Optimal Flow Control of a Three Tank System

Marius-Constantin Popescu and Nikos E. Mastorakis

***Abstract*—**The 3TS system has two PI regulators with identical parameters of the intended adjustment of the level in two tanks. This paper is intended to determine the optimal parameters for the automated flow system between two open containers of a laboratory equipment "Three tank system". In doing so, a multidisciplinary paper is achieved that includes the hardware and software knowledge and adjustment.

***Keywords*—** Nonlinear mathematical model, automated control system.

I. Introduction

Three tank system (3TS) is an application model widely used for teaching purposes for study of automated control.

The fact that the system is strongly nonlinear, with different possibilities of disturbance, made this system to be present as a model for study in most laboratories of renowned Faculty of Automation in Europe (Duisburg, Budapest, Vienna, Lund ...). The system consists of three modules Fig. l, the system with three tanks, including the execution (pumps) and measurement elements (sensors): the electronic part of the execution element (actuator) and driving board DAC98. The DTS200 program is provided with the driving board, which enables the design of new management programs [1], [2], [8], [9].

The maximum level that can be reached is 60cm (+3 cm), after which - by the firing of the protection - the pumps are automatically disconnected. Pumps are driven by DC-motor. For possible disturbances in the system simulation, interconnecting pipes as well as the nominal drain are equipped with valves. At the same time, each tank has a direct exit to the fluid collector tank. Measurements of fluid levels are made for each tank by piezo-resistive pressure transducers (Fig. 2).

Actuators incorporates the execution and the measuring element and is designed to convert die fluid level (from die dire tanks) in voltage (to the digital computer), but, at the same time, also to increase die voltage signal from the computer in voltage signal to pumps. The electronic component of the execution element: it is equipped with two internal boards (Servo), one for each pump [3].

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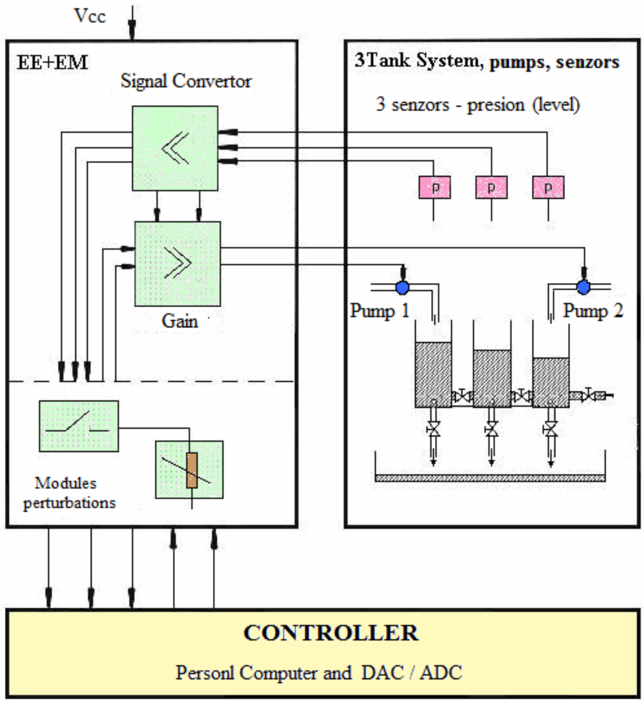


Fig. 1: Three tank system, inner scheme.

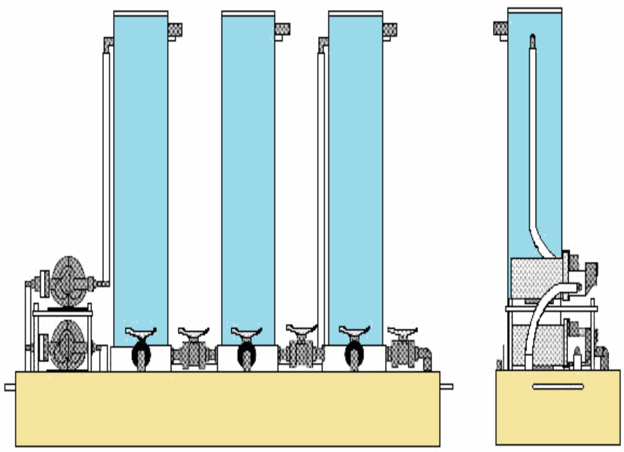


Fig. 2: Three tank system (the process).

For each of the pumps, dire is the possibility to shift from "Manual" to "Automatic" mode and vice versa, respectively, using P1 and P2 potentiometers the flow "control" possibility of both pumps exists.

The Sensor part allows measurements (voltage) of flow for two pumps (the input of the two execution elements), as well as the measuring of corresponding voltage for the liquid levels in tanks (the output of execution elements). Part of Signal

Error is am additional "kit" (Opt.200-05 option). It is dedicated to control the system's sensitivity to measurement errors. Using a potentiometer the sensitivity percentage for each tank and for each pump can be adjusted separately (Amira, 1998). To avoid leakage of liquid outside the tank, for the "Manual" mode the limit value within a tank is reached, the electronic part of the execution element (actuator) was equipped with automatic shutdown of pumping fluid if the limit value is reached (protection).

The DAC98 driving board is the interface with the automated control system. This board together with various "Kit" links for additional programs (in this case the system is equipped with Opt.200-02, representing the supposed program DTS200, Opt.200-03, representing the source of the supposed driving program DTS200, and Opt.200-05, representing the electrical disturbance module) achieve various cases of study on the 3TS system analysis. The board is connected to the electronic part of the execution element (actuator) through a 50 pin output cable [6].

II. Necessary Equipment for Optimal Flow Control in a Single Tank

For one of the tanks (Fig. 3), we have the following data for the components:

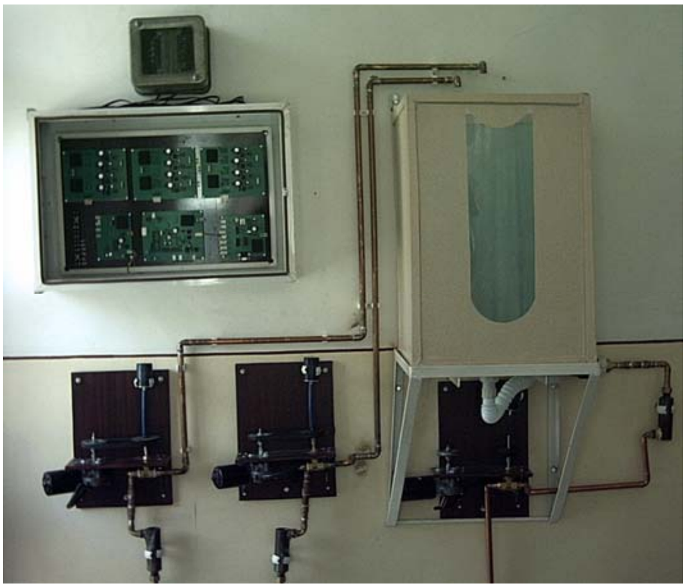


Fig. 3: View of the process (Department of Automation and Applied Sciences, University of “Constantin Brancusi”).

- cross section A=0.16 m^2;
- stationary value of level L_0= 0.24 cm;
- fluid density ρ=960 kg/m^3;
- length/width/height of the tank 0,4m/0.4m/0.6m;
- stationary flow F_0=l. lm^3/min=l. 1/60 m^3/s;
- transducer output signal is (0.2-l) bar
- time constant of transducer T_T =2 s;
- time constant of the control valve T_E=20s;
- valve's characteristic - is proportional
- amplification coefficient of the valve is:

$$K_V = \frac{5\%\ flow\ variation}{1\%\ variation\ of\ input\ signal}$$

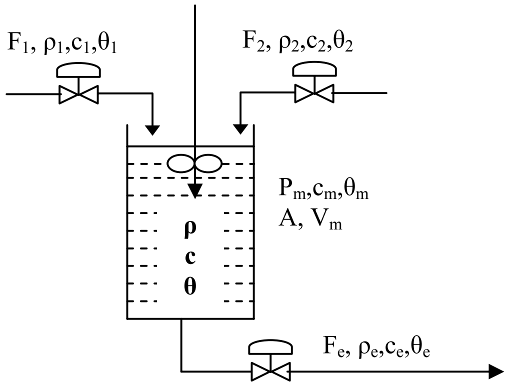


Fig. 4: The principle scheme of the process.

Due process requirements using a transducer based turbine (meter) is used. Fluid flow is proportional to the rotation of the turbine within certain limits on the viscosity and the maximum flow. Display speed turbine is made by special adapters that give one pulse per revolution. Turbine flow meters are chosen with a capacity of 30-50% over maximum flow measured, in this way they have a higher operational resistance. Together with the camera displacement flow meters (immobile room) are the most accurate devices.

Below are some of the characteristics of the flow meter that we used. Flow analysis of a liquid in a closed pipe, around a barrier mounted diametrically and perpendicular to the flow direction, shows, that at minimum speed, a two-dimensional vortices flow is created (Fig. 5). This is known in literature as "vortices paths of von Karman" in which the obstacle axis velocity gradient is zero. The space contained between the jets there is a decrease in pressure and hence an attraction to jet Lag (Coanda effect [11]), forming vortices. The effect of clamping and separation of flow occurs alternately on the two sides of the shutter (the vortex generator) [4].

The frequency of these oscillations is directly proportional hydraulic flow velocity of the liquid according to:

$$f = \frac{S \cdot v}{d}, \qquad (1)$$

where: f is the oscillation frequency, S is the Strouhal's number, v is average flow velocity and d is the width of the shutter [7].

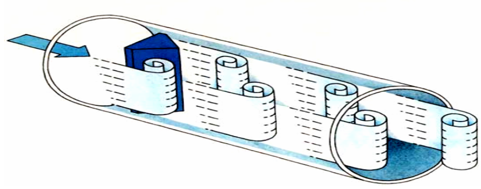


Fig. 5: The explanation on the flow of liquid pumps.

Differential pressure that occurs with hydraulic oscillation frequency is detected by the sensor which generates an alternating electrical signal with the same frequency. It is processed electronically through the amplification and transformation into rectangular pulses and/or analog signals. In one configuration time for a wide range of values of Reynolds number ($Re \geq 10^4$), of Strouhal number is constant, so the frequency is directly proportional to the speed and volume of fluid flow implicitly [10]. The range of measured flow rates and pipe diameters that convey flows are concerned, requires the development and building a family of real-meter detectors favoured the typo-dimensions that can differ essentially in terms of constructive function of the nominal diameter (Dn) of pipeline.

The system consists of the following parts (Fig. 6): block transducer (flow meter transducer) and electronic block calculation and display (meter adapter).

Fig. 6: Flow meter and associated equipment.

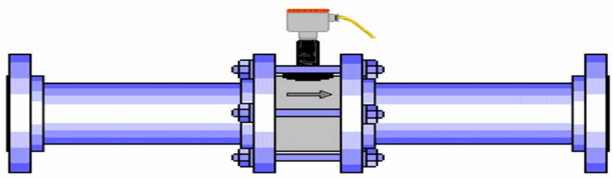


Fig. 7: Flow meter transducer.

Transducer flow meter comprises flow detector and preamplifier signal (Fig. 7). Detector flow jet swirl (vortex) is the most important component of the flow measurement system, because it "personalizes" the system through construction and method of measuring solution through the range of pipe diameters generated by typo dimensions and flow ranges, the nature fluid you are measuring. Vortex flow detector consists of three parts: body detector, generator turbinate (vortex) and sensor. Vortex generator with swirl separation is achieved; in this case, a barrier as the "T" mounted perpendicular to pipe leakage of fluid. Cylindrical ceil that is fixed sensor is placed in a circular room, practiced stabilizing strip detector. Preamp signal is to retrieve the signal, the frequency of the sensor and the increase to a level which will be sent in electronic block at a maximum distance of 10 m.

Adapter flow meter is designed to process signals in order to indicate vortex flow metering and measuring. One of the basic functions of the electronic block is to reject stray signals produced fluids or electrical noise and the signal as "clean" to be Amplifier and converted to analog output signal frequency pulse or rectangular [5].

Technical characteristics of the measurement system are:

- Measuring liquid is any liquid with viscosity>l cst;
- Nominal diameter of the detector is Dn=100 mm, and Dn=200 mm;
- Measuring range (for liquids which flow regime is Reynolds number greater than $3x10^4$) is 12 ... 120 m^3/h, to Dn100, and 60 ... 650 m^3/h, to Dn200;
- Maximum liquid pressure measured at 20°C is 1 MPa;
- Normal grade is IP65 protection for the transducer and IP64 for block E;
- Accuracy is <1%;
- Output signal from the electronic block (option) is an analog signal 4 ... 20 mA, tar rectangular pulse frequency (same frequency sinusoidal pulse supplied transducer);
- Local Display (option): to indicate the degree (4... 20 mA), to indicate the degree (0 ... 100%), to indicate the degree in physical units (optional), to indicate the degree to m^3/h or 1/min with digital display (3 and 1/2 digits) and totalize flow meter (7 digits).

Among the benefits that this type of flow meter offers are listed following:

- very good measurement accuracy for a wide range of speeds of liquids vehicle;
- no moving parts gives easy maintenance and reliability than marry;
- reduced complexity and technology gives the troubleshooting easy and relatively low cost price;
- quick replacement sensor port support;
- measurement parameters are not influenced (including accuracy) in deposits of fluid adherent substance detector elements;
- output of the transducer is the frequency of pulses, with an appropriate filter may well be processed;
- electronic adapter with minor changes (especially appropriate software), is the same for all detectors required typo dimensional pipe diameters and flow default.

III. Mathematical Model of Process

It will consider the case of an aperture containing measurement, valve adjustment and also other coupling valves and plugs that can be considered as some hydraulic resistance (Fig. 8).

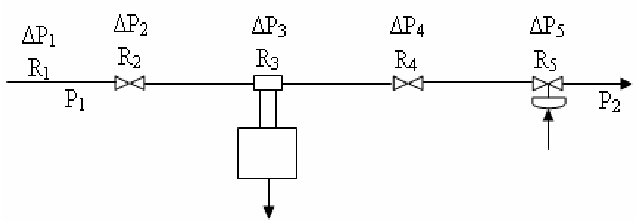


Fig. 8: Structure measurement and flow control.

Liquid through the pipeline comes from a tank whose level is assumed constant and the pressure out of the pipe is assumed equal to the air. For sections crossing the relatively small valve, the valve pressure difference does not change and then the difference between fluid pressure in the tank and pressure drop in line speed will lead to changes in cash flow on a pipeline of length L and section A, according to [12]:

$$\frac{Al\rho}{g}\frac{dv}{dt} = A(-\Delta P_f) \tag{2}$$

where ρ is the specific weight of fluid.

ΔP_f is pressure variation is a nonlinear function of changes in fluid velocity and position of the rod fan but can be liniarized around stationary values of these quantities:

$$\Delta P_f = f(\Delta v, \Delta h) = \left[\frac{d(\Delta P_t)}{dv}\right]\Delta v + \left[\frac{d(\Delta P_v)}{dh}\right]\Delta h \tag{3}$$

the total difference of pressure on P_t pipe is:

$$\Delta P_t = \Delta P_v + \Delta P_{1,2,3,4} + l \cdot \Delta P_1 = (1+R) \cdot \Delta P_v \tag{4}$$

where ΔP_v is the pressure difference valve, $\Delta P_{1,2,3,4}$ is the sum of the resistances constant pressure differences 1, 2, 3, 4, and ΔP_1 is the pressure difference on a linear meter of pipe.

$$R = \frac{\Delta P_v + \Delta P_{1,2,3,4}}{\Delta P_l} \tag{5}$$

From relations (2) and (4) follows:

$$\frac{l\rho}{g} \cdot \frac{dv}{dt} + (R+1) \cdot l \cdot \frac{d(\Delta P_l)}{dv}\Delta v = -\frac{d(\Delta P_v)}{dh}\Delta h \tag{6}$$

If turbulent flow using Fenning's equation results:

$$\Delta P_l = \frac{\lambda\rho}{2gD}v^2 \quad \text{si} \quad \Delta P_{1,2,3,4} = \frac{\xi\rho}{2g}v^2 \quad ,$$

hence the

$$\frac{d(\Delta P_l)}{dv} = \frac{\lambda\rho}{gD}v \tag{7}$$

From equation (6) follows:

$$\frac{l\rho}{gA} \cdot \frac{d(\Delta F)}{dt} + \frac{(R+1)l}{A} \cdot v \cdot \frac{d(\Delta P_l)}{dv}\Delta F = -\frac{d(\Delta P_v)}{dh}\Delta h \tag{8}$$

Using equation (8) ($x=\Delta F/F_0$; $u=\Delta h/h_0$) follows:

$$\frac{l\rho F_0}{gA} \cdot \frac{dx}{dt} + \frac{(R+1)lF_0}{A}\frac{d(\Delta P_l)}{dv}\Big|F=F_0 = -\frac{d(\Delta P_v)}{dh}\Big|h=h_0 \cdot h_0 \cdot u \tag{9}$$

Equations can be used for state variables, marking output y=x:

$$x' = -K_x x - K_u u \quad \text{si} \; y=x \tag{10}$$

where:

$$\begin{aligned} K_x &= -\frac{(1+R)g}{\rho}\left[\frac{d(\Delta P_l)}{dv}\right]_{F=F_0} = -\frac{\lambda F_0(1+R)h_0}{AD} \\ K_u &= -\frac{gAh_0}{\rho g F_0}\left[\frac{d(\Delta P_v)}{dh}\right]_{h=h_0} = -\frac{A^2 D}{\lambda F_0^2(1+R)\rho}\left[\frac{d(\Delta P_v)}{dh}\right]_{h=h_0} \end{aligned} \tag{11}$$

or, in the form of transfer function, by performing the Laplace transform relation (8) the zero initial conditions:

$$\left[\frac{\rho}{g(1+R)\frac{d(\Delta P_l)}{dv}\Big|F=F_0}s+1\right]\Delta X(s) = \frac{gA\frac{d(\Delta P_l)}{dx}\Big|h=h_0}{\rho(1+R)\frac{d(\Delta P_l)}{dv}\Big|F=F_0}\Delta U(s) \tag{12}$$

From (10) transfer function of the process result:

$$H(s) = \frac{\Delta U(s)}{\Delta X(s)} = \frac{K}{1+Ts} \tag{13}$$

where: $K = -K_u$ and $T = 1/K_x$

If a fluid flow regulation, automated installation or process is actually a pipe through which fluid flows and which are located a minimum flow valve and a measuring point (Fig. 9). Note the scheme of principle of the process is automated: u_F is typically a unified signal, q is the flow that is leaving the plant technology, which output is also set size and measured size (q=y_{IT} [m^3/h]), and α is opening the valve or valve adjustment and stroke is represented as% (0% representing the valve closed, and 100% maximum valve opening).

This size is really into technology facility (α=u_{IT}).

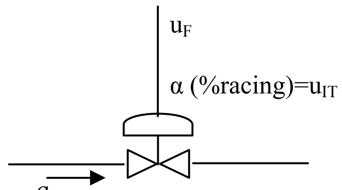
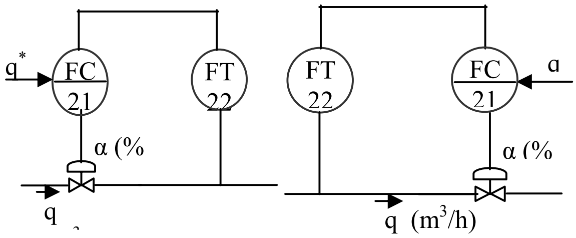


Fig. 9: The principle scheme of a flow SR.

As can be seen from the scheme, changing a is opened via a control element which is u_F input into the system fixed. To achieve a system for regulating the flow transducer is used to measure flow downstream or upstream of control valves. Also be used a flow regulator. Adjust flow must take into account whether that fluid is a líquid or a gas, if the fluid is compressible or incompressible, etc.

Schemes principle of a system for regulating the flow to control valves are illustrated in Fig. 10, where FT is the flow transducer placed locally, FC is located in flow regulator chamber control panel.



a) downstream b) upstream

Fig. 10: The principle scheme of a flow SR.

In principle the scheme can proceed to draw block diagram of the adjustment system that highlights the causal relationship between elements (one entry and exit from an element of the scheme in principle does not automatically mean the same thing and block diagram).

The first step in tracing scheme is to specify the block diagram of principle that all essencial information about sizes, units of measurement, àrea change, end of transmission.

For the physical implementation of the adjustment system is required attending a summary procedure for adjusting the law. These block diagrams each block must be described by its mathematical model in order to finally obtain the mathematical model of the automatic system (closed circuit).

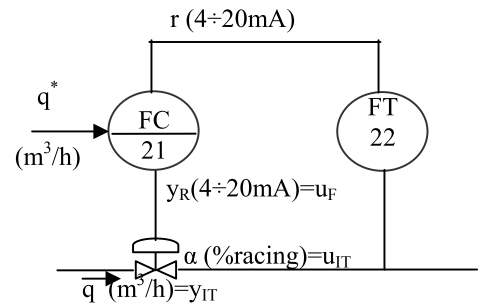


Fig. 11: Block diagram of a flow SR.

System may act on a series of disturbances. The system of regulation must take account of how these perturb eat acts. An example in this direction by implementing appropriate item.

If the element of implementing too, do not be rigid (for a size of command flow q, y_R constant change does not result in change of valve opening α), the flow q acts as a disturbance on the elements of execution ment. For detailed physical implementation of the system must take into account that the flow measurement is not directly but by measuring other quantities such as temperature liquid. Therefore will have the following block diagram illustrated in Fig. 12, where P is pressure, θ is the temperature, ΔP is the pressure differential calculation block which provides the final information about the flow, r is the size of the reaction, which is a unified signal electronically. It is noted that the flow is a set size, while P, θ, ΔP are measured quantities.

The controller processes the error after a law according to its type and draw out a size control u(t). This command working to achieve equality between the desired value of output $y_r(t)$ and the actual output y(t). To obtain a desired behavior of automatic system and thus achieve required system performance we need an appropriate design and implementation of automatic regulator.

The flexibility of adjusting algorithm, led first by the various laws of processing error, and on the other hand the possibility of changing parameters (K_R, T_i, T_d) as involved in the mathematical model of the controller, offers ample opportunities to achieve performance SRA for some fixed a priori.

The most common practice regulators are automatic tuning regulators Continuous linear type proportional (P), proportional-integrative (PI), proportional-derivative (PD) and proportional-integrative-derivative (PID).

PI type regulator has the transfer function:

$$H_R(s) = k_R \frac{1+T_i s}{T_i s(1+T_q s)} \cong k_R \frac{1+T_i s}{T_i s} = k_R \left[1+\frac{1}{T_i s}\right] \quad (14)$$

where k_R is the factor of amplification and T_i integration time constant.

The presence of the pole p=0 in $H_R(s)$ ensure that the function of the automatic system $\lim_{t\to\infty}\varepsilon(t)=0$ to external signals (reference, disturbance) type class features step.

Also, the presence of two parameters k_R, T_i, and in $H_R(s)$ may provide differential action on the frequency characteristics of the fixed part $H_F(j\omega)$ and thus can meet the performance under steady and transient.

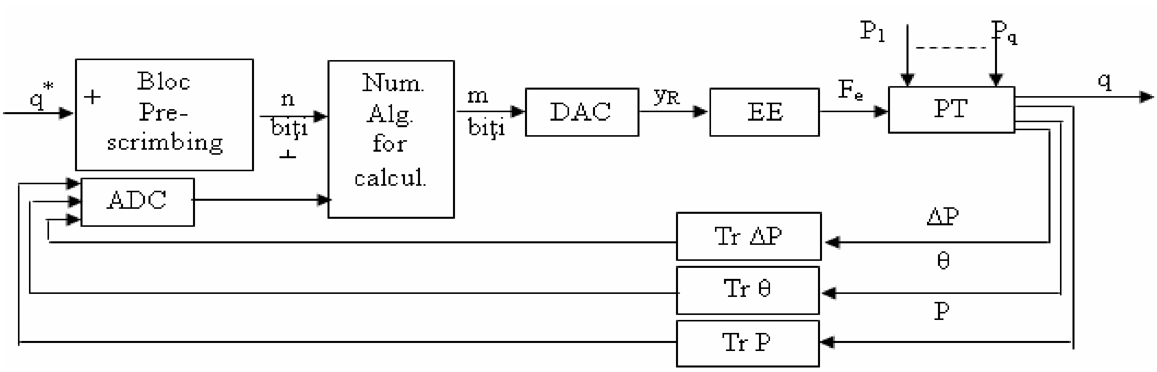


Fig. 12: Block diagram of a system for regulating the flow.

As for the desired adjustment processes (flow, level) are in fact dynamic processes with a relatively slow and is characterized by the presence of delays (dead time) criteria for selection and award of regulators can be extended starting from rapid dynamic processes. Thus the criteria for determining the parameters values agree to ensure optimal behavior in relation to both the entry and system with additive disturbances, we can use symmetry criterion and the criterion module.

Alternative criterion to delimit the areas of performance module is applicable with good results for the two regulators agree parameters such as PI-type regulators which will be used to regulate the system in question.

Criterion module starts from the premise that an adjustment system (RAS) has an ideal behavior with respect to the reference signal and disturbance, meaning that the answer y_r, compared with the reference signal is equal to the reference and the response compared y_v the disturbance is zero. Since:

$$Y_r(s) = H_0(s)R(s) \qquad Y_v(s)=H_{0v}(s)V(s) \tag{15}$$

To ensure an ideal behavior of the RAS in relation to the two signals are required conditions:

$$H_0(s) = 1 \quad \text{or} \quad H_0(j\omega) = 1$$
$$H_{0v}(s) = 0 \quad \text{or} \quad H_{0v}(j\omega)= 0 \tag{16}$$

i.e. for the whole spectrum out to be identical with the unitary step reference, provided that the step disturbance is also a null effect for the entire spectrum. It is obvious that such behavior is practically unfeasible, imposing the use of relationships to allow RAS to the behavior near ideal behavior.

In field conditions to transcribe modules:

$$M(\omega)=|H_0(j\omega)|=1 , \quad M_{ov}(\omega)=|H_{0v}(j\omega)|= 0, \arg H_0(j\omega)=0 \tag{17}$$

These conditions must be met for all possible range of variation of the pulse. For these conditions required modules derived the name of "criterion module. In real systems can not be exact fulfilment of these conditions on the modules M(ω) and $M_p(\omega)$, but is intended to determine the controller parameters which satisfy these conditions as accurately.

To illustrate the application of this variant of the criterion of how IP is considered a regulator and a first-order process (our case):

$$H_R(s) = k_R(1+\frac{1}{T_i s}) , \qquad H_F(s) = \frac{k_f}{T_f s+1} \tag{18}$$

whose optimal parameters K_{Ropt} and T_{iopt} must determined while k_f, T_f are known and require the require performance: $\sigma \le \sigma_{impus}$, $t \le t_{impus}$, $\varepsilon_{st}=0$ for r(t) step unitary $\varepsilon_{st}= \varepsilon_{st\ impus}$ required for r(t) ramp unitary

PI regulator, the presence in the home pole transfer function, provide error for a stationary null unitary step input and compensation time constant of the fixed part because at first-degree binomial numerator transfer function of regulator.

Transfer function of the open system is:

$$H_d(s) = \frac{k_R k_f}{T_i} \frac{(1+T_i s)}{s(T_f s+1)} \tag{19}$$

and the total amplification factor of the open system is given by:

$$k_d = \frac{k_R k_f}{T_i} \tag{20}$$

Closed system transfer function $H_0(s)$ has the expression:

$$H_0(s) = \frac{k_R k_f (1+T_i s)}{T_i s(T_f s+1) + k_R k_f (T_i s+1)} \tag{21}$$

and the characteristic parameters of the system are:

$$\omega_n = \sqrt{\frac{k_R k_f}{T_i T_f}} \ , \quad \zeta = \frac{1+k_R k_f}{T_f 2\omega_n} \tag{22}$$

To determine areas of variation of parameters K_R and T_i in which performance requirements are met in terms of system parameters K_R and T_i have delineated the areas corresponding to these performances. To achieve a stationary error limits for entry ramp, be assured a certain value of K_d.

$$\frac{k_R k_f}{T_i} \ge k_{d\ impus} \tag{23}$$

where K_d is determined from:

$$\varepsilon_{st} = \frac{1}{k_v}; \quad k_d = k_v ; \quad \frac{k_R}{T_i} \ge \frac{k_{d\ impus}}{k_f} \tag{24}$$

Appropriate field condition (24) is located above the right wing defined by:

$$\frac{k_R}{T_i} = \frac{k_{d\ impus}}{k_f} \tag{25}$$

Using the relation coverings for calculating transitional time, we have:

$$t_t = \frac{4}{\zeta\omega_n} = \frac{8T_f}{1+k_R k_f} \tag{29}$$

So the relation for calculating the transient time is of the form:

$$\frac{8T_f}{1+k_R k_f} \le t_{timpus} \ \text{sau} \quad k_R = \frac{1}{k_f}\left(\frac{8T_f}{t_{timpus}} - 1\right) \tag{30}$$

which represents the *b* line in K_R, T_i plan (Fig.13).

Appropriate field performance lies above right, shaded region. In a similar manner to determine the curve has to delimit the field over-adjustment system taking into account this zero transfer function of the system. Curve c of Fig. 13 corresponds to the value imposed over-adjustment, the shaded àrea under the curve. To take into account the effect of parasitic time constants inherent in the transfer function of the fixed part and the non-linearity arising in the functioning party system fixed on the stability and the quality of transient response, using experimental methods for determining the allowable values for controller parameters.

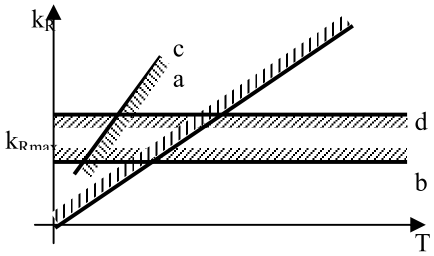


Fig. 13: Areas of variation of the parameters agreed to a PI regulator to meet performance requirements.

If the equipment used to implement automation devices is numerically block diagram of the automatic system is illustrated in Fig. 13. Digital equipment contains the ADC, DAC and an adjustment algorithm. Beyond these basic elements, digital equipment also contains a number of other elements of category acquisition systems and process interfaces.

$$K_u = -\frac{0.0256D}{\lambda 3.36\cdot 10^{-4}(1+R)960\cdot 10^{6}}\left[\frac{d(\Delta P_v)}{dh}\right]\Bigg|_{h=h_0}$$

then the transfer function of the tuning process flow is:

$$H(s) = \frac{\Delta U(s)}{\Delta X(s)} = \frac{K}{1+Ts} = \qquad (32)$$

$$\frac{3.48D}{[0.16Ds + 0.004392\cdot\lambda(1+R)]10^{10}}\left[\frac{d(\Delta P_v)}{dh}\right]\Bigg|_{h=h_0}$$

IV. Numerical Simulation Process

Simulation scheme for regulating system of the flow in Simulink is shown in Fig. 14, in which were introduced following data [13]:

L0=0.24; ro=960; Fe0=100; D=0.01; S0=3.14*D*D/4;
kf=2*L0/Fe0; ks=2*L0/S0;A=0.2; T=2*A*L0/Fe0; F=10;
c=5; roe=1000; ce=5;V=0.036;
F1=-(F/100)*c+F; F2=(F/100)*c; F10=3; F20=3;
teta0=40; teta1=20; teta2=60; teta10=40; teta20=40;
tetaa=15; tetaa0=10; tetam0=40; tetame=30; tetae0=20;
F0=0.24; alfa12=2; T1=(roe*ce*V)/(roe*ce*F0+alfa12*A);
alfa23=2; rom=1000; cm=4; Vm=0.003;
T2=(rom*cm*Vm)/(alfa12+alfa23)*A;
k1=(F10/teta0)*(ro*c*teta10)/(roe*ce*Fe0+alfa12*A);
k2=(F20/teta0)*(ro*c*teta20)/(roe*ce*Fe0+alfa12*A);
k3=(teta10/teta0)*(ro*c*F10)/(roe*ce*Fe0+alfa12*A);

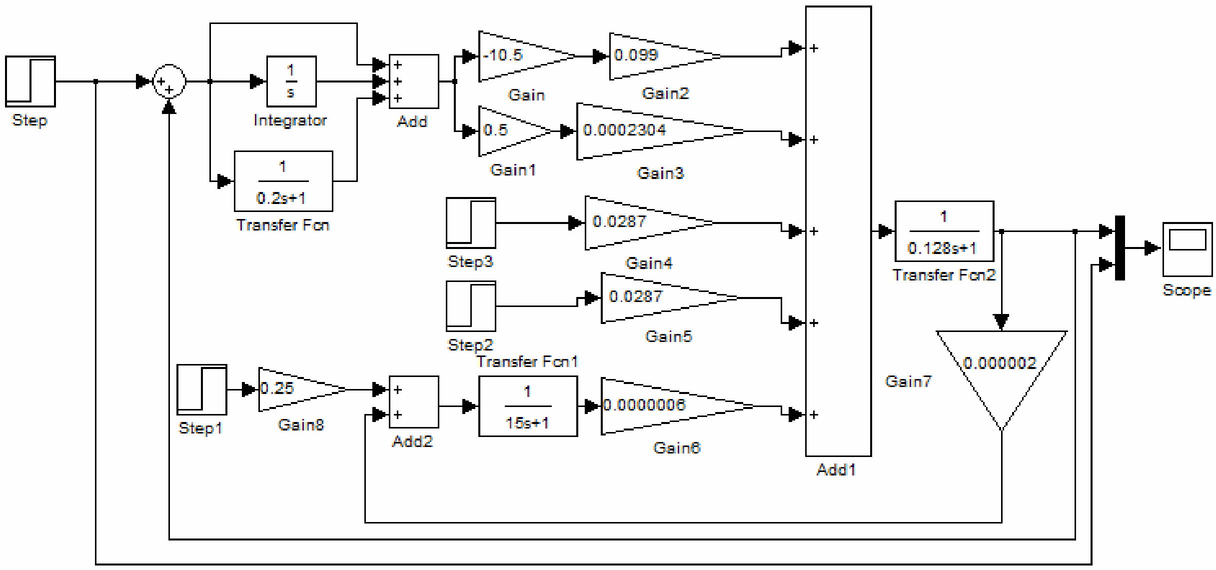


Fig. 14: Simulink block scheme of the process.

Knowing the factors measurements:

$$K_x = -\frac{0.0183\cdot 0.24\cdot\lambda(1+R)}{0.16D} \qquad (31)$$

k4=(teta20/teta0)*(ro*c*F20)/(roe*ce*Fe0+alfa12*A);
k12=(tetame/teta0)*(alfa12*A)/(roe*ce*Fe0+alfa12*A);
k21=(teta0/tetam0)*(alfa12)/(alfa23+alfa12);
k5=(tetae0/tetam0)*(alfa23)/(alfa23+alfa12);

After running in Simulink applying a step-type signal the following from for flow variation resulted (Fig. 15).

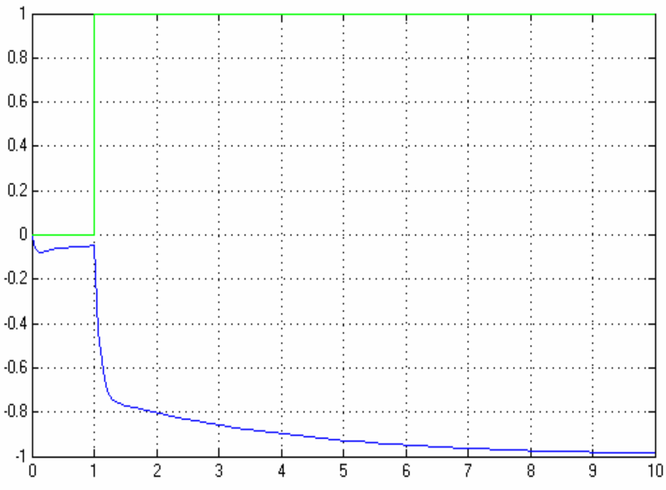


Fig. 15: Variation in signal flow-type step.

V. Conclusion

Any measurement of flow is always accompanied by disturbances. If higher slope proportionality is chosen, these disturbances are attenuated and transmitted automatically to the regulating valve. But for random values of the disturbance it may be that valve adjustment is operated in such a degree as to produce real changes in flow. Therefore, where flow regulation is strongly influenced by disturbance is preferred to introduce a linear regulator to not notice small changes in flow caused by disturbance. In this case we get a smoother movement of the rod valve and better stability for regulation sistem.

Mathematical model of the process resulted in the "three-tank system is many-variable, and strong third-order nonlinear, which brings difficulties in stabilization and regulating problems for the level of liquid in the two external tanks (tanks 1 and 2). Fuzzy regulators for output signals (after error adjustment) or for the state may satisfy these conditions, compared with other regulating solutions.

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