1NAWA3WK1 M5F5XA	Rosemount
4	CV-101	L-001	Control valve	New	Controlling flow on L-001	On L-001	AO 4-20 mA	PCS	0	100	%	F000867084	Fisher
5	P-101	L-001	Pump	New	Discharging T-101	On L-001	AO 4-20 mA	SIS	N/A	N/A	Rpm	N/A	Rosemount
6	P-201	L-002	Pump	New	Discharging T-201	On L-002	AO 4-20 mA	SIS	N/A	N/A	Rpm	N/A	Rosemount
7	XSV-101	L-002	On-off valve	New	Open/Close L-002	On L-002	DO	SIS	N/A	N/A	N/A	F000867085	Fisher
8	LT-101	L-001	Level transmitter	New	Measuring level in T-101	On T-101	AI 4-20 mA	PCS	10	150	cm	3102HA2FSCNA	Rosemount
9	LT-201	L-002	Level transmitter	New	Measuring level in T-201	On T-201	AI 4-20 mA	SIS	10	150	cm	5302HA2S1E4AM00140 RCNA	Rosemount
10	LY-101	L-001	I/P transducer	New	Converting 4-20 mA to 3-15 psi	On L-001	AO 4-20 mA	PCS	3	15	psi	N/A	Fisher

4.3. BOM

It is a comprehensive, properly organized list of all the components that comprise a product or assembly. The list includes the item number, amount, and unit of measurement for each component

Part Number	BOM Level	Part Name	Part description	Quantity	Unit of measure
PT-0105	1	Rosemount 3051S	Pressure transmitter	1	Psi
LT-0101	1	Rosemount 3102	Ultrasonic level transmitter	1	cm
LT-0202	1	Rosemount 5302	Radar level transmitter	1	cm
FT-0104	2	Micro Motion 2400	Coriolis flow meter	1	m^3/h
LS-0102	2	Rosemount 2120	Vibration fork	2	N/A
SC-0103	2	Emerson M200	Variable frequency drive	2	N/A
TT-0106	1	Rosemount 648	Wireless temperature transmitter	1	°C
CV-0107	1	Fisher EZ control valve	Gate valve	1	N/A
WG-0301	1	Rosemount 1420	Wireless gateway	1	N/A
CV-0303	2	FIELDVUE 6200	Digital valve controller	1	N/A
CV-0302	2	Fisher 657	Actuator	1	N/A
XV-0204	1	Fisher V150	On-off valve	1	N/A
S-0401	1	DeltaV S-series	Controller	1	N/A
S-0402	2	DeltaV S-series	Power supply	1	N/A
S-0404	5	DeltaV S-series	I/O modules	5	N/A

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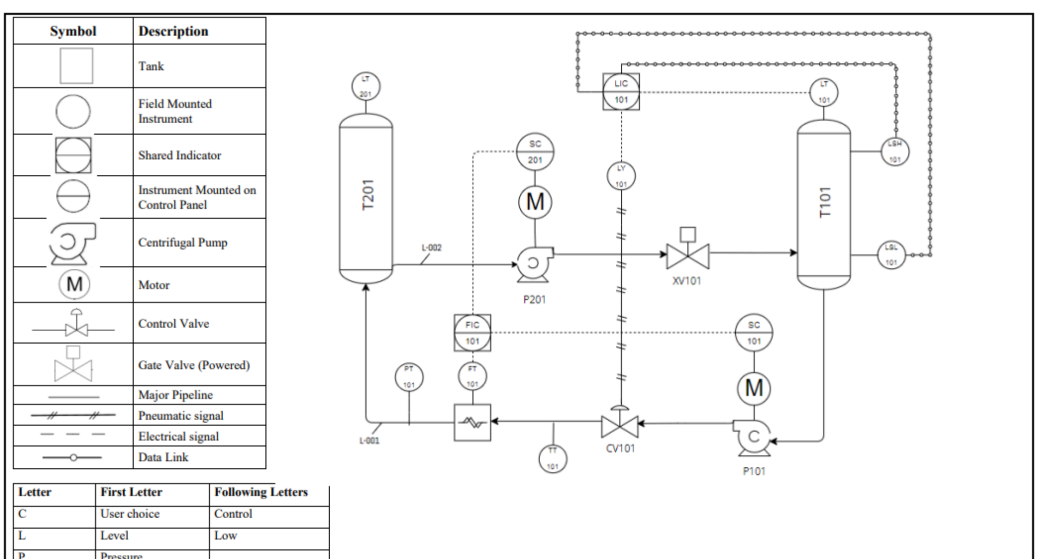
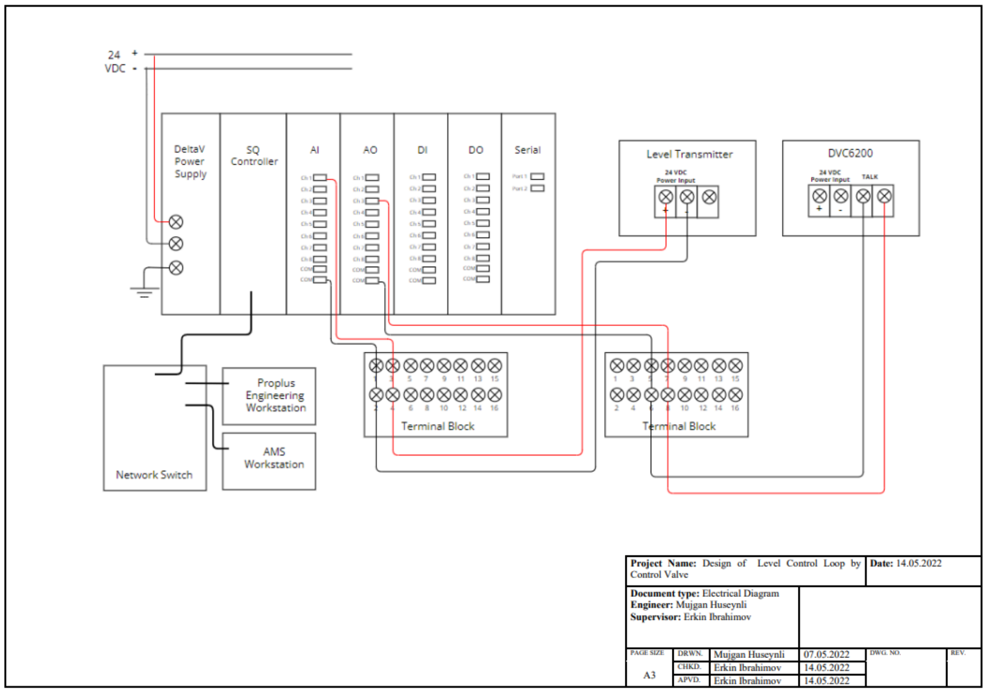
4.4. P&ID

The primary purpose of the P&ID is to depict the process's equipment and their interconnections. In order for it to be employed for process maintenance and change. This figure would be particularly valuable throughout the design phase, serving as the basis for the control system's development.



4.5. Electrical and Interconnection Diagrams

This diagram illustrates the instrument connection and cabling from the field instrument to the I/O card of the control system. Details on the termination box, connections, wiring, incorporating screens are included.



4.6. Cause & Effect Diagram

The literal definition of "cause" is something that causes something else to occur, whereas "effect" is the outcome of the cause. Cause and Effect is arranged in a matrix format. The causes are mentioned on the left, while the consequences are given on the right; both are detailed using tag numbers and their respective descriptions; extra information, such as P&ID, may supplement. The marked crossing between both indicates that they are causally connected.

Design of Level Control Loop by Control Valve					General								
					DESCRIPTION	Stop flow to T-101	Stop flow to T-201	Stop pump P-101	Stop pump P-201	Increase P-101 speed	Increase P-201 speed	Decrease P-101 speed	Decrease P-201 speed
					P&ID	V-101-I-001	V-101-I-001	V-101-I-001	V-101-I-001	V-101-I-001	V-101-I-001	V-101-I-001	V-101-I-001
					Tag No.	XV-201	CV-101	P-101	P-201	P-101	P-201	P-101	P-201
					Action	Close	Close	Stop	Stop	Increase speed	Increase speed	Decrease speed	Decrease speed
Description	**Tag No**	**P&ID**	**Trip Tag**	**Note**									
T-101 Level High	LSH-101	V-101-I-001	LSHH-101							x			x
T-101 Level Low	LSL-101	V-101-I-001	LSLL-101								x	x	
T-201 Level High	LT-101	V-101-I-001	LTLL-101				x	x			x		
T-201 Level Low	LT-101	V-101-I-001	LTHH-101			x			x	x			
Control Valve Close	CV-101	V-101-I-001	N/A					x					
On-Off Valve Close	XV-201	V-101-I-001	N/A						x				

Project Name: Design of Level Control Loop by Control Valve			**Date:** 14.05.2022	
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	APVD.	Erkin Ibrahimov	14.05.2022		

5. Conclusion

The objectives of the project are to set up and to configure a level control loop at the BHOS test rig. The level transmitter continuously measures the tank level and sends the measured value to the controller. The PI controller compares the received value with the given set point and calculates the error by subtracting the measured value from the setpoint. If there is any error, the controller sends a control action to the control valve.

The level control loop devices of BHOS demo rig are selected according to the system requirements. Firstly, Guided-Wave-Radar transmitter has been selected as it has a wide measuring range and less sensitivity to the disturbances. Then, the globe valve has been selected as it is most suitable for full-range flow control situations. PI control has been selected as a control algorithm as it is most suitable to the system. The controller has been tuned using Trial-and-Error approach, which relies on estimate-and-check. The controller's gain, Kc, is modified with the integral action kept at minimum, until a required output is achieved.

In the implementation stage, the program has been developed in DeltaV software provided by Emerson with the required logic and communication has been established between the control loop devices. The system can monitor and control all parameter values. In order to achieve and ensure a successful level control, the controller has been tuned by the adjustment of control parameters - proportional and integral terms. During the implementation stage, necessary documents for the system, such as I/O List, P&ID, BOM, Cause & Effect Diagram, Electrical & Interconnection diagram and Instrument index has been developed.

In conclusion, the level control loop for BHOS Emerson Test Rig has been developed by taking into account the considerations mentioned above and technology selection to satisfy safety requirements. As a contribution to the course curriculum, a laboratory work leaflet was prepared based on this project for the students.

6. References

[1] Control User Guide Unidrive M200/M201

[2] Fundamentals of Control – Instrumentation and Control

[3] Getting Started with Your DeltaV™ Digital Automation System

[4] Instruction Manual of Fisher™ 657 Diaphragm Actuator

[5] Instruction Manual of Fisher™ EZ easy‑e™ Control Valve

[6] Instruction Manual of Fisher™ FIELDVUE™ DVC6200

[7] Manual of Rosemount™ Guided Wave Radar Level and Interface Transmitters

[8] Measurement and Control Basics, 3rd Edition, Thomas A. Hughes

[9] The Engineer's Guide to Level Measurement, 2021 EDITION

Appendix

IO list.pdf

Instrument
Index.pdf

BOM.pdf

P& ID.pdf

Electrical and
Interconnection Dia

Cause& Effect
Diagram.pdf