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Considerations on the Perspective of Electrical Adjustable Drives Introduction within the Oil Products Transporting Through Main Pipelines

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Abstract

The decision of installing a frequency static converter for pumps activating to transporting system of oil through the main pipelines is always justified by the electrical energy saving for the whole life of the equipment. But energy saving does not depend only on the frequency static converter or on the activating motor, but also on the transporting system characteristics, and a correct decision regarding the investment must avoid those calculation errors which may overestimate this saving.

Key words: *frequency static converter, enrgy saving, oil pipelines.*

Introduction

Transporting system of oil through the main pipelines is considered to be the most economic one, mainly due to the technological transporting and transfer processes, based on the exploitation by the help of a *closed equipment (being called like that because the contact with the atmosphere is not allowed).*

On the other hand, by command and automatic adjustment of the pumps operation and of the automatic supervising of the process we have in view to increase the economical efficiency, the safety exploitation and the installations reliability and also their rational exploitation.

Automation and telemechanization of the pumping stations provide the pumps starting and stopping, the local adjustment of the pressure, protection against damages and their preventive signals, local measurements of pressure, flow, temperature, tanks levels and transmitting to the dispatcher working point the pressure and the flow through the pipeline. Sometimes are verified the temperatures from the engines' bearings and from the pumps, the lubrication oil temperature and the temperature of the electrical motors' coils.

Flow adjustment of the centrifugal pumps, which are used within the transporting systems, is executed at a constant speed, modifying the hydraulic characteristic of the outlet pipe, changing this way its hydraulic strength, fixing an adjusting device on the pipeline. This way, the automatic system will modify the hydraulic characteristic of the system in the manner that the intersection with the pump's characteristic to be done in a point which has an abscissa that corresponds to the prescribed flow.

In the followings, the author considers that for the current stage of the endowment with command and adjustment equipment, the economical and the reliability goals are far from the modern technique possibilities; hence a viable solution consists in the implementation within the process of the state of the art realisations from the field of adjusting and acquisition systems, data transmitting and processing and also using the programmable automatic devices.

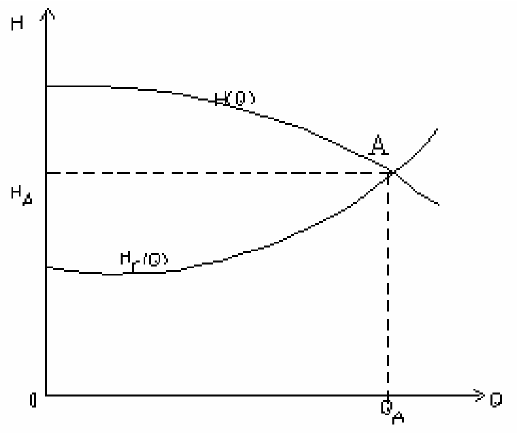

Fig. 1.

Transporting installations working regime

The working regime corresponds to the equilibrium between the lift height of the turbo-pump, *H* and the lift height of the transporting network H_t, at the intersection of the turbo-pump characteristic H (Q) with the transporting network characteristic $H_r(Q)$ (on the chart, fig. no.1, the functioning point A).

Q_A flow decrease of the transporting installation may be obtained either modifying the characteristic H_r (Q) of the transporting network, or based on the modification of the characteristic H(Q) of the turbo-pump.

When establishing the adjusting procedure, we must take into account a lot of aspects and the fact that: the process economising, reliability and automation possibilities are very important.

Adjusting a transporting installation means in fact adjusting its flow. The main index which defines the flow adjustment quality, is the flow adjusting domain, written as ΔQ.

The flow adjustment domain is defined as the ratio between the minimum flow Q_{min} and the maximum flow Q_{max}, which may be obtained by the considered adjustment method:

$$\Delta Q = \frac{Q\min}{Q\max} \tag{1}$$

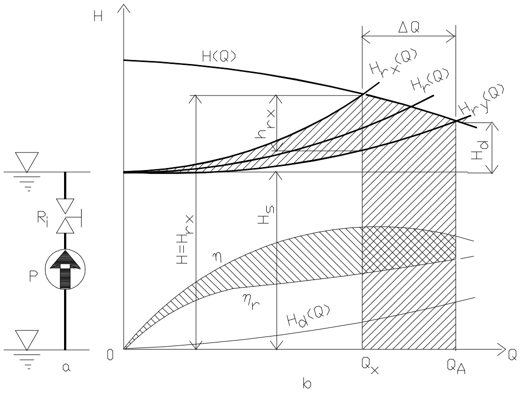

Fig. 2.

Adjustment by lamination of the liquid flow is done by a closing cock R_i, inserted on the outlet pipe of the pump (fig.2a). Closing the respective cock we artificially introduce in the network a variable supplementary pressure loss, h_{rx}. The hydraulic system equilibrium pump-transporting network takes place when the lift height of the pump, H becomes equal with the network one:

$$H = H_r = H_s + H_d + h_{rx}, \tag{2}$$

Where: H_s is the transporting network static lift height and H_d is the dynamic lift height of the network.

Varying the pressure loss h_{rx}, produced by the help of the closing cock R_i, we obtain a flow adjustment of the transporting installation, hence will result the flow domain ΔQ (fig. 2b).

Energetic losses which appear at the adjusting process by laminar procedure were marked by the surface contained between the characteristic *H(Q)* of the turbo-pump and of the transporting network H_r *(Q)*. The more inclined the turbo-pump characteristic is and the more flat the network characteristic is, these losses are greater. Therefore, laminar adjustment is indicated only in case of transporting installations equipped with radial pumps, with a small specific speed, namely $n_s \leq 100$, as they have the *H (Q)* characteristic flatten.

Adjustment through lamination has the constructive simplicity advantage of the realisation means, but also presents the great disadvantage of causing great energetic losses, which implicitly reduce the global output of the transporting installation.

Adjusting by varying the rotation speed

This way of adjustment is based on adjustable electrical activatings usage as they involve a variable speed of the turbo-pumps. Applying this method, we obtain turbo-pumps artificial characteristics, H(Q), parabolics, situated with the concave area upwards, which ideally are overlapped over the transporting network characteristic H*r*(Q), therefore installations are provided with considerable higher outputs.

The main indexes which define the quality of the speed adjustment are: the domain of the speed adjustment: $\Delta n= n_{min}/n_{max}$ and the speed adjusting coefficient: $k_{rv} = (n_n- n_{min}) /n_{n}$, where n_n is the nominal speed.

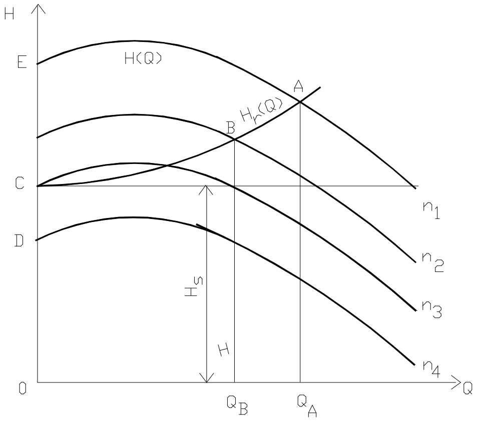

Fig. 3.

In order to establish a calculation relation for the speed adjustment coefficient based on the lift height, we use Q-H charts containing a few rotation speed values like in fig.3, where we can see that the flow adjustment by speed variation within ΔQ = 0…100% domain, the minimum speed $n_{min} = n_3$ takes place in the C point, where the turbo-machine lift height becomes equal to the static height of the network H_s; in this point the turbo-pump flow is equal to zero (Q_c=0). The functioning equations lead us to the known relations:

$$n_{min}= n_n \sqrt{Hs / Ho} \quad \text{şi } k_{rv}=1- \sqrt{Hs / Ho} \qquad (3)$$

In order to ascertain the operating stability we issue charts like those in fig.4.

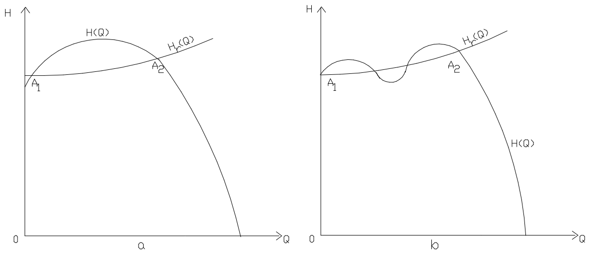

Fig. 4.

From such charts we can notice the way that the operating stability of the transporting installation depends on the two characteristic forms of the installation, respectively the turbo-pump one, H(Q), and that one of the transporting network H_r (Q). After analysing some similar situations with those considered in the above mentioned charts, we can see that in the point A_2, the running regime of the pump may be stable (fig.4 a) or unstable (fig.4.b).

Pumping systems of oil products through main pipelines are systems with a static and dynamic lift height. Within this type of network, the adjustable turbo-machine goes through a not too wide speed adjustable domain, and in the area of minimum flows, the installation may run with acceptable outputs; and this is because the running domain on the artificial characteristics obtained by turbo-machine adjustment is maintained in the vicinity of the optimum output characteristic, $\eta_{opt}(Q)$, (fig. 5). In these conditions, the variation domain of the flow is not very limited.

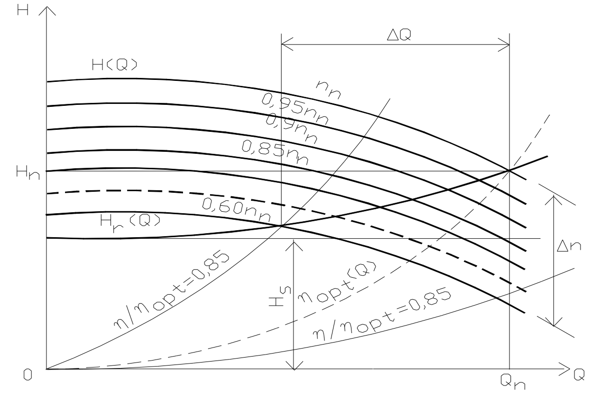

Fig. 5.

Introduction opportunity of electrical adjustable activating

When adjusting the flow of a transporting installation, the election of the flow domain, ΔQ, is recommended to be done according to the nature of the electrical activatings that the turbo-pump is endowed, which is according to its electrical adjustable activating endowment (with an adjustable speed) or not adjustable (with a constant speed), namely:

- in case of not adjustable turbo-pumps, it is rational that the flow variation domain integration, ΔQ, to be done on the projection of the descending part of the output curve, η_t (Q), starting from the maximum output point, $\eta_{t\ max}$, as on this portion are provided minimum values for the specific energy (fig. 6.a);

- in case of adjustable turbo-pump, it is rational that the flow domain integration, ΔQ, to be done on the projection of the rising part of the output curve, η_t (Q), ending in the maximum output point, $\eta_{t\ max}$, as on this portion are are provided minimum values for the specific energy (fig. 6.b.)

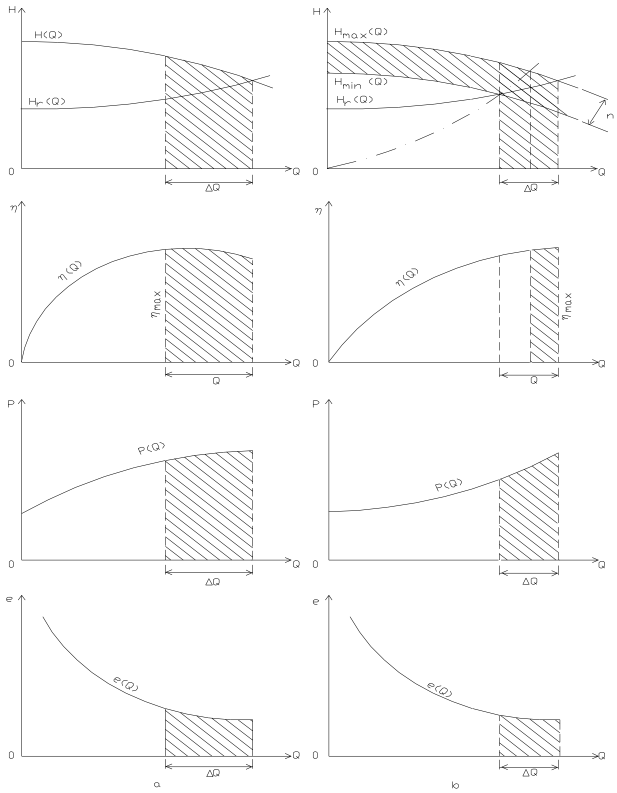

Fig. 6.

Certainly, expressing the useful power, P_u, by $\rho QH_r / k$ and the absorbed power P_t, by $\rho QH / k\,\eta_t$, will result the expression of the global output, namely:

$$\eta_g = \eta_t \frac{Hr}{H}. \tag{4}$$

As it was shown, a transporting installation flow may be adjusted either by modifying the transporting network characteristic $H_r(Q)$, or by modifying the pump characteristic H(Q).

In the first case, as the transporting installation is equipped with not adjustable engines (with constant speed) will result $H_r / H < 1$, because, generally $H > H_r$, therefore we will obtain only $\eta_g < \eta$. In the second case, as the transporting installation is equipped with adjustable engines (with variable speed) will result $H_r / H \approx 1$, because $H \approx H_r$, therefore we may obtain $\eta_g \approx \eta$.

The relation (4) also presents the fact that when adjusting the flow within a domain ΔQ, in order to provide a high output, it has to fulfil two conditions, namely: 1- to be used pumps with a high global output and 2- to be used pumps which are able to provide a ratio H/H_r with a value as close as possible to 1.

The economical efficiency of the investment

The decision of installing a frequency static converter for pumps activating is always justified by the electrical energy saving for the whole life of the equipment. But energy saving does not depend only on the frequency static converter or on the activating motor, but also on the transporting system characteristics, and a correct decision regarding the investment must avoid those calculation errors which may overestimate this saving.

Even for a simple pumping station, it is recommended that the graphic analyse to be preceded by a functioning characteristics modelling, therefore, after being processed by the computer, the models may be adjusted in order to finally lead to a reasonable estimation of the saved energy.

This modelling consists in representing the H(Q) characteristic of the network and the pumps characteristics H(Q) and P(Q) as polynomial equations operable by a computer. Individual formulae which determine the relation between pressure and flow for the network and for the pump are adjusted in order to obtain a general equation of the flow and pressure for the whole transporting process.

Pumps performance is defined by three performance characteristics: pressure-flow characteristic, power-flow characteristic and output characteristic. The effects of the three pump performance characteristics are cumulated in the following equation:

$$P_H = 0.981\,\gamma QH / \eta_p \tag{5}$$

Where: H is the pumping height (m), Q represents the nominal flow (mc/h), γ is the density of the fluid (Kg/mc), P_H – the power at the pumps shaft (Kw), and η_p represents the pump output (%).

The calculation stages are the followings:

- establishing the power required by the pump for each flow.

-establishing the electrical power consumed at each flow, taking into account all the partial outputs of the electrical-mechanical transforming chain (transformer, line, converter, motor, etc). The motor output is different in the speed adjustment regime towards the one of the constant speed regime, as the motor speed is different for each value of the flow and the wave form the converter exit increases the heating process. Hence, it is preferable to purchase from the same supplier the converter and the engine in order to own experimental mill data regarding the output of the converter-motor group for different speeds.

- taking into account the yearly working hours with a certain flow.
- calculating the yearly consumed energy.

The difference of the consumed energies for the two cases, multiplied by the European market price of the electrical energy, establishes at last, the depreciation duration of the investment.

The results of the electrical adjustable activating implementation on the Ploieşti-Bucureşti pipelines system of Petrotrans S.A. Ploieşti

The analysed system, which was conceived for a transporting capacity of 80 mc/h, was endowed with pumps activated by asynchronous motors with short circuit rotor with a 160 KW nominal power. Products transporting is done by certain pipelines for each type of product and every pipeline is endowed with an active pump and a spare one. As for the final station the taking over capacity is not greater than 45 mc/h, the flow adjustment was realised by the help of the outlet pump valve, which introduced a hydraulic strength that generated important energy losses when the pump had worked at a 110 KW power.

After finalising the technical-economical study regarding the investment opportunity, based on the output characteristic of the pump- network system (experimentally drawn) and on the real necessities analyse for adjusting the flow, the old pumps were replaced with high efficiency pumps, activated by asynchronous motors with short circuit rotor, which for a flow of 80 mc /h corresponding to the pipeline transporting capacity, have a power of 90 KW and are supplied from frequency static converters. For a 45 mc/h flow, with the outlet valve completely opened, the motor load is not greater than 40 KW, which is an important fact referring to the electrical energy consumption.

Regarding the output characteristic, the system will be run for inferior flows towards the optimum one, which is of 80 mc/h.

From this point of view, pumps exploitation in a speed adjusting regime seems to be justified. On the other hand, the energetic indexes and the powers result didn't correspond to the current realised performances within such processes as the actual technique disposes of high efficiency pumps and adjustment possibilities which can obtain superior outputs and important decreases of the energy consumption.

Comparing analysis of some variants allowed the following conclusions:

- if for the actual functioning conditions for the most frequent load (which is of 45 mc/h, having the pump output of 52% and the motor output of 83%) the pump is used for 7000 hours/year, then, the necessary investment for installing a frequency converter of about 22,000 USD will be depreciated in 3.7 years making a yearly energy saving of about 99 MWh. If the yearly functioning period decreases, then , the depreciation duration will increase;
- using some high efficiency pumps, that may reach the parameters $\eta_p = 82\%$ and $\eta_m = 93\%$, which case the resulted installed power is of 90 KW and the converter investment

would be depreciated according Table 1, which shows that the pump functioning output is extremely important for the global efficiency of the process.

It was selected this solution and the realised energetic efficiency had confirmed the executed calculations.

Table 1

Number of yearly functioning hours	Yearly energy saving MWh	Depreciation period years
7000	238	1.6
6000	204	1.8
5000	170	2.1
4000	135	2.7
3000	101	3.6
2000	68	5.4

The adopted solution

It was selected the exploitation of the pump's (pumps') motor in a variable speed regime, introducing some frequency converters, which applies the modern vectors control method of the couple – DTC (Direct Torque Control), which offer many advantages, among which:
- a rapid answer at the couple requirements (in about 5 msec);
- precision in maintaining the prescribed speed (under 0.1% from n_n);
- optimising the motor flow according to the load, minimising the losses in the electrical gap and in the winding.

Automatic adjusting of pumps activating is provided by the help of a frequency static converter which provides the motor running in a variable speed regime, according to the value of the prescribed outlet pressure. The reaction loop is based on the signal collected from a pressure transducer fixed on the outlet pipe of a pump.

By the help of a serial communication RS 485 on a screened bifilar cable, the frequency converter is connected to process computer endowed with a display and a programming console (fig. 7).

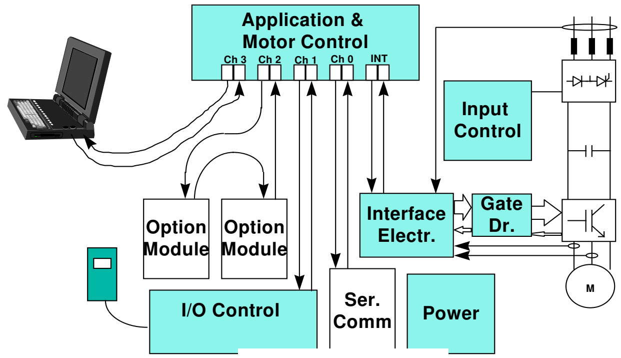

Fig. 7.

Using the keys situated on the console, the technological dispatcher will prescribe the pressure value and will be able to visualise the following parameters: The outlet pressure prescribed value; The current absorbed by the drive; The absorbed active power ; The drive speed; The frequency; The couple developed at the drive shaft; The drive supplying voltage; The consumed active energy; Number of running hours; Other converter parameters.

Electrical adjustment of the programming activating is realised either locally, by the user, by the help of the keyboard and the front panel display of the converter, or a remote one from the technological dispatcher room by the help of a process computer.

The start and stop motor command for may be also realised in two ways : locally, by the user, using the keyboard situated on the converter front panel or a remote one by the help of a start/stop button situated in the drive vicinity.

Conclusion

Frequency converters usage for speed adjustment of the pumps from the oil products transporting system through main pipelines, automatically provides the flow modification according to the technological requests, depending on the prescribed pressure and may realise (when such a solution is opportune to be adopted) an important decrease of the electrical energy consumption in the necessary domain for adjusting the flow.

The opportunity of introduction the speed adjustment results from the fact that for the most frequent flow, the pump usage at a constant speed, establishes the running point for the ascending portion of the output characteristic. This saving measure will be reflected in an acceptable depreciation period of the investment.

The quantities values of the saved energy must be precisely known providing the certainty that the installing costs of the frequency static converter will have a satisfactory depreciation rate.

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Asupra perspectivei introducerii acționării electrice reglabile la transportul produselor petroliere prin conducte magistrale

Rezumat

Decizia instalării unei convertizor static de frecvență pentru acționarea pompelor din sistemul de transport al produselor petroliere prin conducte magistrale are întotdeauna ca justificare, economia de energie electrică realizată pe durata de viață a echipamentului. Economia de energie nu este însă dependentă numai de convertizorul static de frecvență sau de motorul de acționare, ci de caracteristicile sistemului de transport, iar o decizie corectă privind investiția trebuie să evite acele erori de calcul care pot supraestima această economie.