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THE ANALYSIS OF TECHNOLOGICAL REHABILITATION SOLUTIONS FOR THE IRRIGATION WATER SUPPLY PUMPING STATION *MIRCEA VODĂ*, FROM DOBROUDJA

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Abstract

The modernization of an old pumping station aims to lower water and electrical energy consumption. Consequently, the rehabilitation solution is chosen after an analysis of the possible options. The paper presents the case study of the irrigation water supply pumping station *Mircea Vodă*, Dobroudja, Romania. The replacement of the old impellers Ø950mm with new impellers Ø 1000 mm resulted in superior operation parameters of the pumping station.

Key words: Irrigation system, Water supply, Pumping station, Energetic efficiency

INTRODUCTION

The *Mircea Vodă* pumping station (P.S.) is the base water supply pumping station in the irrigation system *Carasu* – Dobrudja, Romania. It is placed at Km 183 +720, on the left side of the Danube- Black Sea Canal(D.B.S.C.) and takes water from the canal CA_0. The pumping station (Fig. 1) is equipped with 14 electopumps type 24 NDS-impeller Ø950mm. The pumps are organized in two groups, each one of 6+1 pumps mounted in parallel. The pumps have separated suction ducts of 1200mm in diameter. The two discharge ducts of 1900 mm in diameter have 1150m in length. Each discharge duct is protected from hydraulic shock by a horizontally mounted air chamber with a total volume of $30m^3$.

The P.S. has to be modernized due to its low energetic efficiency.

DATA AND METHOD

The rehabilitation technical solution adopted in order to optimise the functional parameters was based on the data provided by the analysis of the *Mircea Vodă* P.S. operation. There were taken into account the main geodetic head values, the head losses on both suction and discharge ducts, the corresponding pumping head and the optimal operation range of the hydraulic pumps.

The main features of the PS *Mircea Vodă*

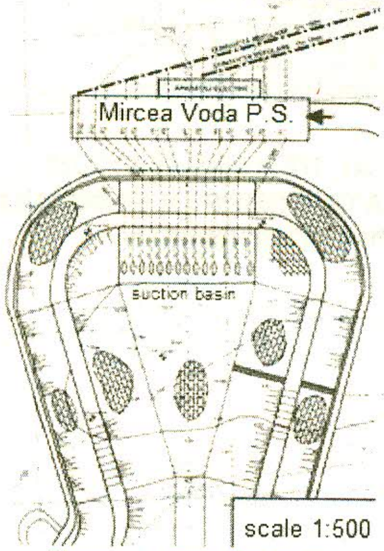

Figure 1. Plan layout of *Mircea Vodă* P.S.

In the current variant, each pump delivers a discharge of 1,8 m^3/s (6480m^3/h), at the head of 65m, and is driven by an electric motor of 1600kW at the rotational speed of 750 rot/min. It is supplied at a voltage of 6kV.

The main water level values, both for suction (CA_0) and discharge (CA_1) basins, are given in Table 1 as they were considered in the initial engineering design project of the existing station.

The geodetic head values, determined with these water levels, are : $H_{g\ max}$ = 52,00 m; $H_{g\ med}$ = 50,00 m; $H_{g\ min}$ = 48,50 m.

The total head losses (Table 2) were calculated along the ducts from the suction to the discharge duct downstream section, taking into account the turbulent flow regime [4].

The pumping head varies with the water level in both suction and discharge basins (Fig. 2).

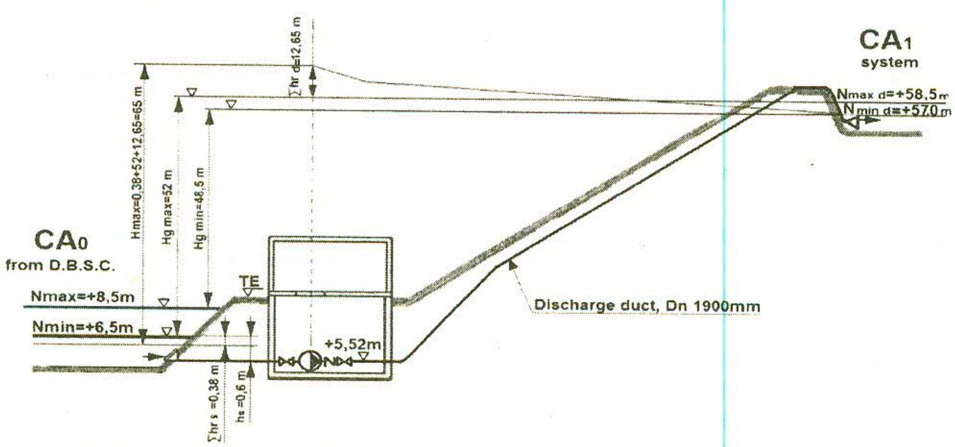

Figure 2. Operation features of the *Mircea Vodă* P.S. Geodetic and pumping head

Table 1

Main levels for the engineering design of the *Mircea Vodă* P.S.

No.crt	Feature	Water level in CA_0 (D.B.S.C.)	Water level in CA_1
1	Crest elevation	C_c = + 9,50 m BS r	C_c = + 60,00 m BS r
2	Maximum level	$N_{max\ s}$ = + 8,50 m BS r	$N_{max\ d}$ = + 58,50 BS r
3	Minimum level	$N_{med\ s}$ = + 7,50 m BS r	$N_{med\ d}$ = + 57,50 m BS r
4	Medium level	$N_{min\ s}$ = + 6,50 m BS r	$N_{min\ d}$ = + 57,00 m BS r

where BS r – Black Sea reference level.

Table 2

Total head losses, h_r (m)

	Number of parallel operation units					
	1 pump	2 pumps	3 pumps	4 pumps	5 pumps	6 pumps
(m)	**7,45**	7,97	8,43	**9,81**	10,50	**13,00**
Observation	**minimum**			**medium**		**maximum**

The above values of the geodetic head and the calculated head losses led to the following total pumping heads: H_{max}= 65,00 m; H_{med} = 59,80 m; H_{min} = 56,00 m.

These data were the basis on which the pumps operation was analyzed in both variants. The improvement of the pump operation [2] was achieved by a combined method: ***replacement of the old impellers*** with larger ones, for 6 pumps in a group and ***variation of the rotation speed*** of the 7th pump in a group.

RESULTS

The operation analysis for the existing solution

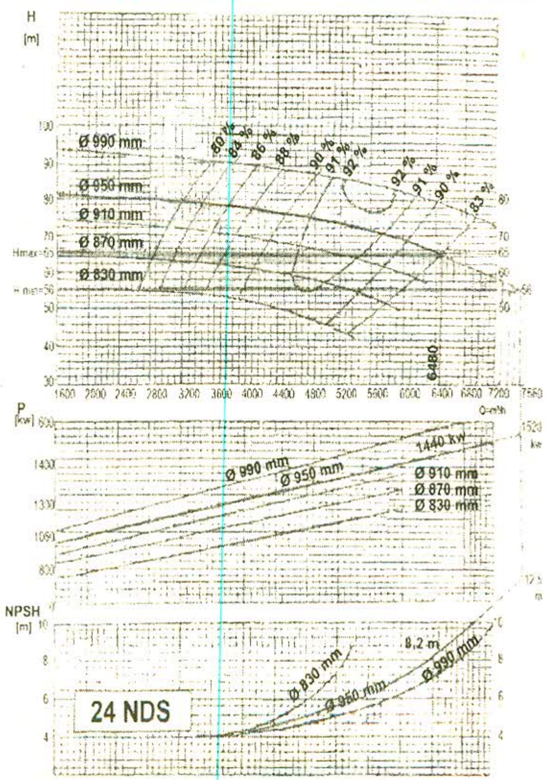

Figure 3. The characteristic curves of the existing 24 NDS pumps, impeller Φ 950 mm

The existing 24 NDS pumps, with impeller of Φ 950 mm in diameter, should operate in between ***H_{min}=56m*** (at Q=7560m³/h) and ***H_{max}=65 m*** (at Q=6480 m³/h). The operation point situated at the head of ***H_{max}=65m*** assures a pump efficiency of η_p=0,83. That means a total unit efficiency of 80%, for the electric motor efficiency of η_e=0,96. The absorbed electrical power is ***P_a=1440 kW.*** The net positive suction head, given by the characteristic diagram, is *NPSH = 8,20 m*. Consequently, the admissible geodetic suction head becomes: *H_{gs}= + 1,75 m.* This positive value provides a correct operation (furthermore, the pump axis is 0,60m under the suction water level).

At the operation point of head ***H_{min}=56m***, the pump efficiency drops under the value η_p =0,79 and the absorbed power will be ***P_a=1520 kW***. These parameters are out the pump operation range.

The correspondent value *NPSH*=12,5m leads to a negative suction head H_{gs}=-2,55m.The characteristic curve *Q-H*, Fig.3, indicates that the pump 24NDS may operate correctly only between 65m and 61,5m. As this type of pump was the single offer in 1990, when the pumping station was built, it was made the decision to partially close the valves on the discharge ducts as soon as the pressure at the discharge flange of the pumps drop to 61,8 bar. This method is very expensive from the energetic view point [1], [5].

The operation analysis for the proposed solution

The solution proposed for the improvement of the *Mircea Vodă* P.S. operation took into consideration the similar centrifugal pump NDS 800-600-1000 with the following features: ***Q=6.500m³/h***, ***H=65m***, ***n=745rpm***, ***NPSH=8,5m*** and ***η=90*** (Fig. 4). All the other technical and geometrical characteristics, such as the electromotor power, pump's suction diameter, Dn 800mm, pump's discharge diameter, Dn 600mm, are the same for both types of pumps.

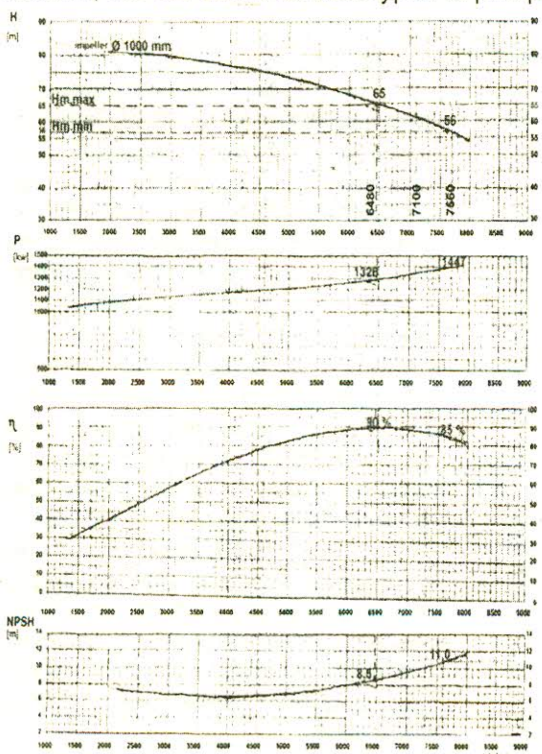

Figure 4. The characteristic curves of the 24 NDS pump, impeller Φ 1000 mm

It was proposed the replacement of the old impellers **Ø950mm** for 12 pumps 24NDS, with new ones of diameter **Ø 1000 mm**.

The pumps with the new impellers operate in the same field of head, that means in between: H_{min}***=56m*** (at Q=7560m³/h) and H_{max}***=65m*** (at Q=6500 m³/h), at constant speed. The pump efficiency, at the maximum head H_{max}***=65m***, is η_p=0,90 at the same efficiency of the electromotor, η_e = 0,96. Results an absorbed power P_a***=1328 kW.***

From the pump characteristic curves (Fig. 4.) results *NPSH=8,50m* and the geodetic suction head becomes H_s=+1,45 m. This positive value is convenient for a correct operation of the pumps, taking into account the pump axis is 0,12m under the suction water level.

It may be noticed that at the minimum head H_{min}**= 56m**, the pump efficiency lows down to η_p = *0,79* and the absorbed power becomes P_a **= 1447 kW**.

The pump characteristic curves indicate *NPSH=8,20m*, so that the geodetic suction head will be H_s=-1,05 m. The pump axis remains at *0,98 m* under the suction water level.

We may conclude that the proposed solution assures the pump operation inside its optimal range. It is recommended to be maintained the existing priming installation.

Besides, one pump from each pumping group will be equipped with a frequency converter, so that it will operate at variable rotational speed. This low cost additional measure [7] will make possible the station to deliver small discharge values.

DISCUSSION

An analytic comparison of the technical parameters of the two solutions, the existing and the proposed one, may be done at a glance using Table 3. The data refer to the maximal and minimal pumping heads. These data show a net superiority of the proposed solution from both technical and economic point of view.

Table 3

Technical parameters of the pumping station in both variants

Operation point	Parameter	Existing solution	Proposed Solution
H_{max}=65m Q=6480 m³/h	**NPSH** (m)	8,20	8,50
	H_s (m)	+1,75	+1,45
	η_p (%)	83	90
	P_a (kW)	1440	1328
H_{min}=56 m, Q_p=7560m³/h	**NPSH** (m)	12,50	11,00
	H_s (m)	-2,55	-1,05
	η_p (%)	79	83
	P_a (kW)	1520	1447

The graphical representation of the operating points for each of the two groups of 6 pumps 24NDS–impeller Ø 1000, mounted in parallel, may be seen in Fig. 5. They operate at a constant rotational speed.

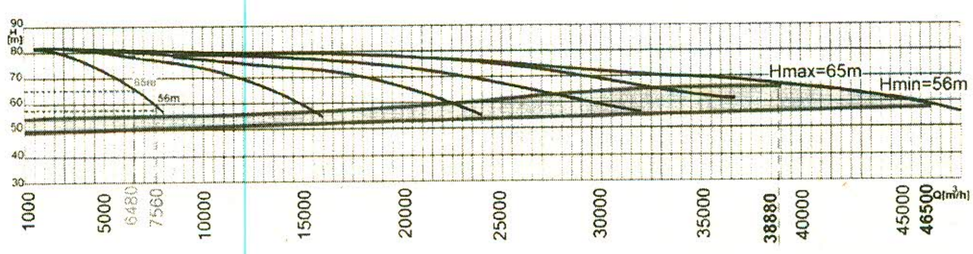

Figure 5. Parallel operation of 6 pumps, type 24NDS 800-600 – Ø 1000.

CONCLUSION

The new configuration of the pumping station comprises two groups of 6+1 pumps. Each group consists of 6 pumps with new Ø 1000mm impellers and constant rotational speed and one pump with the same Ø 950mm impeller and variable speed.

Considering in comparison the technical data of the existing pumping station with the proposed one, it is obvious that relative simple solutions, with minimal investment costs, may lead to a significant improvement of the pumping station operation.

The first solution considered for the *Mircea Voda* P.S. was the ***replacement of the old impellers*** with new larger ones that resulted in an appropriate operation of pumps all over the pumping head range. Moreover, the energy efficiency of the pumps increases for all the operation points. For Hmax = 65 m, the efficiency rises to 86.5%, from 79.7%, and for Hmin = 56m, the efficiency rises to 79.8%, from 75.9%.

In favor with the proposed solution, it was estimated the difference between the specific electric power consumption in both variants at about 23kWh for 1000m^3 of pumped water.

The second technical solution considered for the *Mircea Voda* P.S refers to the two pumps equipped with frequency converters. They will operate at ***variable rotational speed*** and will be able to deliver small discharge values, often required in irrigation system exploitation.

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