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THE ASSESSMENT OF OPPORTUNITIES REGARDING POWER ELECTRONICS' APPLICATION AT THE SPECIFIC DRIVING FROM ONE HPP

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Even with smaller power ratings, the auxiliaries enlisted into one hydro-electric power plant-HPP play one decisive role, in keeping ready for safer operation, the entire HPP, well known for their rapid start-up and dynamic participation to cover the peak-loads in a large electric power system.

The auxiliaries' specificity and splitting categories mainly covers either some motors involved into the variable services like cooling water pumping system and fans, and which could -at their turn- better operate, at variable speed - otherwise the additional wear and energy excessive consumption means aspects of weakness; other motors, e.g. like those belonging to the pressurized oil system, are exceedingly in start-stop regimes, wearing excessively the switchgear electric equipment and so getting down the power unit's whole reliability

The answer could be the power electronics specific tools, quite knocking at the HPP's door today, like frequency converters and soft-start-soft-stoppers Their significant impact here will be shortly analysed by the paper and through its useful drawn conclusions, it does to encourage the spreading of such modernising efforts

Keywords: HPP auxiliaries, variable speed, frequency converter, soft-starter.

1. Introduction

The important role played by the auxiliaries enlisted into one hydro-electric power plant HPP, is evident. Even with smaller power ratings, the auxiliaries are to play one decisive role in keeping ready for operation, the entire HPP; especially, this is well known, thanks for their rapid start-up and dynamic participation, in order to cover either the peak-loads, either the lack in spinning reserve following one major disturbance in a large power electric system. So, the HPP family stands as a reliable partner at one regional dispatching point and, at their turn, are indebt for this high reliability, directly to their internal network of auxiliaries.

HPP's auxiliaries' specificity and splitting categories. One analysis at a glance upon these auxiliaries, made just to have some order in this diversity, shows major differences regarding their behaviour. Some, with moderate - to high

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rated power, are working for a long period of time, while others, by reverse, being quite powerful, have however, smaller operation time; the last 3rd category, could be seen as unimportant like cranes, regarding the amount of energy absorbed from the internal supplying network, usually 0.4 kV, but in real need for slow motion.

One HPP's simplified typical electric wire diagram is shown into the fig. 1, in which one important role is played by the internal network of these auxiliaries in sustaining the stable running of entire machines' room, of HG 1,2.

The purpose of the paper is to carefully investigate the family of auxiliaries involved into one classic HPP in order to decide which of these could be the next candidate at variable speed to be driven with some modernizing efforts through frequency converters FC or only soft-starter-soft stoppers SST.

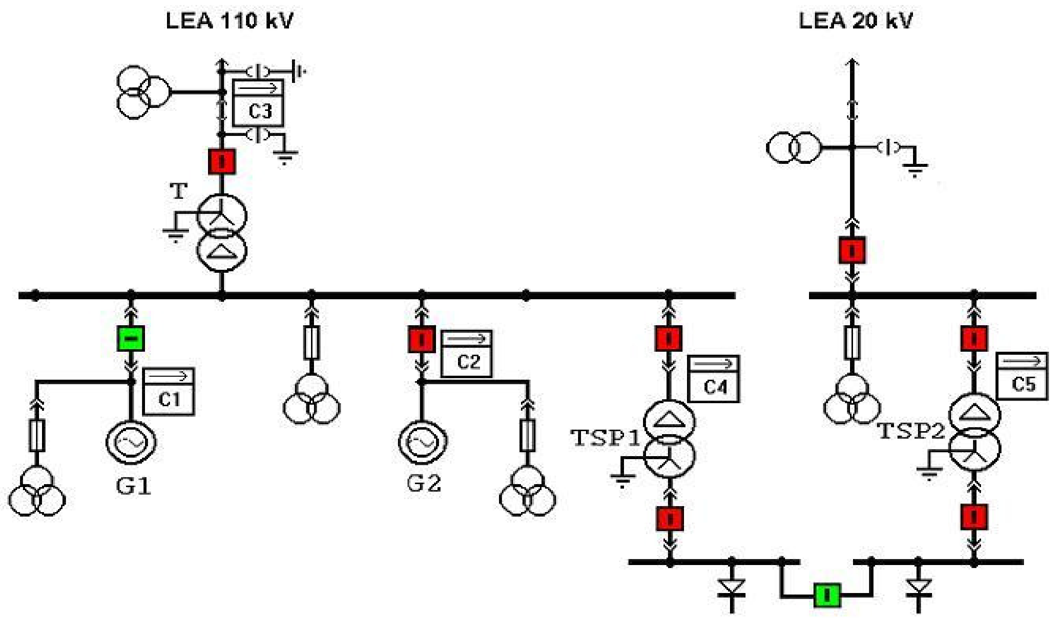


Fig. 1. Typical single line electric lay-out diagram for one medium rated power HPP analysed with the main injection of its power to the external power grid 110 kV, via the step-up tresformer T, while some small amount of generated power is backed into the internal network to feed the HPP's auxilliaries through the step-down transformer TSP1, 25 MVA, 6/0.4 kV (or its booster-reserve step-down transformer TSP2,400 kVA, 20/0.4 kV)

2. Categories of split auxiliaries, regarding energy savings

The 1st category at one typical HPP analysed, rated 2·11 MW, mainly covers the motors involved into the cooling water pumping system and ventilation fans, while the 2nd - typically stands for the oil pumps plus air compressors;

sometimes also could be added the motors involved into the water drainage pumping system, operating at the HPP basement, lower level, and electric cranes.

The readiness for significant energy savings among the HPP auxiliaries driven by the modern high efficient electric motors, could be also mentioned. As far as the electrical machines' domain, if the synchronous generator stands over a century as backbone of our civilisation - on the generation side, quite the same is to be said about the old a.c. induction motor, as an outstanding achievement in its simplicity – on the utilities' side. Even the driving a.c. induction motor, discovered in 1888 by the Russian engineer Doliwo-Dobrowolski and Nikola Tesla (probably of Romanian origin !) is now well known, also for over 100 years, the acerb competition of today between EU and US different manufacturers, releases the same old type of induction electric motor EM, but at outstanding higher rate of its overall efficiency, namely quite recently fixed EFF 1 and 2;

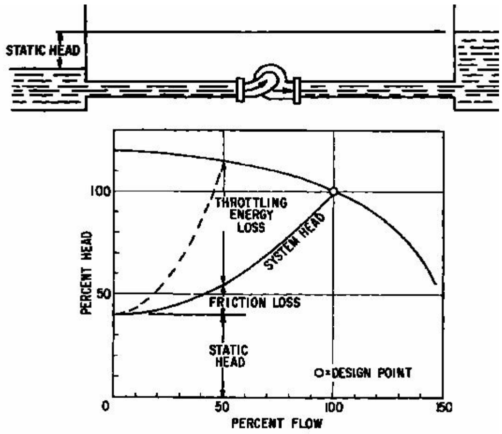


Fig. 2. System characteristics showing important loss in efficiency with flow controlled by throttling valve, as usually today, at the focused HPP rated 2·11 MW.

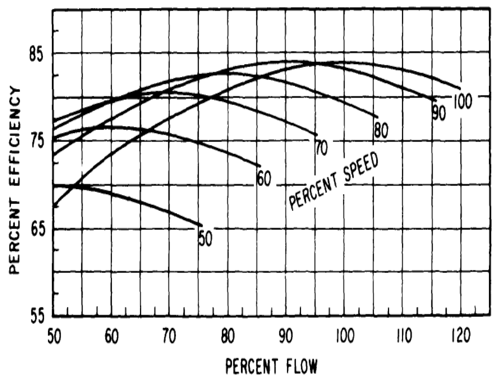


Fig. 3. Centrifugal pump P characteristics with proposed improved efficiency at lower adjustable driving speed coming from the frequency converter FC and the induction electric motor EM.

However, the further developed analysis will show, slow disappointing little step forward in this respect, onto *the interesting line of energy savings*, as well as into acquisition of better pumping or compressor units.

3. Power electronic devices applied on variable driven auxiliaries

The correct answer and further domain of research lies into the increased trust in modern power electronics of nowadays, ready to sustain real applications and make one consistent inrush onto the HPP auxiliaries, variable electric supply.

The advantages expected from the standard power electronics' applications into one common HPP prevented with specific classic schemes of supplied auxiliaries, were to be carefully and balanced-investigated; in this respect, the above enlighten three categories of auxiliaries, commonly encountered into one classic electrical wiring diagram at one HPP, offer for the first time one consistent approach on this way of modernizing efforts in order *to get down the absorbed energy* directly, or indirectly. Were focused two HPP, so:

HPP-A. [rated 2·11 MW;6/110 kV] Let's start with the situation regarding the 1st category, already above characterised, by the figs. 1, 2 [1,2]. As usually it happens in some older HPP, the system characteristics show an important loss in efficiency: e.g. the cooling water flow is controlled through the old, onerous *method of throttling valve*, as usually happens today in many cases - where the very specific analyse was conducted. The amount of energy is called in the fig. 1 as *throttling loss* accompanied by *friction loss* so developed. That is because the focused analyse was regarding one power unit rated 11 MW, which frequently operates at 6 MW, because of its poor hydraulic conditions into the upstream accumulation, partial being mudded filled; however, the pump type Cris 150 rotor A, [3,4] driven by a motor rated 14 kW, was found to operate at constant speed, irrespective was the real amount of energy needed to be evacuated from the warm HG. (Remember, that too hot machine over 70^{o}C means one reduced life expectation for its electrical insulation, while under 15 ^{o}C the aggressive condensing phenomena could end the stable operation into internal short circuit)

The proposed remedy could be seen into the fig. 2, where the centrifugal pump P has proposed characteristics with sensible improved efficiency, if the operation regimes at lower adjustable driving speed, could be assured for the assembly - pumping unit and electric motor (P+ME), as a whole.

HPP-B [rated 2·3,5(2,8) MW; 6/20 kV] Into another smaller HPP, as a second typical example, one drain water pump Sigma - equivalent Criş-150 rotor B type, rated 11 kW is frequently working from time to time, downstream discharging the amount of water lost during the common turbine's operation (only at start-up/shut-down or changing load). In this case, the entire electric commutation equipment together with the motor itself are stressed exactly at the maximum absorbed current during the very start-up critical period; the question which arises in respect of this situation is how could be avoided or at least to be smoothed a little, regarding this transient consistent with the in-rushed current regimes.

How's to be done this? Simply, apparently (avoiding costs and harmonic pollution), following those two ways quite offered by the newly introduced power electronics into the old, quite unchanged-until now, hydro-power house: frequency converters FC + Soft-Starter/Stopper devices SST.

These newly introduced modern devices allow us to deliver *as much as needed rotational speed* (energy) to the pumping or fans units from the 1st category of auxiliaries, in order *to better cope with the real need of cooling* or ventilation; this is to be performed in direct correlation within one automatic system to control step-by-step the output flow rate, in direct relation with the amount of heat to be extracted from the power hydro-generator's – either copper windings and iron magnetic circuit working at variable loading, or oiled bearing system, step-up transformers etc.

4. Additional requirements and care about

In so doing, this *superposed automatic control loop* takes the temperature as an input measure and gives as output the desired percentage flow of cooling water, the exact needed amount of air ventilation every moment, as the loading conditions are changing in the power output released by the hydro-generator HG, following the dispatching step rules for its area of competence.

Until now, much more costly philosophy was badly followed in this specific field of application, either throttling the water flow with manual valves, either endangering the right interval of allowed flowing cooling fluids – water / air temperatures through the HG in question using alternative start/stop operational regimes; obviously, there will be added savings from eliminating the cost and installation of a control valve plus one or more manual valves. There will be one cutting in the piping cost since a much shorter by-pass line is needed.

While there are energy savings that can be attributed to the use of adjustable speed, there are also some added costs related with the power electronic enclosed into the FC, as rectifiers, smoothers and inverters, plus some other electronic components - as preserving measures regarding *the additional care for the electromagnetic compatibility EMC.*

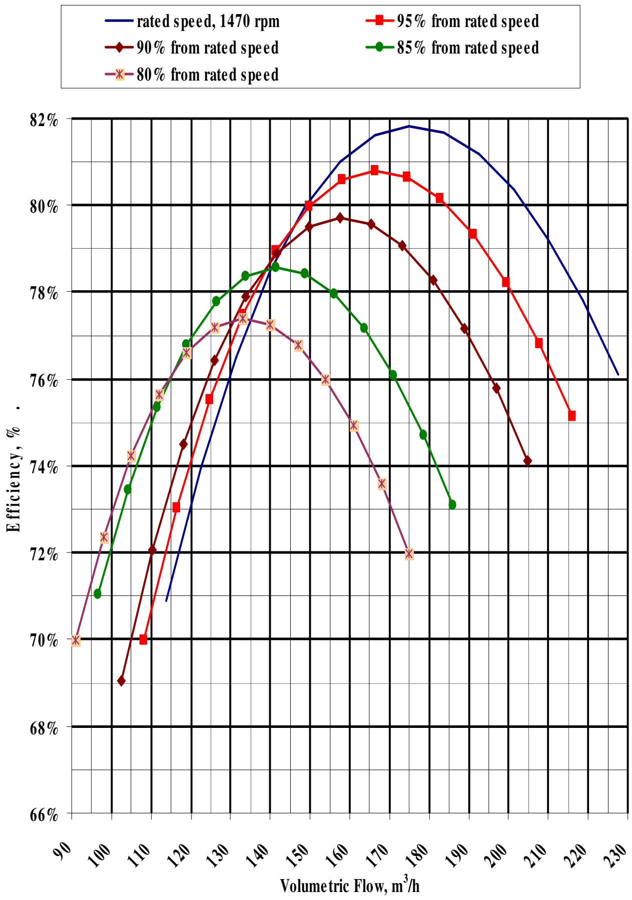
Sometimes, these additional costs are doubling the initial cost allocated for the induction driving motor itself; particularly, for some old HPPs the measures are welcomed because the initial investing costs are quite entirely depleted, regarding the long period they stand in use. Therefore, we could do only one investment right now and this will be into the additional brand new FC, to work with the old driving electric motor, which could be the very case focused at the analysed HPPs. The net pay-out recovery could be very attractive, around 5 years, depending on the energy costs at every generating point. One attempt to indicate this, at different generating situations, was given into the full work [1].

For the 2^{nd} category of auxiliaries commonly encountered at one HPP, there is enough to better implement the soft-starter/stopper devices SSSD on the supplying line, as one indirect measure to enlarge the life for the electrical part, as a whole: motor + contactor/breaker, otherwise under intense wearing regime, within working mainly at the starting period; This operating period even shorter but intense stressing, when the inrush absorbed relative current is usually 5 to 7 p.u., and so frequently repeated, during their usual start/stop kind of operation chosen by the designer (high pressure oil pumps, air-compressors network).

For *the 3rd category of auxiliaries* commonly encountered at one HPP, the introduction of power electronic devices is asked by smoother operational necessities rather than energy savings criteria. Here it will be cited the typical *application for the cranes'* with variable movement at their needed specific smoother operation above the power house, also found as an express request coming from the maintenance personnel only.

4. Graghic investigated regimes for the cooling water pumping unit

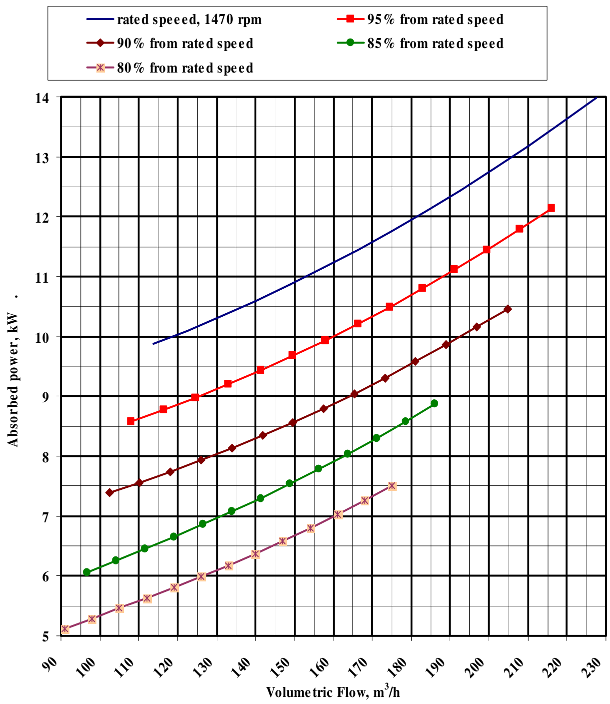
We have taken into account the curve H(Q) - the graphic characteristic of pumping height H[m_{H2O}] and flow Q[m^3/h] for the pumping unit - released by the manufacturer [5]. One mathematic modelling was started, through the subsequent repeated of some 4th degree regression curves, *Excel* represented, as in the following selective last figures (the complete array of figs could be found in [1]).



Were selected here from the whole array of representations, only the last two, graphics considered more significant in the proposed discussion about possible energy savings at one HPP-common scheme for its inner auxiliaries' behaviour;

This figure by side, is the most complete one, and shows here the working point's useful excursion when the speed decreases 1…0.8 pu at acceptable efficiencies, ranging at 0.69…0,82 pu.

Fig. 4. The efficiency variation for the pumping unit, versus the pumped water flow and speed variation at different values.



As far as the final conclusion regarding the investigated opportunity when this electric driven pumping unit works at variable speed, is given from the *absorbed power* at lower speed, which could be nearly halved at only 0.8 of rated speed - as could be seen here into the figure 5, by side.

Fig. 5. The variation in absorbed power by the pumping unit, versus the pumped water flow and speed variation at different values: 100…80% from its rated speed of 1470 rot/min.

5. Some useful considerations regarding the energy saving at variable speed

As far as the overall efficiency, balanced through investments / benefits in the very analysed case –study for one long running cooling water pumping unit, at variable speed, the following assumptions were considered: the HG is nearly ½ year partially loaded at 6 MW from its rated output of 11 MW which is attained average only into 1/3 of the entire year, in the remaining time – being shut down; the machine's need for cooling water is reduced up to 50% during winter time, and up to 80% during summer time; the frequency converter and its additional electromagnetic-compatibility suppressors is average costly as much as the motor itself, let say 2000 ROL, while the medium price for one MWh produced by the hydro power, national scale, is 94.1 /37.76 ROL, day/night, TVA not included.

By applying the above considerations at this particular case study, as could be seen into the below table, one encouraging result was obtained: the variable supply at this cooling pumping unit, strictly related with the HG state of warming, does work - being worthy and, the initial investment is to be recuperated into one reasonable, acceptable time interval of about 5 years. In doing so, in the analysed case, we strongly recommend these modernizing efforts , taking into account that the power electronics' prices will get down in time, compensating the more and more strict measures in the harmonic pollution and the cost with the control loop.

Nr	Object of interest	Notation	Units	Value
1	Number of hours / year, av.	τ_{total}	h/an	8,766
2	Number of hours / year, around the rated power	$\tau_{incarcat}$	h/an	2,922
3	Nr. of hours / year, operation at discharged load	$\tau_{descarcat}$	h/an	4,383
4	Number of hours / year at one pumping unit	$\tau_{functionare}$	h/an	7,305
5	Minimum / maximum pumped flow	Q_{min}	m^3/h	90/144
6	Absorbed power at min./max. flow, constant speed	$P_{ct\ min}$	kW	9.35/10.75
7	Average absorbed power at constant speed	$P_{ct\ med}$	kW	*10.05*
8	Absorbed power, at minim flow and 80% speed	$P_{v\ min}$	kW	5.10
9	Absorbed power, at max. flow and 90% speed	$P_{v\ max}$	kW	8.50
10	Average absorbed power at variable speed	$P_{v\ med}$	kW	*6.80*
11	Average reduced power at variable speed	ΔP_{med}	kW	3.25
12	Yearly reduction in electricity consumption	ΔW_{an}	MWh/ year	23.741
13	Electricity produced, day-price, for sale		RON/MWh	94.41
14	Electricity produced night-price, for sale		RON/MWh	37.76
15	Number of working hours , per day		h/ year	5.698
16	Number of working hours , per night		h/ year	1.607
17	Electricity medium price, for sale		RON/MWh	81.95
18	Additional incomes from sold electricity		RON/ year	1,946
19	Additional investment in the frequency converter		RON	10,000
20	Time recovery investment from the electricity sold		years	5.140

6. Final conclusions

a. By careful analysis on split auxiliaries – mainly into three categories - in relation within their measured operational regimes, significant energy savings are to be obtained in the specific domain of HPP, through power electronics - like frequency converters FC and soft-starter-stoppers SST.

b. The analysed cooling water pumping unit has to be FC driven at variable speed – in relation with HG warming state and, the initial investment is to be reasonably recuperated in av. 5 years, gaining significant energy savings, and better protection, longer life, for the electrical equipment.

c. However, the analysed sewage water pumping unit has to be SST only indirect started, its operation time isn't long, but frequently starts/stop.

R E F E R E N C E S

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