The pipeline oil pumping engineering based on the Plant Wide Control technology

2015 IOP Conf. Ser.: Mater. Sci. Eng. 81 012111

(http://iopscience.iop.org/1757-899X/81/1/012111)

The pipeline oil pumping engineering based on the Plant Wide Control technology

D P Starikov[1], E A Rybakov[1], E I Gromakov[1,2]

[1] Institute of Cybernetics, National Research Tomsk Polytechnic University, Tomsk, Russian Federation
[2] National Research Tomsk State University, Tomsk, Russian Federation

E-mail: dstarikov@me.com

Abstract. This article provides recommendations for the use technology Plant Wide Control to control the pumping of oil through the pipeline. The proposed engineering using pipeline management in general (Pipe Wide Control) will reduce the loss of electric power at the expense of the balance of pumping stations located along the pipeline route.

1. Introduction

The pumping oil through the pipeline main task is providing required operational modes: maintaining regulatory requirements set by the pressure in the main oil pipeline and performance targets in terms of the transfer. In many companies, the main oil pipelines transition are occurs on the frequency controlled pump units now. Energy consumption that can reach tens of megawatts of electricity per year, depending on the volume of transported oil and the quality of the dynamic characteristics of all automatic pressure regulators on the pipeline.

Oil pumping system is a set of regulating purposes, pumps and tanks controlled by automation system. In modern operating conditions the system requirements process automation oil pump are follows:

- Continuous maintenance of the specified setpoints (SP) pressure / flow in the pipeline;
- Flexible adjusting the set values;
- Operative stabilization of change (fall / increase) the pressure in the pipeline;
- Optimization of the production process transfer (in this paper establishes the requirement to control pumping stations pipeline provides energy-efficient mode of operation);
- Possibility of operative business process management transfer (increase / decrease the volume of pumping) ERP (MES) system.

The problem pumping oil efficiency improving is presented in papers [1–4]. An example the technological process of the "reprocessing pipe" is a refinery where the pumped oil is processed to the commercial product. Refineries optimize the entire cycle of processing efficiently solved using automated technology perspective Plant Wide Control (PWC) [5], thereby minimizing the loss of various resources due to the energy balance of all process units. However, the controlling and optimizing pumping oil problem with automatic optimization of energy consumption of pumps pumping oil with help of PWC technology was not solved.

2. The problem statement

The aim of this paper is the substantiation of innovative process management framework pumping oil on the main oil pipeline (Pipe Wide Control) at the expense-balanced operation of pumping stations on the pipeline.

Consider a production process diagram pumping oil main oil pipeline (Figure 1), which is includes the following elements:

- Tank (with automatic level control).
- Booster pump.
- Bulk pump (or pump system).
- The pipeline with consumers.

Figure 1. The typical scheme of pumping.

In [7,8] describes the energy-saving algorithms for controlling the pressure in the pipeline by the valve and the main pump. Such algorithms provide optimization of individual pumping stations, but do not provide the balance of its overall pipeline.

Oil transportation in the considered model structure is as follows: crude oil is pumped from the tank farm booster pump by the main pump station and then used for transfer of oil through the pipeline. Control it maintaining the pressure equal to the target value (SP) is carried out electronically frequency drive control and electric valves in the pipeline (pipeline). During operation of the pipeline may change the planned volume pump, and pressure in the pipeline (Figure 2) and the operating point (PT) in the feed-pressure coordinates (Q, H) continuously pump’s drift (Figure 3).

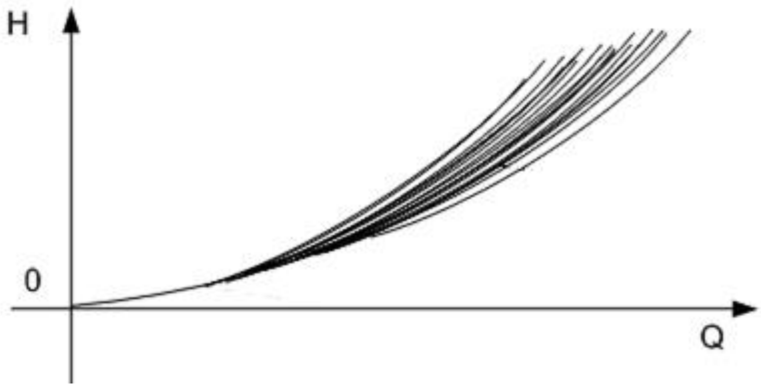

Figure 2. Changes in the characteristics of the pressure in the pipeline parameters.

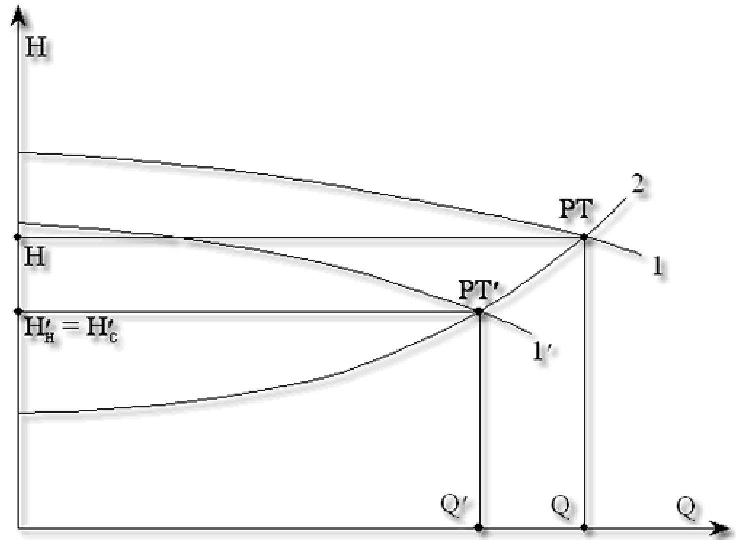

Figure 3. The pump operating point changing.

The reasons for changing the position of the operating point of the pump set may be different values of backwater pump due to differential pressures at the pump, pressure changes the pressure side of the pump caused by the change in cross-section pipes (the appearance of sediments, ice formation), throttling valves, oil consumption, and others. As a result of the pipeline route with the portions formed of different feed oil. This leads to the changes in the performance of the main pipeline and, often, to business losses oil-company.

Therefore there is a necessity for a coordinated automatic control of the whole complex of pumping oil, which are ensure the minimization of consumption of electric energy consumption of pumping units, and improve the efficiency of main oil pipeline as a whole.

3. Plant Wide Control application

PWC is a concept of automatic control of production in general with accent on hierarchy optimization problem. It may be represented as multilayered architecture of control actions. Here interaction between upper and lower layers is determined by control settings (set point, SP). SP is a degree of freedom for automatic regulators of a process (Figure 4). Values of those set points are being calculated to balance operation of technological units.

Set points of hierarchy located loops of pump control are used for maximize efficiency of a process on a bottom level of PWC structure. During PWC design the problems such operator control, start of control object, its shutdown, failures diagnostic, SIS design and ERP-locking are being solved.

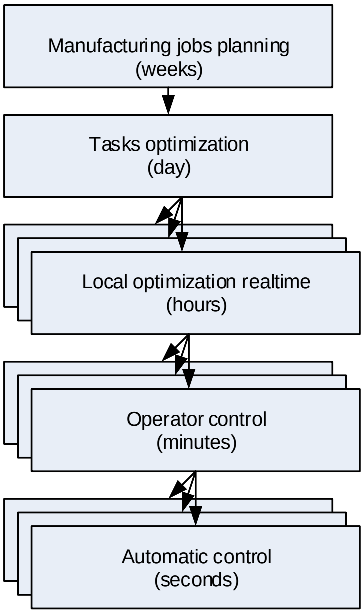

Figure 4. Production Automatic control layers (Plant Wide Control).

Controlling object in proposed PWC technology is process of an oil tranportatin and main algorithms on top level. It provides minimization of power consumption in general when limited pumping volumes.

Choosing optimal control strategy, its efficiency and attainability depend on "good choice" of free controlled variables.

For this degree of freedom is assigned to that independent controlled process variable which will effect on one or more crucial indicator, which characterizes value of a process. According to the task in the article, that parameter will be energy consumption of a pump unit.

Mathematically optimization task of oil transportation in general may be formalized as three components. It is minimization of energy cost (J), reachable of set points and technical specifications (s.t.) and operation limits (g):

$$\begin{aligned} &\min \mathrm{J}(\mathrm{x}, \mathrm{u}_{\mathrm{ss}}, d), \\ &\mathrm{s.}t,\ f(\mathrm{x}, \mathrm{u}_{\mathrm{ss}}, d), \\ &\mathrm{g}(\mathrm{x}, \mathrm{u}_{\mathrm{ss}}, d) \le 0, \end{aligned}$$

where u_{ss} – controlled variables, which characterize efficiency of transportation (pump rotating speed, valve's opening degree, set points of automatic pressure regulators); d – disturbances; x –variables that characterize process of pumping condition (pump energy consumption, pressure and pressure in pipeline).

Then function of process cost J may be written as:

$$J = \sum_i k_{p_i} P_i + \sum_i k_{F_i} F_i + \sum_i k_{Q_i} Q_i,$$

where P_i – pressure in pipeline; F_i –quantity of pumping; Q_i –power consumption of pumps stations.

Now Model Predictive Control (MPC) algorithms are being used as optimization algorithms of operating control of process in oil productions. The idea of it is being implemented in automatic regulators and follows from modern problem of optimal control: determination of the best influence on certain time interval T in a future. Implementation of this requires experience of object dynamic characteristics, robust and high-speed computer-assisted calculation. It is because for each sampling step it is necessary to solve system of differential equations with initial conditionals.

But in case of oil transportation MPC solution is difficult because of complexity of hydrodynamic processes of oil pumping. Nonetheless the problem of pressure effective control may be solved. But better way is application of PID regulators. It should be kept in mind that suitable option of choosing controlled variables according Plant Wide Control is ISA-PID structure with calculated by optimization algorithms parameters [9]. Feature of this algorithm is possibility of simultaneous control of process two degrees of freedom: setting SP and measured variable x (pressure in pipeline) as follows on Figure 5.

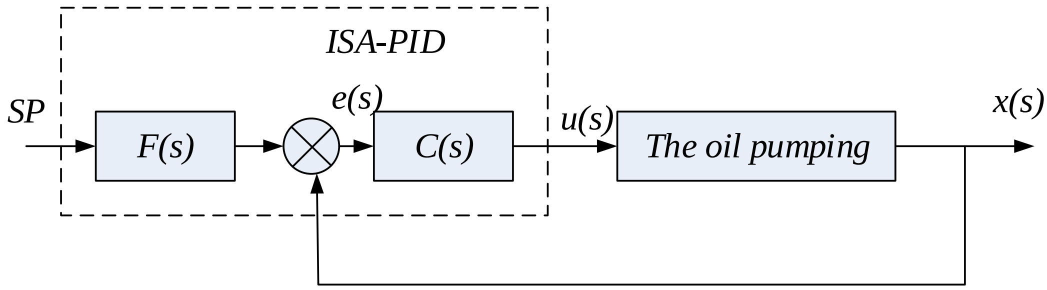

Figure 5. ISA-PID structure of oil transportation.

$$C(s) = PID(K_p, K_i) = K_p + \frac{K_i}{s},$$

$$F(s) = \frac{bK_p s + K_i}{K_p s + K_i},$$

$$u(s) = K_p(1 + \frac{1}{T_i s})e(s) - K_p(\frac{T_d s}{(1 + T_d / N)s}).$$

Here transfer functions of PID-control of both degrees of freedoms; u(s) is control actions on process of oil transportation. Parameters of regulator are SP (setting point), x(s) (measured variable), e(s) (difference between set and actual values of a pressure). Advantage of this regulator is possibility to provide required smooth changing of pressure in pipeline and as a result decrease pump's power consuming during transients.

4. Conclusion

Recommendations of Plant Wide Control technology application for oil transportation in pipeline were proposed in the article.

Proposed engineering with pipe control in general application (Pipe Wide Control) will allow decreasing energy losses due to balancing operation of pumps stations located along the pipeline.

PWC algorithms will allow to control of pump units operating point and provide maximum throughput opportunity with minimization of energy consumption.

References

[1] Kutukov S.E. Infromation and analitical system of main pipelines *SIP RIA,* Moscow, 2002, 324 p.

[2] Shtukaturov K.Y., Katanov R.S., Abdullina A.D. Calculation of operation modes of pipeline with automatic regulations system. *Oil Business*, **2**: Ufa, 2007. pp.113-119.
[3] Bykov, K.V. Modernization of crude oil pipelines control system. *CINAREM'11: proceedings of the 6th IC on use of mineral resources*, 2011, p. 23-24.
[4] Jiang D J, Design And Application Of Automatic Monitoring System For Crude *Oil Pipeline Transportation*, Master Thesis, China, 2012, pp.128.
[5] Elvira Marie B. Aske Design of plantwide control systems with focus on maximizing Throughput, Thesis for the degree of philosophiae doctor, Trondheim, 2009, pp.126.
[6] Kadam, J.V., W. Marquardt, M. Schlegel, T. Backx, O.H. Bosgra, P.-J. Brouwer G. D¨ unnebier, D. van Hessem, A. Tiagounov and S. de Wolf Towards integrated dynamic real-time optimization and control of industrial processes. In: Proceedings Foundations of Computer-Aided Process Operations (FOCAPO2003). Coral Springs, Florida, 2003, pp. 593–596.
[7] Starikov D. P. , Rybakov E. A. , Gromakov E. I. Application of a Bypass Pipeline during Pressure Control *Communications in Computer and Information* Science 2014 **487**, p. 406-414.
[8] Starikov D. P. , Rybakov E. A. , Gromakov E. I. SMART Pressure Regulation In Main Oil Pipeline *2nd International Conference on Advanced ICT (Information and Communication Technology) for Education (ICAICTE2014): proceedings,* Dalian, August 16-17, 2014. Paris: Atlantis Press, 2014, p. 53-56.
[9] King, Myke, Process Control: A Practical Approach. Chichester, UK: John Wiley & Sons Ltd, 2011, pp.396.