Division in sectors technique applied to hydric supplying systems

FABRÍCIO RAMOS DA FONSECA
Escola Politécnica da Universidade de São Paulo
Av. Professor Luciano Gualberto, Trav. 3, 158, Room A2-06
BRAZIL
fabriciorf@gmail.com

WELLINGTON SPERANDIO SILVA
Power and Electric Automation Engineering Department
Escola Politécnica da Universidade de São Paulo
Av. Professor Luciano Gualberto, Trav. 3, 158, Room A2-06
BRAZIL
wellington.sperandio@usp.br

CAIO FERNANDO FONTANA
Power and Electric Automation Engineering Department
Escola Politécnica da Universidade de São Paulo
Av. Professor Luciano Gualberto, Trav. 3, 158, Room A2-06
BRAZIL
caioffontana@uol.com.br

EDUARDO MARIO DIAS
Power and Electric Automation Engineering Department
Escola Politécnica da Universidade de São Paulo
Av. Professor Luciano Gualberto, Trav. 3, 158, Room A2-06
BRAZIL
emdias@pea.usp.br

Abstract: *The decrease of the hydric losses with the reduction of the operation pressures of the distribution nets is a phenomenon a long time known for the sanitation and water distribution companies. Among the used techniques for this purpose, the division in sectors technique comes, now, as one of the more effective instruments of improvement and optimization of the supplying services. The wide diffusion of this technique, however, would not be possible without the technological evolution of the key elements, necessary to carry out this control method of urban hydric supplying. In this work are presented solutions implemented by the Basic Sanitation Company of the State of São Paulo which has been carried out for more than five years. This time allowed that the techniques and the methods presented reach the necessary maturation degree so that a functional and each more reliable model of the division in sectors technique would be established.*

Key words: *Division in sectors technique, sanitation automation systems, pressure reduction valves.*

1 Introduction

Many are the reasons for the deficiencies found in the control of the urban hydric provisioning in Brazil. Many of these reasons, however, find convergence in a common reason: the lack of planning in the implantation and in the expansion of the nets and control systems of water supply.

Data of the National System of Information About Sanitation - SNIS (BRAZIL, 2004), indicate that the index of urban provisioning in Brazilian territory is about 94,5%. This elevated percentile of covering, however, doesn't reflect the quality index related to the installment of this service.

According to the Brazilian Association of Public Services of Water and Sewer Private Concessionarys - ABCON, the index of waste of water with leaks and secret connections was of 38% in 2005. The high index of hydric losses and the continuous interruption in the water supply are, unhappily, problems widely found as in country areas as in the great centers.

In this context, SNIS mentions the division in sectors technique of the provisioning nets as basic requirement for the control of supply water systems and for the decrease of the hydric losses. TSUTIYA (2004) reaffirms that necessity when suggests the pitometric districts as units of operational control, emphasizing, among other factors, the necessity of isolation of the nets.

In spite of these recommendations and the good acting verified in the control of the hydric urban provisioning systems of places in that the division in sectors technique was adopted, some managers still resist to the adoption of this technique, because it requests studies and, sometimes, substantial investments. In this way, the division in sectors technique, when not established during the project stage of the system, it ends later for competing with the investments disputed by the own expansion of the nets of provisioning, being relegated then to a secondary action.

However, the important positive impact presented in the systems of urban provisioning where has been opted the implantation of this technique, compels the managers of the basic sanitation sector to consider the use of the division in sectors technique as instrument of improvement and optimization of the offered services. This action tends to cart larger readiness of the provisioning system to the population and great reduction of the waste of hydric resources, factor that heads the list of concerns of the basic sanitation companies.

1.1 Social Impact

The scenery of inefficiency of the basic sanitation companies decrease its capacity of investment, which ends for turning slow the expansion and the improvement of the hydric provisioning systems. This factor, added to the worsening of shortage of hydric resources due to the pollution of the manancials, to the irregularity in the demographic distribution and to the unavailability of water in certain areas of the country, causes great negative impact in the society, committing its more basic necessitys.

According to the Health World Organization, each $0,60 invested in sanitation takes to the economy of $2.40 in treatment of diseases, once a high number of pathologies come from water.

Besides of that, the reduction of the losses indexes in provisioning systems takes to the reduction of the production costs for the same amount of water gave to the consumers, considering that the hydric volume captured, treated and transported decreases, making possible the decrease, also, of the amount of chemical products used in the treatment of this resource, besides the evident advantage of the decrease of the amount of captured water of the manancials, more and more scarce.

Actions that look for the improvement of the dealers' efficiency became, therefore, priority and are already part of the activities of larger importance of the main sanitation companies. Such activities, however, demand the involvement of specialized technical labor and, many times, great investments in interventions in the provisioning net.

2 Problem Formulation

2.1 Administration of the Hydric Losses

The decrease of the hydric losses with the reduction of the operation pressures of the distribution nets is a phenomenon a long time known for sanitation and water distribution companies. In 1980 an extensive report was published about pressure control as part of National Leakage Iniciative - England, that became a traditional reference of the relationship between pressure and leak volume in systems of urban provisioning.

The effective control of hydric losses is made by four activities mentioned by the technical document of support D1 of the National Program of Waste of Water Combat - (PNCDA - D1, 1999, p.11):
(a) administration of the pitometrics zones pressure;

(b) active control of leaks;

(c) speed and quality of the repairs; and

(d) administration of the infrastructure.

The pitometrics zones pressures administration looks for to control of the pressures of these zones and assure minimal patterns of provisioning to the consuming extensions. These dual objectives are reached by the specific division in techniques project of the distribution systems, which involves direct pumping in the net through stations of pumping reinforcement (boosters) or for the introduction of reduction pressure valves (RPVs) in strategic points of the distribution net.

The active control of leaks opposes the passive control that is, basically, the activity of just repairing the leaks when they become visible. The methodology more used in the active control of leaks is the research of leaks non visible, accomplished by listening of the leaks for mechanical or electronic geophones. That activity reduces the time of leak, in other words, as high goes the frequency of the research, high will be the rate of annual flow recovered. A cost-benefit analysis can define the best research frequency to be accomplished in each area.

From the knowledge of the existence of a leak, the time spends for its effective localization and stopping is a key point of the administration of hydric losses.

The practice of the mentioned activities already brings improvements to the infrastructure of the provisioning system. Therefore, the substitution of pieces of the water net is just accomplished when, after the accomplishment of the other activities, be still detected high losses in the area, avoiding higher costs. However, to make possible the effective carrying out of these activities, it is necessary the segmentation of the provisioning net in zones, technique denominated division in sectors technique.

2.2 Division in Sectors Technique

The division in sectors technique consists in the separation of the hydric urban provisioning system in districts denominated pitometrics zones, with the general objective of establishing a more effective control of the pressures and flows of water of these zones. Among the benefits obtained by the use of this technique are:

(a) the domain of the consumption of the sectors, in an individualized way, allowing its control and accompaniment;

(b) flexibility in the conduction of the hydrics resources for areas that present pressures below demanded for its provisioning or of areas that present pressures above the necessary;

(c) speed in the discovery of the intervention needs in the system, through the fast breaking detection or obstruction of lines of provisioning;

(d) structured and systemic vision of the hydric provisioning net and its components;
(e) economy of financial resources with the minimizing of the damages caused by the hydric losses and suitable spare uses by the rising of the profile of consumption of each pitometric zone.

Each pitometric zone is defined by the area supplied by a distribution reservoir (leaning, semi-buried or buried), destined to regularize the provisioning variations and to condition the pressures in the distribution net. Some planners opt for the provisioning of the distribution net for a direct derivation of the water main pipe or through the exit of reinforcement boosters with static rotation pumps. This technique, however, is highly condemnable, because the control of the

ISBN: 978-1-61804-056-5

pressures of the sectors becomes impracticable due to the variety of the happened oscillations.

Once the main reservoir is located inside of the pitometric zone, in the division in sectors technique is necessary the existence of a high reservoir, external to the controlled sector, whose main function is to condition the pressures in the areas of high topographical quotas once they cannot be supplied for the main reservoir. In that case, the sector is divided in pressure zones, where the static and dynamics pressures obey preset limits. According to the Brazilian Normalization NBR 12218/1994 the maximum static pressure in the distributing pipes should be of 500 kPa (50 mca), and the minimum dynamic pressure, of 100 kPa (10 mca). Values out of that strip can be accepted since justified technical and economically.

So that the whole pitometric zone could be provisioned by a only one reservoir it is necessary that this be a elevated one or be located out of this zone, located in a quota of, at least, 10 meters above the highest quota of the sector.

In the implantation of a divided in sectors system, the definition of the pressure zones is made taken as base the limitation of the maximum static pressure in 50 mca in the lowest point of the pressure zone and the limitation of the minimum dynamic pressure in 10 mca in the extreme point of the zone of pressure control.

The extreme or critical point is that, inside of the pitometric zone, where is verified the smallest dynamic pressure, that is, the highest point or the most distant. In this way, the critical point can move due to the increase of rugosity in function of the age of the pipes, tending being located, initially, in the highest point of the pressure zone and, hereafter, in the most distant points in relation to the referential pressure (reservoir, booster or RPV). This point is used to consider the pressure potential of reduction of the area, besides being the referential point for control of the provisioning. The low acceptable pressure in this point can vary among the hydric provisioning companies, however, in most of the areas, the maintenance of the minimum pressure of the distribution nets between 10 and 15 mca is enough for maintenance of the provisioning in a satisfactory way.

The technical document of support of the national program of combat to the waste of water (PNCDA - D1, 1999, p.21) exemplifies a supplied area for a leaning reservoir and a high one with a variation of a dynamic pressure maxim of 10 mca, where the area of influence of the reservoirs can be demarcated through level curves that define static pressures of 20 mca and 50 mca, for both reservoirs.

Illustration 1 demonstrate that this will define an redundant provisioning area , that as can be provisioned by the leaning reservoir (closer pressures of 20 mca) as for the high reservoir (closer pressures of 50 mca).

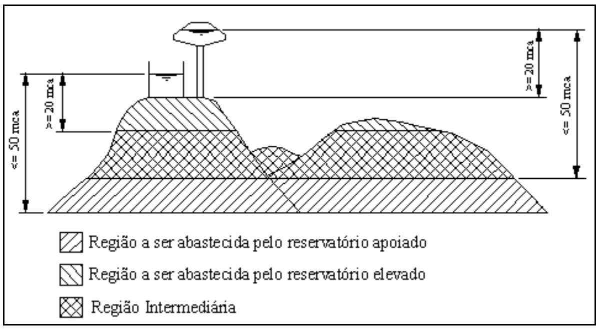


Illustration 1 - Outline of division in sectors with a redundant provisioning area - Source: Technical document of support of the national program of combat to the waste of water - D1 - Special Secretariat of Urban Development, Brasília,1999.

Once, for the reduction of hydric losses, it is desirable to submit the net to low pressures, most of that area should be provisioned by the leaning reservoir, what reduces the flow also pressed down for the high reservoir, bringing, in this way, reduction in the electric power consumption.

The technical document of support of the national program of combat to the waste of water (PNCDA - D1, 1999) recommends that the maximum geometric unevenness for the division in sectors of lands with low topographical variation is of 50 meters. In areas of more uneven topography, it is necessary the use of an intermediate reservoir. The high implantation costs and maintenance

ISBN: 978-1-61804-056-5

of reservoirs (mainly the high ones) just led the planners to the elaboration of alternative solutions, available after the technological development of the control devices and automation. This way, today is common the use of boosters of variable rotation and of RPVs for the control of the pressure in the sector, keeping as basic function of the reservoir the regularization of hourly variations of demand and fire reservation.

3 Components of the Automatic System of Control of the Pitometric Zones

The wide diffusion of the division in sectors technique would not be possible without the technological evolution of the key elements, necessary to the development of this method of control of urban hydric provisioning. Among these elements are the RPVs, the measurement and automatic control devices and the supervision and administration system.

Seeking the analysis of technologies for the control, supervision and administration of the pitometrics zones and its diffusion, has been opted for a case study accomplished in the dependences of the Company of Basic Sanitation of the State of São Paulo (SABESP), the largest company of basic sanitation of Latin America, with the intention of presenting solutions used by this company for automation of the division in sectors system.

As SABESP constitutes a system of great dimension, that involves about 366 municipal districts and countless configurations of hydric provisioning, became necessary the limitation of a context that offered typical sample characteristics of different arrangements of the elements that compose a system of that nature. That limitation allowed to indicate as focus of the study the Superintendency of the Coast for being this an unit that gathers identification conditions and study of different guiding analysis referentials for the taken of decision about divided in sectors automated systems.

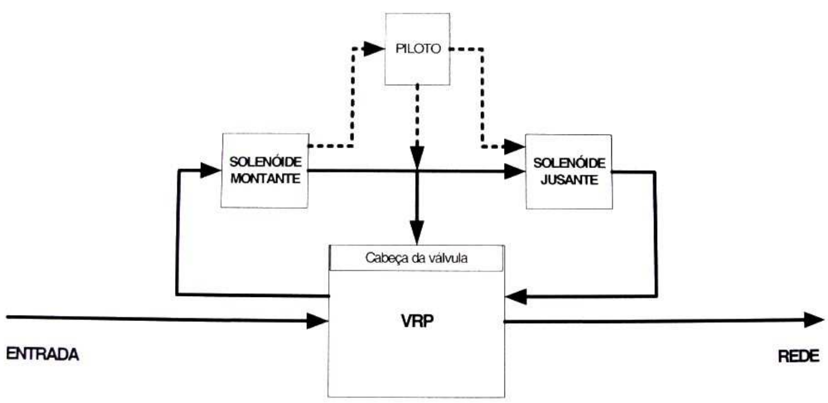
3.1 The Reduction Pressure Valves (RPVs)

The RPVs have as main purpose maintaining, in the controlled sector, the minimum pressure necessary for the satisfactory provisioning of the consuming extensions. The dynamics characteristics present in the modern reduction pressure valves allow maintaining, with more precision, the control of the flow and pressure in the exit of these valves. These characteristics, added to the countless possibilities and strategies available by the digital devices of control associated to these equipments, make possible the necessary control of the pressure in the areas divided in sectors and, for consequence, the significant reduction of the hydric losses existent in these sectors.

The RPVs are used to generate a controlled loss of load so that, in cases of pressure instability, can maintain, to the downstream of the line in that they are installed, a fixed pressure.

The system involved in the development of a control through RPVs is composed, besides the own valve, of a group of devices that have for function to establish the control of the pressure of operation of this equipment.

The Illustration 2 present, in a diagram of blocks, the modules that constitute the system of operation of a typical RPV, used by SABESP for stabilization of the pressure of the pitometrics zones:



Ilustration 2 – Modules of the operation system of a RPV – Source: *Descriptive memorial of the typical project of automation*

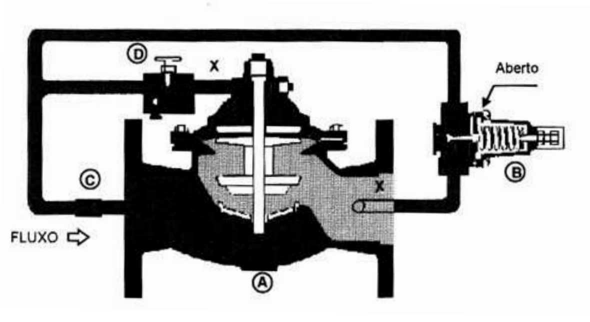
ISBN: 978-1-61804-056-5

of reduction pressure valves , SABESP - Superintendency of the Coast, 200.

Most of RPVs, used in the division in sectors technique of the controlled districts, is of the globe type, operated hydraulically through direct action of a diaphragm through a pilot valve that, in this way, is operated by solenoids valves.

The pilot circuit allows the self-adjustment of the valve, assuring a necessary control of the reduced pressure, inside of extensive flow variations.

The valve is usually open when the pressure of the line is applied in its entrance. When that same pressure is applied to the head of the valve, what happens through the pilot valve, it closes, because the area of the diaphragm that composes the actuator of the valve is larger than the area of its seat. Is the control of the pressure above the diaphragm that determines the position of RPV, in other words, open, closed or in an intermediate position. Illustration 3 and 4 shows the hydraulic circuit of operation of a RPV:



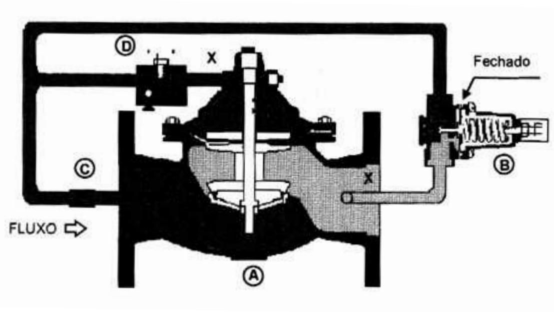


Illustration 3 - Vision of the hydraulic circuit of an open RPV

Illustration 4 - Vision of the hydraulic circuit of a closed RPV

Technical support document of the National Program of Combat to the Waste of Water, Special Secretariat of Urban Development - Brasília, 1999.

Fundamentally, the system shown in the illustrations 3 and 4 does with that the main valve reproduces the movements of the pilot valve (B) under the action of the pressures to amount and the downstream.

When the pilot valve is open, the present pressure in the control circuit doesn't exercise any force in the membrane of the main valve (A), what does with that the closing system became free and the valve opens.

From the closing of the pilot valve, the pressure contained in the control circuit exercises a force in the membrane of the main valve causing its closing.

The fixed hole (C) makes possible the conduction of the pressure to the downstream of the valve to the operation circuit, while the valve holes (D) provides the adjustment of the speed of actuation of RPV.

The control through a pilot valve is an adjustable operation, projected to allow the flow through the main valve when the pressure to its downstream is below the adjusted for the spring of the pilot actuator. The increase in the fluid demand produces, as result, the fall in the pressure to the downstream of RPV (controlled pressure). The pilot valve "feels" this fall in the pressure while the spring of its actuator causes the opening of the valve. With the opening of the pilot valve, the pressure is drained of the head of the main valve, allowing to the line of main pressure to open the RPV. The main valve continues to open until the pressure in the downstream has come back to the value corresponding to the fitting in the pilot valve.

The reverse will happen in an increment in the controlled pressure (to the downstream of the valve), resultant of a reduction of the demand of water, that causes the proportional closing of the pilot valve that, consequently, provokes the same reaction in the main valve.
The RPVs are installed in the points of entrance of each pitometric zone that has its bounds established for the installation of

manual valves on its bordering points. The entrance of the pitometric zone has its provisioning proportionate for a reservoir or variable booster, which gives water to amount of the RPV.

The current RPVs possess the self-regulation capacity, with operation parameters established remotely through digital ways of telemetry and digital instruments that constitute the measurement devices and automatic control of the system.

3.2 Devices of Measurement and Automatic Control of RPVs

According to PEREIRA (1995 apud SOUZA, 2006, p.28), the automation [...] makes possible the methodological collection and precise data that can be used to obtain the optimization of the process". In that sense, the automation systems make possible the reduction of the cost of the whole productive system, with the consequent increase of the profits and the decrease of losses.

Of the operational point of view, the Superintendency of the Coast of SABESP makes use of the following elements in the remote stations that compose the automatic system of control of the pitometrics zones:

(a) Instrumentation: group of instruments (pressure and flow transmitters) that allow monitoring specific parameters of RPVs. For the characteristic of the places of installation of these instruments, they should have degree of protection that makes them possible to work under intense humidity;

(b) Local panels: group of devices (relays, power sources, batteries, terminals and cables) that allow linking and sourcing the devices of the remote station of control of RPVs;
(c) Programmable logical controller (PLC): device that receives the signs of the instruments processes these signs according with a internal program and operates the solenoids valves conjugated to the pilot valve of RPV controlling its position. It works in an autonomous way, according with pre-established parameters sent remotely by the center of operational control (COC) of the system.

The remote stations constitute the industrial plant of the system of hydric provisioning. The automation system and the monitored and controlled variables of each station vary according to the function that it exercises in the system. The responsible stations for the control of RPVs present similar structure to each other. The diagram that illustrates the structure of a station of this nature can be visualized in Illustration 5. The impact caused by an eventual loss of a station also determines the amount of redundancies, be them of communication or of instrumentation.

The control of RPV is accomplished with base in the parameters sent by the instruments of its remote station and for parameters sent by the COC. Its position varies among totally open and partially closed. The total closing of the extension of RPV, when necessary, it is accomplished through manual valves.

In balanced conditions of the desired pressure in the exit of RPV, a controller maintains signs acting in both solenoids valves, what makes the RPV stay in its position. To close the RPV, the controller removes the sign sent to the solenoid valve SV1, shown in Illustration 5, opening it and injecting, in this way, pressurized water in the actuator of RPV until the valve downstream pressure lowers for the desired value, moment that the solenoid SV1 is closed confining the pressure in the head of RPV. If the valve downstream pressure is below the desired value, the controller removes the sign sent to the solenoid valve SV2, emptying the actuator of RPV through the connection between this and the valve downstream, provoking its opening until the downstream desired pressure be reached, moment that to solenoid SV2 is closed.

ISBN: 978-1-61804-056-5

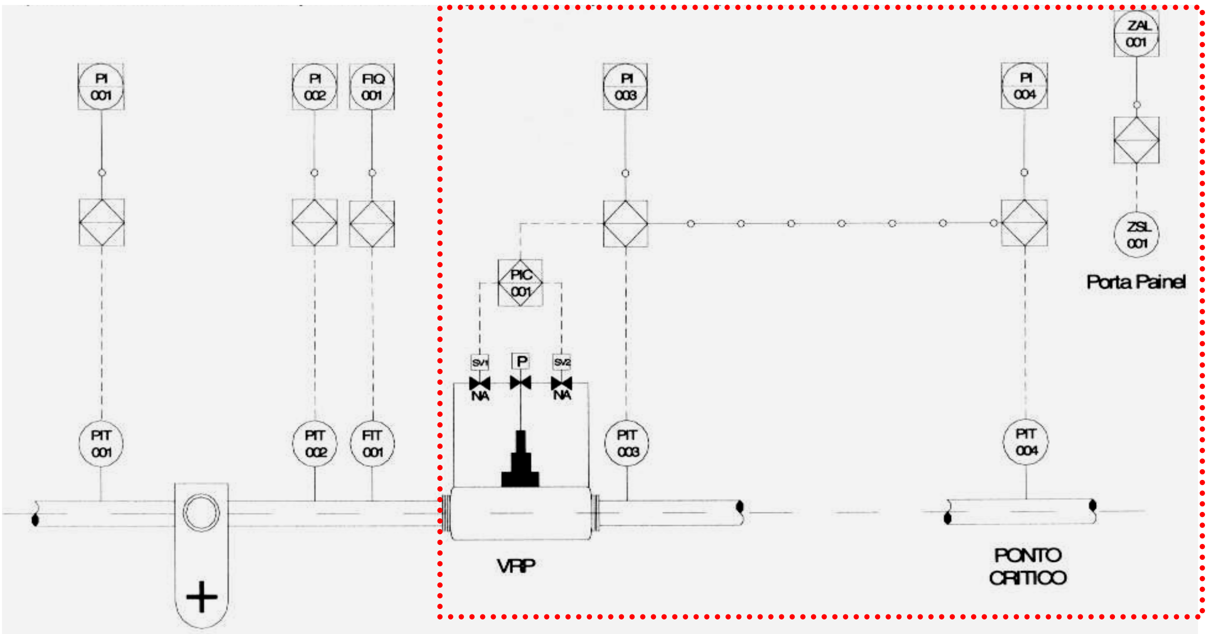


Illustration 5 - P&I diagram of a remote station of control of a RPV. Source: Descriptive memorial of the typical project of automation of RPVs, SABESP - Superintendency of the Coast, 2006.

The fact of the valves SV1 and SV2 be usually open makes possible that, in the absence of energy or defect in the controller, the RPV stays opened, guaranteeing a pressure on its downstream by a manual adjustment previously accomplished in the pilot valve that, in these conditions, should assume the control of RPV. This condition preserves the provisioning of the controlled sector in case of faults of electric nature.

The remote stations of control of RPVs can assume two states of automatic operation:

(a) State of normal operation: The position of the valve is established in function of the pressure of the critical point in the controlled pitometric zone. This value is transmitted to the PLC of the station by the COC. For the comparison of this value with a established set-point, the controller generates the out signal from the analysis of the difference among these two values. The analysis of these greatness and the determination of the out signal occur from a internal algorithm programmed in PLC. This out signal, consists of a value of 0 or 100%, modulated in the time, in other words, the algorithm establishes the time that the signal stays in its maximum level until the valve reaches the necessary position for the establishment of the desired pressure to its amount and, for consequence, in the critical point.

(b) Contingency state: From the communication loss between the remote control station of RPV and the critical point of the controlled sector, PLC assumes the state of contingency control, where the position of the valve is established by the controller for the measurement of the downstream pressure and for a table hour x pressure, previously defined and programmed.

This table is resulted of a study deepened about the seasonal behavior, diary and schedule of the supplied area and it establishes the demanded pressures every hour of the day for maintenance of the minimum pressure necessary in the critical point of the pitometric zone.

The other instruments that compose the station (additional flow and pressure transmitters and alarms) exist to give subsidies to the operators for the control of the system. They provide the detection of ruptures in the nets of provisioning, defects of operation of RPV or non authorized access to the remote station.

The inherent slowness of the process determines that the gain of the control system be low, as well as its integration constant, for the system to notice the result of an action executed before deciding for

ISBN: 978-1-61804-056-5

the maintenance, increment or decrease of the position of the valve.

3.3 Information and Supervision System

The information systems are defined as " [...] the systems that allow the collection, the storage, the processing, the recovery and the difusion of information " (BARRELLA; BRUNSTEIN, 2000, p.3).

The core of the information and supervision system of the hydric provisioning nets is constituted by a supervisory system: a computing system with a program application for process supervision.

This system, installed in COC, concentrate the information of the control remote stations of the RPVs turning available remotally the:

(a) access to the screen of command of each station;

(b) visualization of the operational state of the equipments of the station;

(c) visualization of the happened alarms;

(d) values of the measured variables and calculated by the autonomous devices;

(e) established operation parameters;

(f) historical registration of all the variables, monitored and controlled.

The Illustration 6 shows a screen of supervision of a remote control station of a RPV.

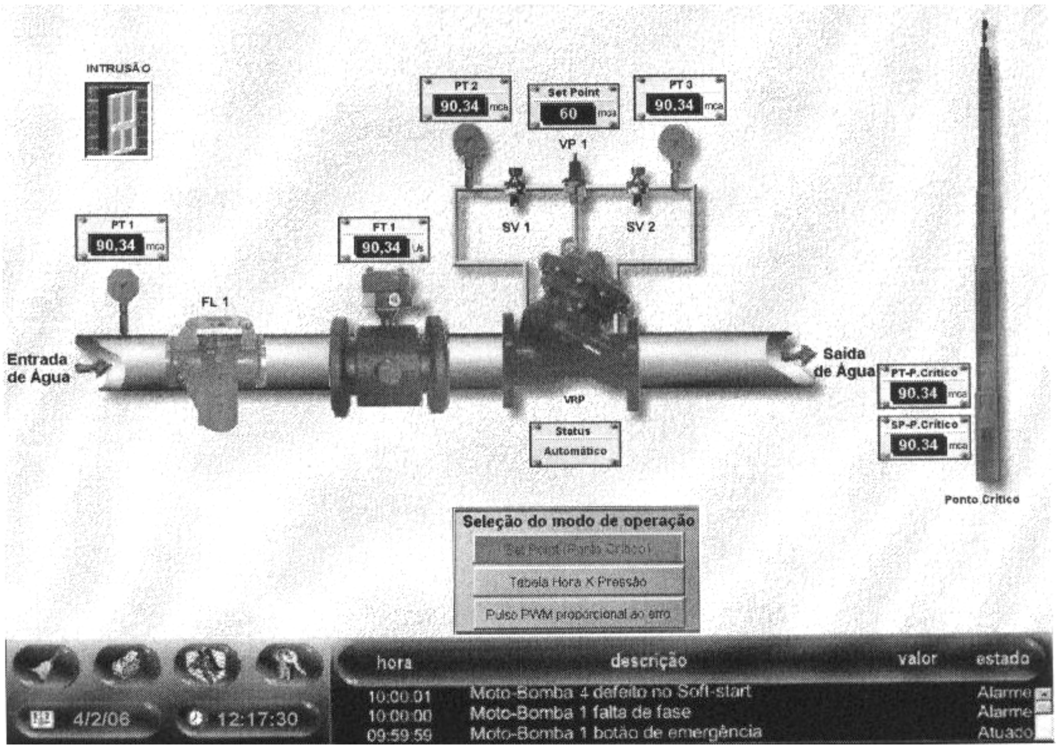


Illustration 6 - Screen of a supervision system of a control remote station of a RPV - Source: System of supervision of the Company of Basic Sanitation of the State of São Paulo - Superintendency of the Coast, 2008.

The control of the pitometric zones for the supervision system happens through the visualization of the control variables, typically the pressure and the flow of each sector, and for the configuration of the control remote stations of the RPVs located in the entrance of each zone.

The modification of these parameters can happen in function of the change of the characteristics of the system of hydric

ISBN: 978-1-61804-056-5

provisioning, as for example, the increase of the rugosity of the pipes or temporary maintenance in one of the sectors, or still, in a more common way, for the seasonal modification of the profile of consumption of the population.

The supervisory system allows, still, the access to more technical parameters, as constants of the control algorithm or programming parameters of the PLC. These parameters, however, for define the philosophy of the system control and fordemand deepened technical knowledge of the equipments, are accessed by inserting specific passwords, granted, in general, to the automation engineers.

4. Conclusion

The expansion of the hydric provisioning systems is a continuous and necessary process to the propagation of the basic sanitation to the communities that are in constant growth in most of the Brazilian areas. The planning of this process has fundamental importance in the subsequent maintenance of these systems and in the identification of the inevitable intervention needs that, almost always, are urgent, because they commit a service related to the public health of the population.

The administration of the pressure and a good plan of research of leaks, according to researches accomplished with SABESP engineers, constitute procedures of highest importance inside of a plan for reduction of hydric losses in a system of urban provisioning (C&I, 2006, p. 49).

In this context, the division in sectors technique comes as an option that goes to the encounter of these objectives, while brings benefits as a most efficient control of the provisioning nets, better administration of losses and larger effectiveness of the maintenance interventions.

The importance of the popularization of options as that happens in function of the constant and increasing technological evolution, which will allow to the automation of provisioning systems to reach the reliability edges and necessary robustness to the installment of these services.

It is expected, therefore, that this work supplies indicators of the need of deepness of researches in the area of sanitation and that comes to contribute for the diffusion of available technological knowledge in this area.

Bibliographical References

[1] ABCON – Site of the Brazilian Association of Public Services of Water and Sewer Private Concessionary. Available in <http://www.abcon.com.br >. Accessed in Aug. 02, 2010.

[2] BRAZILIAN TECHNICAL NORMS ASSOCIATION. **Projeto de reservatório de distribuição de água para abastecimento público – NBR 12217**. Rio de Janeiro, 1994.

[3] **_______ Projeto de rede de distribuição de água para abastecimento público – NBR 12218**. Rio de Janeiro, 1994.

[4] BARRELLA, W.D.; BRUNSTEIN, I. Necessidades e tendências dos sistemas ERP, 2000. In: Simpósio de engenharia da produção UNESP, 2000, Bauru. **Electronic anais**... 2000. Available in: <http://www.simpep.feb.unesp.br/anais7/ana7c.html>. Accessed in Aug: Nov. 14 2008, p.1-3.

[5] BARRETO, G. C. GOMES, D. M. CARDOSO, L. A. GUTIERREZ, L.; PEREIRA, J. A. R. Impacto da setorização no abastecimento de água em áreas urbanas. João Pessoa, PB. **anais**... 2006.

[6] BRASIL. National Secretariat of Environmental Sanitation. National System of Information About Sanitation. Brasília, 2004.

[7] PEREIRA, S. L. SOUZA, M. Instrumentação inteligente empregada na gestão de sistemas de tratamento de água e análise de benefícios e vantagens. **Controle e Instrumentação.** São Paulo, ed.117, 2006, p.58-66.

[8] PNCDA - Documento técnico de apoio do programa nacional de combate ao desperdício

de água: Special Urban Development Secretariat, Brasília, 1999.

[9] FERNANDES, J. J .P. Sob pressão – **Controle e Instrumentação.** São Paulo, ed. 117, 2006, p.50-62.

[10] FONSECA, R.F. **Modelo para Automação de Sistemas de Abastecimento Hídrico**. Dissertation of Master's degree. São Paulo, EP-USP 2009.

[11] SABESP - Company of Basic Sanitation of the State of São Paulo: Memorial descritivo do projeto típico de automação de válvulas redutoras de pressão, SABESP - Superintendency of the Coast, 2006, p. 07.

[12] SNIS – National System of Information about Sanitation. Diagnóstico dos serviços de água e esgotos, 2002. Brasília, DF. Available in <http://www.snis.gov.br/diag_2002_ae.htm>. Accessed in: nov. 01 2008.

[13] TAMAKI, H. O. SILVA, G. S. GONÇALVES, O. M. **A medição setorizada como instrumento de gestão da demanda de água em sistemas prediais: estudo de caso na Universidade de São Paulo**. USP. São Paulo, EP-USP 2005, p.65–70.

[14] TSUTIYA, M. T. **Abastecimento de Água**. Hydraulic and Sanitary engineering department of the Polytechnic School of the University of São Paulo. São Paulo, – *EP-USP*, 2004.