CONSIDERATIONS ON REHABILITATION OF MONOPHILAR PUMPING STATIONS OF THE IRRIGATION SPRINKLER PLOTS

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Abstract

The paper presents an analysis of the directions of rehabilitation of the single-line pumping stations from aspersion irrigation plots. The single-line pumping station consists of one or two pumping units supplied from a canal. Each pumping unit supplies a distribution pipeline equipped with irrigation hydrants. The rehabilitation and modernization has been differentiated on the structural and functional components: foundations, hydromechanical technological line, power supply system, monitoring and automation system. The case study was prepared for an irrigation plot located in the Moldavian area (Plot 7, Doniceasa Falciu, Vaslui County). The irrigation plot has 1222 ha and is equipped with 15 single-line pumping stations. The pumps type is 6 NDS and has the parameters: flow rate 241 - 345 m^3/h, pressure 6.5 - 7.5 bar and power 75 - 110 kW. The paper presents two options for the rehabilitation of the pumping stations: a - equipping with horizontal pumps; b - equipping with vertical pumps.

Key words: pumping unit, hydraulic installation, design, modernization

The stability of agricultural production in the climatic conditions of Romania is achieved through the use of irrigation systems. Romania had an irrigated area of about 3.0 mil ha before 1990. The irrigation systems were made using the technology and the materials available about 40-50 years ago. Most of the irrigation systems were abolished after 1990. In 2017, only parts of the irrigation systems are in service. Irrigation systems in service (generally those for aspersion watering) show degradation processes to the constructive system and installations.

Most of the currently used irrigation systems utilise aspersion watering. Most of these were carried out during 1967-1985. The irrigation plot was designed for two pumping units equipment options: a - plot equipped with a pumping station for raising the pressure (SPP encoded); b - plot equipped with single-line pumping stations (the unit supplies a single irrigation water distribution pipe, encoded SPPM). In the second version, SPPM supplies a buried distribution pipe and is equipped with irrigation hydrants located at determined distances. The pipeline has been sized for a determined number of watering equipment operated simultaneously. The supply pressure of the single-line pipe is 6.5 - 8.0 bars. Single-line pumping stations are located at the edge of the irrigation plot supply canal. SPPM may be equipped with one or two pumping units.

The rehabilitation and modernization of SPPM is achieved differently for the structural and functional components: the constructive structure, the hydromechanical technological line, the hydraulic connection installation, the power supply system, the monitoring system for the functional parameters, etc. SPPM requires a complex monitoring and automation program for the operational process. Case studies drawn up for a series of SPPMs in Moldova have highlighted the complexity of the rehabilitation and modernization process. The rehabilitation process must be carried out in successive stages, by using modern materials and work technologies.

The present document is arranged so that it can be used as a model. It is also a template on which you can work directly by replacing the corresponding paragraphs.

MATERIAL AND METHOD

The case study was prepared for Doniceasa - Fălciu Plot 7 from the Complex Irrigation and Drainage Unit Albiţa-Fălciu, Vaslui County. The irrigation plot provides aspersion watering for an area of 1222 ha. Water pumping and pressure raising is achieved with SPPMs located on the edge of the secondary supply canal CS82. SPPMs are equipped with 6NDS horizontal pumping units (some have been replaced with RDN pumps)

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(*figure 1*). SPPM supplies one or two tertiary irrigation pipes (main laterals), in which case they are equipped with one or two pumping units. The pumps take the water from the supply canal and each one pumps it into the two pipes located perpendicular on both sides of the canal. Doniceasa - Fălciu Plot 7 is supplied from Prut River through the SRP4 Berezeni reversible pumping station and the CP5 supply canal.

To analyze the current operational state of the irrigation plot, a technical expertise has been carried out. It analysed the current state of the constructive structure, the installations and the functional process of the single-line pumping stations after 35-38 years of service.

Figure 1 **RDN 200-150-200 pump from Doniceasa - Fălciu Plot 7 SPPM (**Photo Luca M., 2016**)**

The study methods used were: analysis of technical design documentation, technical expertise, field studies, energy analysis of pumping units, structural analysis of buildings, pumping units + tertiary pipe operational simulation, options analysis for the structure of the single-line pumping station, selection simulation for new pumping units, etc.

The energy balance of the pumping station is based on measurements made in site for various operational situations. The main parameters considered in the analysis are (Exharhu M., 1997a):

- specific energy consumption for transport under *H* head of the pumped volume unit:

(1) $$e_H = \frac{2{,}725\,H}{\eta_a} \cdot \left(\frac{kWh}{1000\,m^3 \cdot m} \right)$$

- the specific energy consumption per volume of water unit under H = 1,0 m head:

(2) $$e_V = \frac{2{,}725}{\eta_a} \cdot \left(\frac{kWh}{1000\,m^3 \cdot m} \right)$$

where: *H* is the pump head, mcA; η_a – pumping units efficiency;

- pumping unit efficiency (Exharhu M., 1997b):

(3) $$\eta_a = \eta_T \cdot \eta_m \cdot \eta_p \cdot \eta_h ,$$

where η_a is the total efficiency; η_T - power transmission efficiency; η_m - electric motor efficiency; η_p – pump efficiency; η_h – hydraulic efficiency.

Equations (1, 2 and 3) are only applicable if the pumps are identical. For the pumping station with new equipment, parameters of the operating point (QF, HF, n, D) will be determined. Parameters are determined using the equation system (Burchiu V. et et al., 1982):

(4) $$\begin{cases} H_c = H_g + MQ^2 \\ H_p = f_1(Q) \\ \eta_p = f_2(Q) \\ N_p = f_3(Q) \\ NPSH_p = f_4(Q) \end{cases}$$

where H_p is the pumping head; Q_p – pump flow rate; H_g – geodetic pump head; N_p – pump power; $NPSH_p$ – pump cavitation height.

RESULTS AND DISCUSSIONS

Most of the SPPM irrigation plots were built during 1970s -1985, according to the standardised design project. The SPPM pumping stations are located at the edge of the supply canal and may have one or two pumping units. Water distribution can be done on both sides of the canal, in which case SPPM is equipped with two pumping units. The SPPM pumping stations are over ground and comprise the following components: constructive structure, hydromechanical technological line, hydraulic installations, electrical installations, borders, etc.

The technical expertise analysed the current structural and functional state of the single-line pumping stations components:

- constructive structure:
  - a – pumping units base;
  - b – electrical panel base;
  - c – concrete and metal stands for pipes and valves;
  - d – valve and flow meters homes.
- hydromechanical technological line: suction pipe, discharge pipe, pump, valves, joint fittings:
- hydraulic connection system for tertiary pipes: pipe section, valves, fittings, ventilation valves, anti-shock devices etc. (the installation can be placed in a chamber or not);
- monitoring and flow meter installation;
- electric installation:
  - a - power line for the electric motors,
  - b - electric panel,
  - c - external lighting system and sockets,
  - d - the earthing device,
  - e - transformation station and lightning protection;
- protective area with enclosure and access gate.

The functional status of the hydromechanical technological line is achieved by analyzing the energy balance of the pumping units.

The SPPM pumping stations were equipped with horizontal NDS and RDN type pumps. Pumping equipment was designed to ensure operating parameters for the aspersion watering method and furrow watering for some plots.

SPPM pumping stations in Doniceasa-Fălciu Plot 7 were equipped with 6NDS 150-250 and RDN 200-150-25 type pumping units, with an electric motor of 75 kW-100 kW, speed of 2950 rpm, 60-90 l/s flows at H = 78-48 mCA depending on the pump (rotor a, b and c). Pump discharge is made of Dn 150 steel pipe, Dn 150 slide valves, Pn 10, Dn 150, Pn 10 check valve, Dn 150, Pn 10 fittings.

Plot 7 surface is 1222 ha. The plot is supplied with irrigation water from the CS82 canal, which is connected to the CA5 canal. The canal supplies 15 6NDS/RDN type electropumps (Q = 270 m^3/h, H = 70 m, n = 3000 rpm, P = 110 kW) located in 8 single-line pumping and pressurising stations (*figure 2*).

SPPM pumping stations in Plot 7 have the following features (Luca M., 2016):

- SP 7/1 equipped with 6 NDS pump with the following parameters: Q_{SPPM} = 79 l/s, H = 71 mCA, P = 110 kW;
- SP 7/2 equipped with two 6 NDS pumps with Q_{SPPM} = 135 l/s, Q_p = 67 l/s, H = 66 mCA, P = 2 x 75 kW;
- SP 7/3 equipped with two 6 NDS pumps with Q_{SPPM} = 148 l/s, Q_p = 72,4 l/s, H = 74 mCA, P = 2x100 kW;
- SP 7/4 equipped with two 6 NDS pumps with Q_{SPPM} = 135 l/s, Q_p = 67 l/s, H = 76 mCA, P = 2x100 kW;
- SP 7/5 equipped with two 6 NDS pumps with Q_{SPPM} = 121 l/s, Q_p = 60,7 l/s, H = 77 mCA, P = 2x100 kW;
- SP 7/6 equipped with two 6 NDS pumps with Q_{SPPM} = 140,5 l/s, Q_p = 70,2 l/s, H = 73 mCA, P = 2x100 kW;
- SP 7/7 equipped with two 6 NDS pumps with Q_{SPPM} = 185,5 l/s, Q_p = 92,7 l/s, H = 62 mCA, P = 2x100 kW;
- SP 7/8 equipped with two 6 NDS pumps with Q_{SPPM} = 189,5 l/s, Q_p = 90,7 l/s, H = 61 mCA, P = 2x100 kW.

The 15 pumps are RDN / 6NDS type, with suction pipes with 300 mm diameter and discharge pipes with 150 mm diameter made of steel. Valves with Dn 150, Pn 10 are placed on the discharge pipes. The irrigation water is distributed on the two pipes through a straight tee joint made from a steel pipe. Water supply to the surface on the other side of the canal is accomplished with a pipe overcrossing the supply canal. The overcrossing pipe is made of steel and is bound to two simple concrete anchorage blocks located on the edge of the canal.

The power supply of the SPPM pumping station comes from a 20.0 KV to 0.4 KV transformer station. The electric panel is powered by buried electrical cables. Each pump is equipped with an earthing device for accidental touch protection. The transformer station is equipped with a lightning protection installation.

Field analysis was carried out at the location of each SPPM. The analysis took into account the constructive and functional structures presented in the selected design drawings, the field situation, the results of the field inspection and the additional studies carried out.

Single-line pressure stations were designed and built during 1980 ... 1983.

Figure 2 **Doniceasa-Fălciu Plot 7 site plan (original version) (Luca M., 2016)**

From the field and technical design documentation analysis resulted the following (Luca M., 2015, Luca M., 2016):

- Irrigation Plot 7 with single-line pressurised stations and single-line pipes was designed for aspersion watering using 1980s technologies. The single-line pumping stations equipped with 6 NDS type pumping units were designed to meet the technical requirements imposed by irrigated agriculture during 1978 - 1980.
- Single-line pressurising stations examined, placed in the canal which supplies main laterals, have a degree of degradation of 60-100% to the constructive structure and hydro mechanical installations.

- The pumping units are manufactured during 1975-1980 and have an exceeded service period (*figure 3, 4*). The rehabilitation of some SPPMs was done by replacing the pump and the electric motor. Only the hydraulic connection of the pumping station to the single-line pipes is the original one.

Figure 3 **View of 7/5-2 pumping unit (6NDS), electric panel and discharge pipe of the SPPM 7/5 (**Photo Luca M., 2016**)**

Figure 4 **SPPM 7/7-2 pump aggregates status (RDN 200-150-200 pump and motor) (**Photo Luca M., 2016**)**

- The structural and functional state of the hydraulic installation in the pumping stations made of steel and cast iron (suction and discharge pipes, fittings, valves) is inadequate, being degraded in proportion of 60-85%.
- The horizontal pumping units, including those which have been rehabilitated (replacement of the pump and / or the electric motor), do not have primer installations (*figure* 5, 6). The operational simulation of the single-line pumping station with modified pump parameters after 38 years in service showed an increase in energy consumption by about 32-41% compared to the initial state at the time it was put into service (Luca M., 2015).
- The auxiliary power supply technological line has a long service life, which has led to a degree of physical wear on components (electrical panels, connections, cables), which caused damage and interruption of power supply to electric motors.
- The enclosure of single-line pumping stations is partially degraded, a situation in which it no longer ensures the integrity and protection of pumping and power equipments.
- Single-line pumping stations do not have functional systems for monitoring the work parameters and for the automation of the operational process.
- The operating efficiency for functional components of the single-line pumping stations (pump, electric motor, hydraulic, pumping, etc.) is totally unsatisfactory due to the physical and moral wear of the main and auxiliary technological components.

The total state of degradation of the SPPM requires the execution of a complex rehabilitation and modernization project to bring the pumping station to the level of the current technologies.
Rehabilitation is carried out for the constructive structures and installations. SPPM needs to be modernised by introducing monitoring, automation and data transmission equipments, etc.

The equipments replaced and newly attached to SPPM consume electricity. A condition for designing the SPPM rehabilitation is to stay within the existing power at the electric transformer station.

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Figure 5 **General view of Doniceasa-Fălciu Plot 7 SPPM SP 7/2, partially rehabilitated (replacement of electric motor and electric panel) (**photo Luca M., 2016**)**

Figure 6 **General view of Doniceasa-Fălciu Plot 7 SPPM 7/5 partially rehabilitated (replacement of an electric motor and the electric panel for the pumping unit 7/5-1) (**Photo Luca M., 2016**)**

The designer must consider rehabilitation options meant to reduce the energy consumption of SPPM and reduce water losses in the operation process.

Three of the possible rehabilitation options, which are accessible for the current structure of the sprinkler irrigation plot, are presented below. Rehabilitation options are as follows:

- Option I for SPPM rehabilitation and modernisation through the use of horizontal pumps with hydraulic, mechanical and geometric parameters identical to the original ones.
- Option II for SPPM rehabilitation and modernisation through the use of vertical pumps with hydraulic and mechanical parameters identical to the original ones.
- Option III for SPPM rehabilitation and modernisation requires a "conversion" of the irrigation plot. This option requires the transformation of the SPPM sprinkling irrigation plot into an irrigation plot with a SPP central pressurising station.

The analysis of the three options of rehabilitation results in the following:

Rehabilitation option I – horizontal pumps – requires the following steps:

- recalculation of the SPPM functional parameters according to the supplied flow rate and pressure of the tertiary sprinkler irrigation pipes;
- analysis of the SPPM pumps' equipment options according to the gauge and hydromechanics characteristics of the pump, taking into account the market offer in the field of pump units; compliance with design conditions; the selection of pump units for each SPPM;
- replacing the horizontal pump units for each SPPM with similar constructive structure ones and with functional parameters required by the supplied pipe (generally, Qpump = 80-90 l/s, Hp = 70-90 mCA); pumps will have higher efficiency to reduce energy consumption; each electropump will be sized according to flow and pressure requirements of the tertiary irrigation pipe served (A1 - A16).
- compliance with the constructive and mechanical installation parameters onto the existing pumping station construction (base block, available space, pipe lay-outs); otherwise the base will be redesigned for the new load given by the pumping unit and its annexes as well as the pipeline lay-outs;
- rehabilitation of the base block by restoring the integrity of the reinforced concrete structure, applying protective plasters, restoring the gripping system to the pumping unit, etc.;
- rehabilitation of the suction and discharge hydraulic system by redesigning the geometrical characteristics according to the parameters of the purchased pumps; piping sections, fittings, joints fittings (valves, strainers), mounting compensators, etc., will be replaced with new, high performance ones; the hydraulic system will be protected against corrosion and, if necessary, will be placed in a reinforced concrete home;
- design and execution of a pump priming installation (vacuum electropump, liquid ring tank, pipe circuit), according to the parameters required by the new units; the installation will be suitably sized and mounted on a reinforced concrete platform or inside a container;
- rehabilitation and modernization of the hydraulic shock protection equipment for the pump station;
- rehabilitation of the electrical installation by replacing the electric supply and power cables, the distribution and control panels for the electric

pumps and the adjacent installations; the electrical panels will be placed in a container to protect them against the action of climate agents;

- rehabilitation of electrical earthing installations for electric motors, lightning protection; designing a monitoring system (mandatory the equipment with flow meters) and automation of the operational process.

Rehabilitation option II – vertical pumps – requires the following steps:

- recalculation of the SPPM functional parameters according to the supplied flow rate and pressure of the tertiary irrigation pipes; each electropump will be sized according to the flow and pressure requirements of the main laterals served;
- each SPPM will be equipped with one or two vertical electropumps and they will be placed inside a new hydro-technical building designed on the edge of the supply canal;
- design of a hydro-technical construction for the installation of pumps and the suction of irrigation water from the canal; the construction may be joint for the two pumps and will meet the specific operating requirements of a pumping station: catchment, sediment exclusion, inlet, aggregate stand and accessories; the construction is made of reinforced concrete with metallic structures protected against the corrosive action of water;
- design of the hydraulic system for the vertical pumps connected in parallel, in accordance with the new operating parameters;
- the electrical installation, the hydraulic shock protection installation, the monitoring and automation system will be carried out according to the rehabilitation option I.

Option III for SPPM rehabilitation and modernisation requires the conversion of the sprinkler irrigation plot equipped with SPPM supplied from the canal into an irrigation plot with a SPP central pressurising unit. The execution of the SPP is done according to the standardised project (Project no. 4824-R 1987) and in correlation with the conversion of the pipeline network of the sprinkling irrigation plot.

From the field studies on the rehabilitation of SPPM sprinkle irrigation plots in the Moldova area, a number of negative aspects resulted:

- the lack of rehabilitation works for the simple and reinforced concrete base of the pump unit and the electric panel;

- rehabilitation was done only by replacing the electric motors and not the pumps;

- no rehabilitation of the pumping station hydraulic installation (the old worn out and degraded pipelines were preserved);

- for the equipment of the pumping station with new pumps, the parameters for the operating point (flow, pressure, power) were not computed;

- SPPM has no hydraulic shock protection equipment;

- the lack of a monitoring and automation system for the operational process of the pump station.

The analysed and rehabilitated pumping station serve only aspersion watering.

CONCLUSIONS

1. The sprinkler irrigation plots are the most often rehabilitated components from the old Romanian irrigation systems.

2. The rehabilitation of the single-line pressure pumping stations (SPPM) must be carried out on the entire assembly of constructive structures and components to achieve a maximum pumping efficiency with reduced energy consumption.

3. The rehabilitation of SPPM pumping stations can be done using current structure level (horizontal pumps), or by converting the station to a vertical pump structure, which requires the construction of a suitable building.

4. Rehabilitation of SPPM type pump stations with horizontal pumps must be carried out in a complex way using current technologies, with the adding of priming installations and the monitoring and automation system of the operational process.

5. A series of rehabilitations recently carried out at SPPM pumping stations have not been executed in a complex way, leading to malfunction, with high energy consumption and significant water losses.

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