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MAST

SPM SYSTEM

System of monitoring, managing and operating submersible pumps and deep-water intakes

ENERGY SAVING SYSTEM

SYSTEM DESCRIPTION

ver. 1.21 – 2015

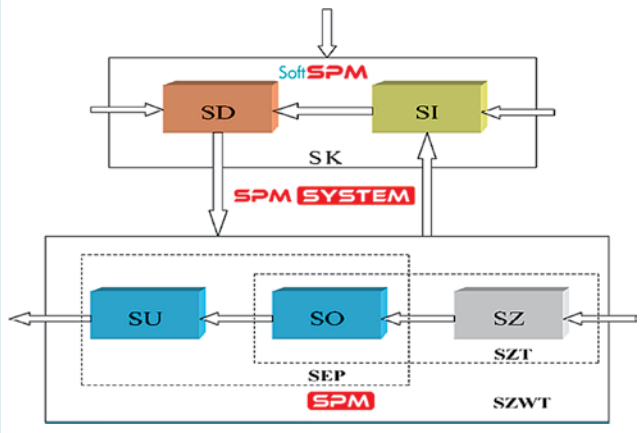
INTRODUCTION

Contemporary operation of submersible pumps' pumping systems is mainly focused on energy-saving water intakes and providing water to treatment stations. The issue of energy savings influences the optimization of the pumping systems construction, metering and their proper conduct of the optimal operation management by appropriate control and monitoring. All these issues require cooperation in different fields, such as: hydrogeology, pump technology, hydromechanics, electrotechnics, systems engineering, automatics, etc. The most important issue for the operation of submersible pumps is the right choice of pump parameters for working conditions in the pumping system of water intakes. The proper selection of a submersible pump guarantees a high energy efficiency in future operation of a submersible pumping unit and ensures its long-term and reliable functioning. Mathematical models developed for the selection of pumps for the current characteristics of the well and pumping system together with energy consumption models: well – pumping unit – pipe fittings, systemically change the way of managament of the intakes operation. The **SPM$_{SYSTEM}$** – **Sabmersible Pumps Managment** system is an example of a modern approach to management and operation of pumps and deep-water intakes being currently implemented in Poland and abroad.The system is designed for water and mining companies or other companies dealing with the operation of submersible pumps and intakes of underground water. It is perfect for operation of the strip mine drainage of e.g. brown coal or for management and control of drainage with the use of submersible pumps coming from the closed hard coal mines.

SYSTEM STRUCTURE

All data, parameters and information regarding the operation of pumps and deep-water intakes are gathered, processed and archived in the **SPM$_{SYSTEM}$**. The **SPM$_{SYSTEM}$** is a dedicated specialist system for monitoring and controlling purposes. It also provides information and supports decision making, management and the control of the operation of pumps and deep-water intakes. Location of **SPM$_{SYSTEM}$** against the functioning structure of a company, e.g. water intake company or mining company (with the description of the structure) has been shown in the scheme – picture 1.

The characteristic element is the fact that the submersible pump operating system (**SEP**) consists of two



Picture 1. SZWT – system of water extraction and distribution, SEP – system of submersible pumps exploitation, SU – system of pumps use, SO – system of use, SZT – system of technical background, SZ – system of delivery, SK – system of control, SI – system of information, SD – system of decision

components: the system of pumps use (**SU**) and the system of operating (**SO**) that together with the system of delivery (**SZ**) create the system of technical background (**SZT**). The system of pumps operating **SEP** with the system of technical background **SZT** set up the system of water extraction and distribution **SZWT** that is supervised by the **SK** control system consisting of the **SI** information system and the **SD** system of decision. Thus, the system of pumps operating **SEP** has two components (**SU**, **SO**) and has been incorporated partially and completely in two other systems (**SZT**, **SZWT**). It works dependently with two control systems (**SI**, **SD**). **SPM$_{SYSTEM}$** system structure clearly reflects the full control of the information flow at each stage of the management, monitoring and controlling the company operating. **SPM$_{SYSTEM}$** is unique and currently it is the latest solution in this area.

SPM$_{SYSTEM}$ has expanded modularly the **SoftSPM** software levels and the instrumentation as well as metering sets of SPM wells. The mutual software compatibility between **SoftSPM** and the SPM well pump metering systems allows each user to enter any configuration of the system development. **SPM$_{SYSTEM}$** can be optimally configured for the user of dozens or hundreds of wells, regardless of the type of wells (intake or drain wells). The construction system embraces – picture 2.

Software level:

- **SoftSPM$_{BASIC}$** – sets of several or a dozen wells,
- **SoftSPM$_{STANDARD}$** – sets of tens of wells,
- **SoftSPM$_{ENTERPRICE}$** – sets of several hundreds of wells – corporations,
- **SoftSPM$_{TEST}$** – trial stations of submersible pump units.

Picture 2.

Each level of software has been created with the use of up-to-date information technologies described in the separate bookmark.

The set of instrumentation and metering:

- **SPM_{MIN}** – minimal scope of metering,
- **SPM_{BASE}** – most commonly scope of metering,
- **SPM_{OPT}** – expanded scope of metering,
- **SPM_{TEST}** – instrumentation of a trial station.

Each set is based on the latest dedicated solutions from the field of metering of the well's pump units, to which belong among others:

- the individually programmed controllers: **SZ-21**, **S7 1200 SIMATIC** Siemens,
- the system automatics cabinets: **SPM-b.1.1**, **SPM-o.21**,
- the **SGP-21** integrated depth finder for metering pressure inside and outside the pressure pipeline of the submersible pump installed behind the pump's pressure discharge, under water.

According to principles, the scope of processed data and information in the **SPM_{SYSTEM}** is exceptionally wide and contains:

- **the pump technique**:
  - the computer catalogue of submersible pump units with possibility to choose and select pumps,
  - the automatically controlled trial stations of submersible pumps,
  - the visualisation of how the pumps' work points function when set up on their **H = f (Q)** characteristics during operation (the catalogue characteristics or from the trial stations),
  - the assessment of the pump's operation based on the catalogue and real characteristics;
- **the drilling technique and hydrogeology**:
  - the computer catalogue of drainage wells and piezometers,
  - the operation database of wells and piezometers,
  - the database of water chemistry;
- **the electrotechnics**:
  - the computer catalogue of submersible engines,
  - the operation database of submersible engines,
  - the database of electrical equipment and cables,
  - power, control and metering cabinets with devices;
- **the computer technique**:
  - the **SoftSPM** software:

    $SoftSPM_{BASIC}$
    - » the start-up package:
    - » statistics of the intake work,
    - » assessment,
    - » the catalogues of pumps, engines, cables, instrumentation and fittings.

    $SoftSPM_{STANDARD}$
    - » the start-up package:
    - » statistics of the intake work,
    - » assessment,
    - » the catalogues of pumps, cables, instrumentation and fittings,
    - » the trial stations of the submersible pump units.

    $SoftSPM_{ENTERPRICE}$
    - » the start-up package:
    - » statistics of the intake work,
    - » assessment,
    - » the catalogues of pumps, engines, cables, instrumentation and fittings,
    - » the trial stations of the submersible pump units pompowych,
    - » the package of submersible pumps and engines repairs,
    - » management of operation and the pump units repairs;
  - the OPC Siemens software,
  - the SINAUT Siemens software modems GSM/sms/GPRS,
  - the Kepware Siemens software S7-200/S7-300/S7-400/S7-1200 Ethernet OPC Server WiFi;

- **automatics**:
  - controllers: **S7 SIMATIC**,
  - controllers: **SZ-21**,
  - devices: **WiFi**,
  - sbase stations: **SB-21**,
  - controllers: **ST-1**,
  - hubs: **KDP-1**,
  - automatics cabinets: **SZA 1.2 SPM**,
  - metering instrumentation;
- **organisation and management**:
  - storage,
  - operation decisions – operation control,
  - consulting and training.

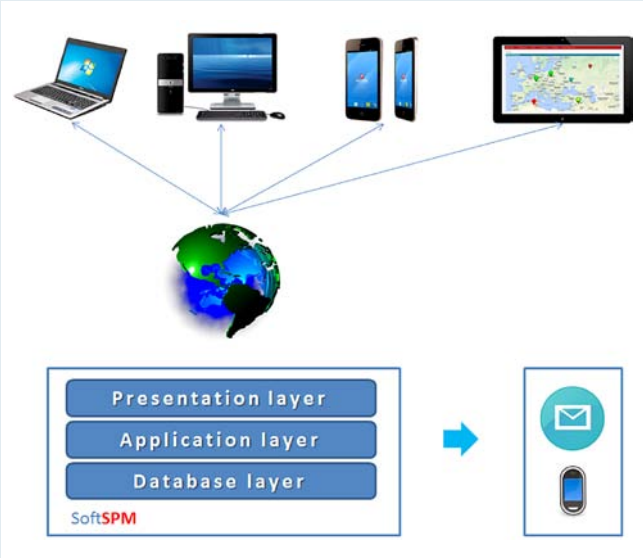
As we can see from the list of elements included in the **SPM$_{SYSTEM}$**, the issue of optimisation in management of operation of wells and submersible pumps is exceptionally multidisciplinary and relatively complex.

SPM$_{SYSTEM}$ has three versions of well instrumentation and metering. Such a system structure guarantees practically any possibilities in terms of the system adaption for each user of the submersible pumps – from the users of several wells to those of a few thousands of objects. The system has been prepared for users from all over the world. The software is available both in Polish and many foreign languages. The system server which is available for users at **www.softspm.com** may serve clients coming from any place in the world. The system also offers the Cloud service in the SaaS model.

STRUCTURE OF SoftSPM SOFTWARE

The **SoftSPM** software is a web application. In other words, this is a computer program that works on servers, and the final user's communication is done via the network and Internet with the use of web browsers. The software design technique has been chosen so that its design and layout can automatically adjust to the window size of the device on which it is displayed (web browsers, smartphones, tablets). Moreover, the software meets the expectations in the context of *user experience design*, i.e. an interactive product with a special stress put on the fact that the product use should provide its users with positive experience. This fact directly influences its intuitiveness in terms of use.

The **SoftSPM** software is based on three-layer architecture, i.e. a database server, application server and presentation server (picture 15). The open source solutions applied here directly influence the global costs of the system implementation. The user does not bear any additional costs for the purchase of third-party license (application servers, database servers, etc.) – picture 3.



Picture 3.

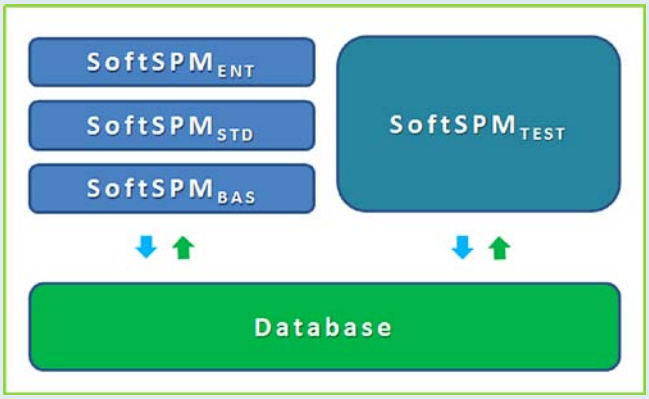
The **SoftSPM** sales model has been configurated in three versions:

1. Subscription – **Cloud Computing**. Users monthly pay the subscription costs but the system is hosted on SDC servers (SoftSPM Data Center). Users use the standard functionality (its range depends on the purchased version of **SoftSPM$_{BAS}$**, **SoftSPM$_{STD}$**, **SoftSPM$_{ENT}$**) via the Internet.
2. **Hosting**. The individual implementation is carried out for a specific user. Finally, the system is installed on the SDC servers (SoftSPM Data Center). Internet needed for access.
3. **Customer's servers**. Similarly to the hosting model, the system is directly adjusted for the users' needs, but the very system is installed on the servers indicated by customers.

The wireless and reliable technologies used for communication between the system and measuring devices installed on the objects provide unlimited possibilities for which there are no any distance or area barriers. Certainly, the system is able to provide for any device located even thousands of kilometers from our application, regardless of the version. Owing to the fact that the application may be used via the Internet, the objects management becomes simple functional and available at any time from each place in the world.

The **SoftSPM$_{TEST}$** software has been created as a desktop application, i.e. installed on a computer directly

connected to the trial stations and to the Internet. The measurement data from the **SoftSPM$_{TEST}$** system are available throughout the **SoftSPM** system (in all its versions) immediately after the trial completion. The scheme shows the structure of location of the **SoftSPM$_{TEST}$** software in the **SoftSPM** structure – picture 4.



Picture 4.

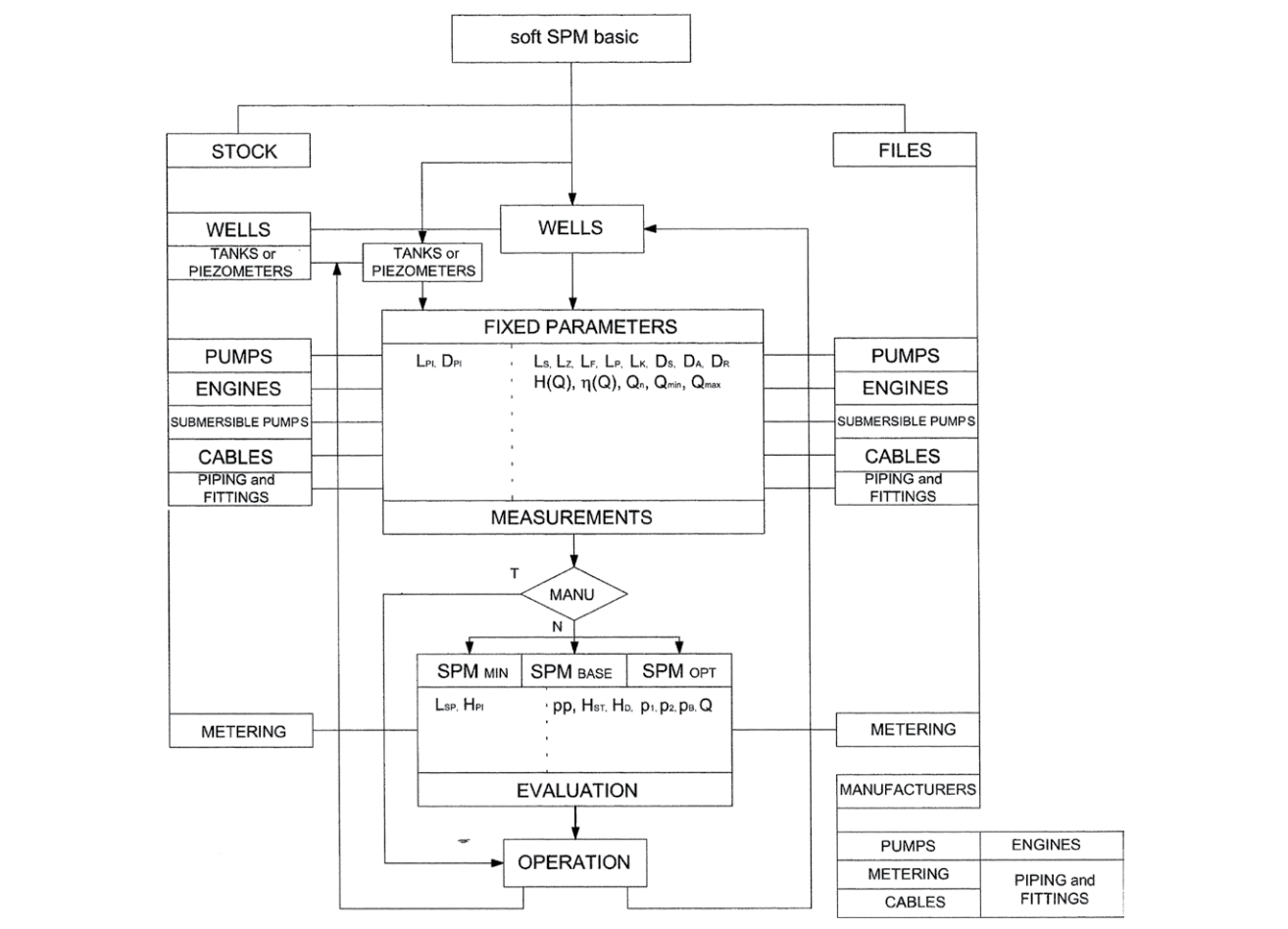
The **SoftSPM** software is optimized to such an extent that even the basic **SoftSPM$_{BAS}$** version offers for its users:

1. Management of pumps, engines, instrumentation, piping and wiring catalogues.
2. Catalogue of aggregates.
3. Management of stock levels.
4. Management of wells, reservoirs and piezometers operation.
5. Remote control of devices (wells, reservoirs and piezometers).
6. OnLine Full monitoring.
7. The full history of objects and devices measurement.
8. Knowledge base.

SPM$_{BASIC}$

The attached scheme shows the structural scheme of the most basic **SoftSPM$_{BASIC}$** software, which constitutes the fundamental level intended for the most common systems of operating the submersible pumps and water intakes – picture 5.

This level of software serves as a base for higher levels and at the same time is prepared for remote monitoring and controlling the pumps and deep-water intakes operation. As we can see in the scheme, the user has



Picture 5.

the whole set of parameters, data and information referring to the operation of submersible pumps, wells, metering, instrumentation and equipment.

The software cooperates with each version of **SPM$_{MIN}$**, **SPM$_{BASE}$**, and **SPM$_{OPT}$** software. In the **SPM$_{BASIC}$** program, there are advanced mathematical models of assessment and modes of control in the system.

SPM$_{STANDARD}$

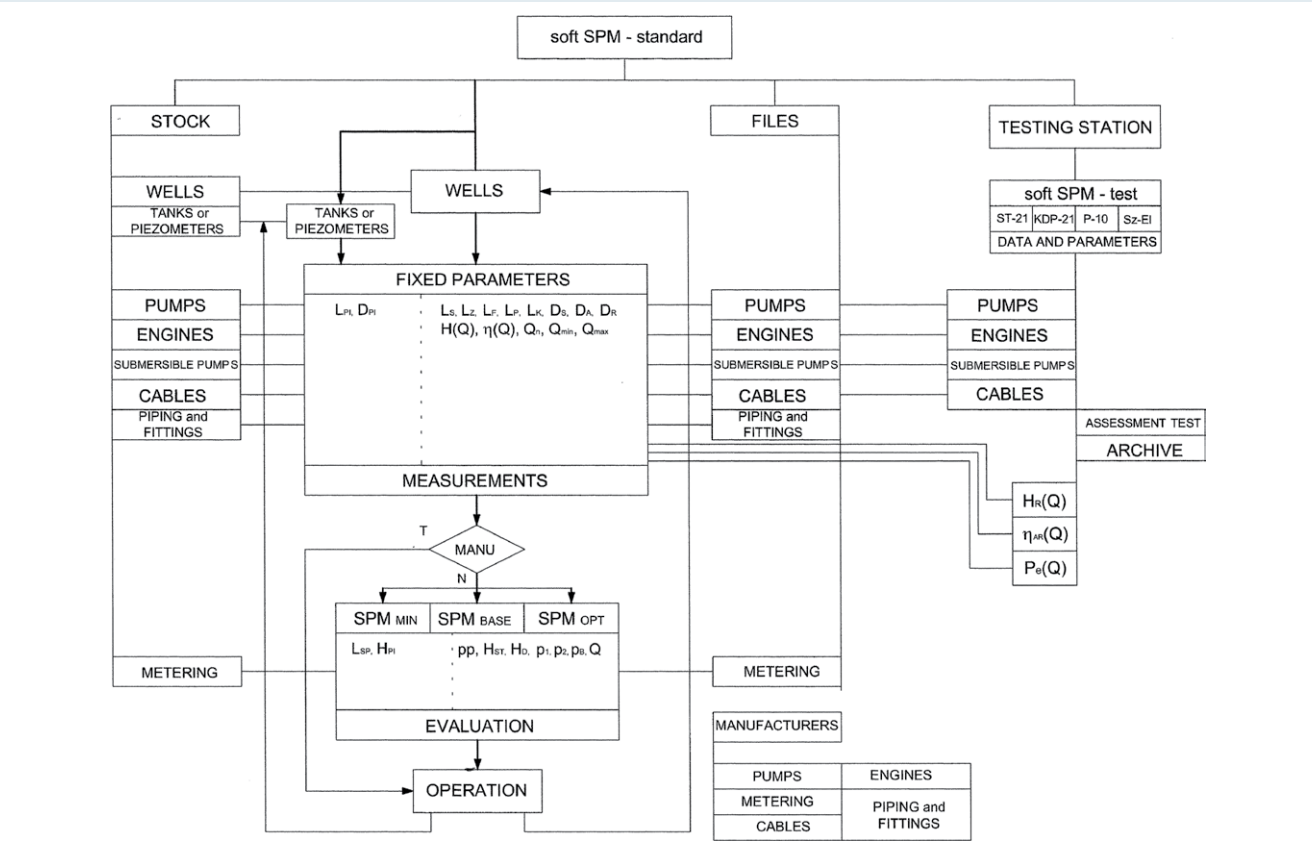
The scheme shows the **SoftSPM$_{STANDARD}$** software dedicated to operating systems users of at least several dozens of wells, often with various conditions of their work – picture 6.

This level of software has been extended, as it includes the software of the submersible pumps trial stations, which fulfils diagnostic function from the one hand, and from the other it generates precise parameters and energy characteristics of the tested submersible pumping units. The actual determined at the trial station **H = f (Q)**, **P = f (Q)** and **η = f (Q)** characteristics serve as a digital 'input' into the work of the mathematical models of assessment and parametric diagnostics of the submersible pumps working in the wells of the system. Similarly to the **SPM$_{BASIC}$** software, the user has the whole set of parameters, data and information appearing during the operation of submersible pumps, wells, metering, instrumentation and equipment. The **SPM$_{STANDARD}$** software perfectly and remotely monitors and controls the operation of pumps and deep-water intakes. As we can see in the scheme, the software cooperates with each version of **SPM$_{MIN}$**, **SPM$_{BASE}$**, and **SPM$_{OPT}$** software. In the **SPM$_{STANDARD}$** program, there are advanced mathematical models of assessment and modes of control in the system.

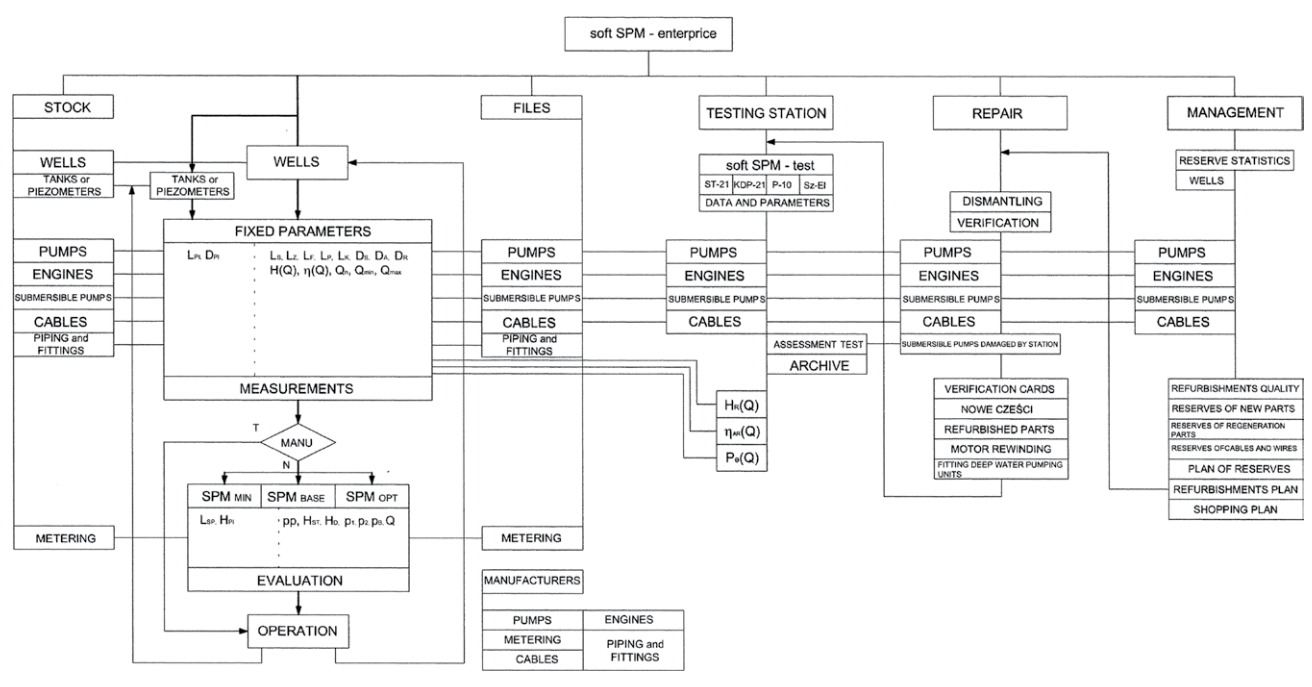
SPM$_{ENTERPRICE}$

The scheme shows the structure of the most extended level of the SoftSPM$_{ENTERPRICE}$ software devoted to the users of large operation systems – even over a thousand of wells, more often used by corporations – picture 7.

This level of software gathers, processes and makes the circulation of information quicker in management, monitoring and controlling the operation of large submersible pump systems and deep-water intakes. It might be said that the **SPM$_{ENTERPRICE}$** software is now the latest information tool supporting the users who supervise e.g. the drainage in the brown coal mines, the systems of water delivery to large agglomerations or the systems of international water corporations.



Picture 6.



Picture 7.

In **SPM$_{SYSTEM}$**, mainly by the use of the **SPM$_{ENTERPRICE}$** software, the user is provided with essential practical knowledge, which enables him to implement optimisations, especially in the following scope:

- considerable saving of energy used to the submersible pumps operation,
- noticeable increase of reliability of the operating submersible pumping units,
- optimisation of the number of pumps and submersible engines' types,
- optimisation of the number of the reserve submersible pumping units in the operation system,
- optimisation of the scopes and number of the pumps and submersible engines repairs,
- optimal, mathematical selection of the submersible pumps taking into account the current and foreseen well's characteristic.

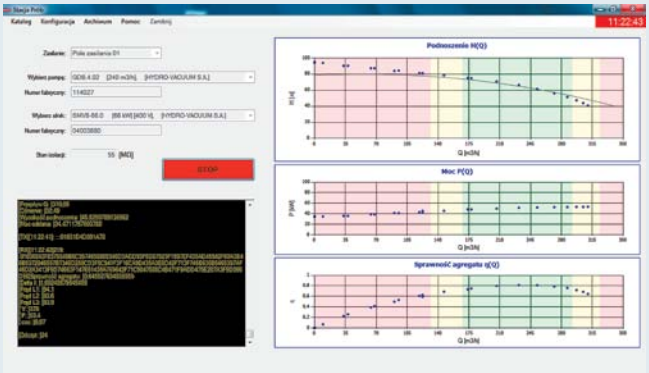
SPM$_{SYSTEM}$ gathers in its knowledge base and in the construction of complex mathematical models of the **SoftSPM** software a number of precise procedures in the operation modes of pumping systems possible to foresee. With the passage of time, these bases systematically extend, and by this the system in itself optimises the functioning of each work algorithm.

SOFTSPM$_{TEST}$

SPM$_{SYSTEM}$ includes also the **SPM$_{TEST}$** software of trial stations of submersible pumping units. From the system point of view, the functioning of a deep-water engine with a real load in the trial station conditions allows to obtain the nominal temperature of its interior, and thus the state of winding insulation and a cable connection (a hot and a cold cable) is checked. The rotational speed of the engine and other electrical and energy parameters are measured during the trial. Based on measurements of a submersible pump efficiency and a pressure measurement in a determined measurement pipeline cross-section, the pump flow **H = f (Q)** characteristic is evaluated. This characteristics is compared to the real rotational speed. Measurements are carried out for various degrees of the pump starving, i.e. for different measurement points. The number of these points has been calculated in such a way, so that it is possible to assess with high accuracy the following characteristics: **H = f (Q)**, **η = f (Q)**, **Pp = f (Q)**. In fact, only the trials performed at trial stations of submersible pump units allow to define and verify the proper course of pumps characteristics.

The specially configurated for this type of application **SoftSPM$_{TEST}$** computer system controls the trial of a submersible pump unit, collects and processes data and measurement parameters. The system evaluates the trial in reference to a given norm. The Picture 13 presents a control console displayed on the monitor screen. The console shows the current trial progress and enables the full access to archived pumps parameters from the previous trials – picture 8.

The picture below shows the protocol of a submersible pump trial drewn up by the **SoftSPM$_{TEST}$** system. The



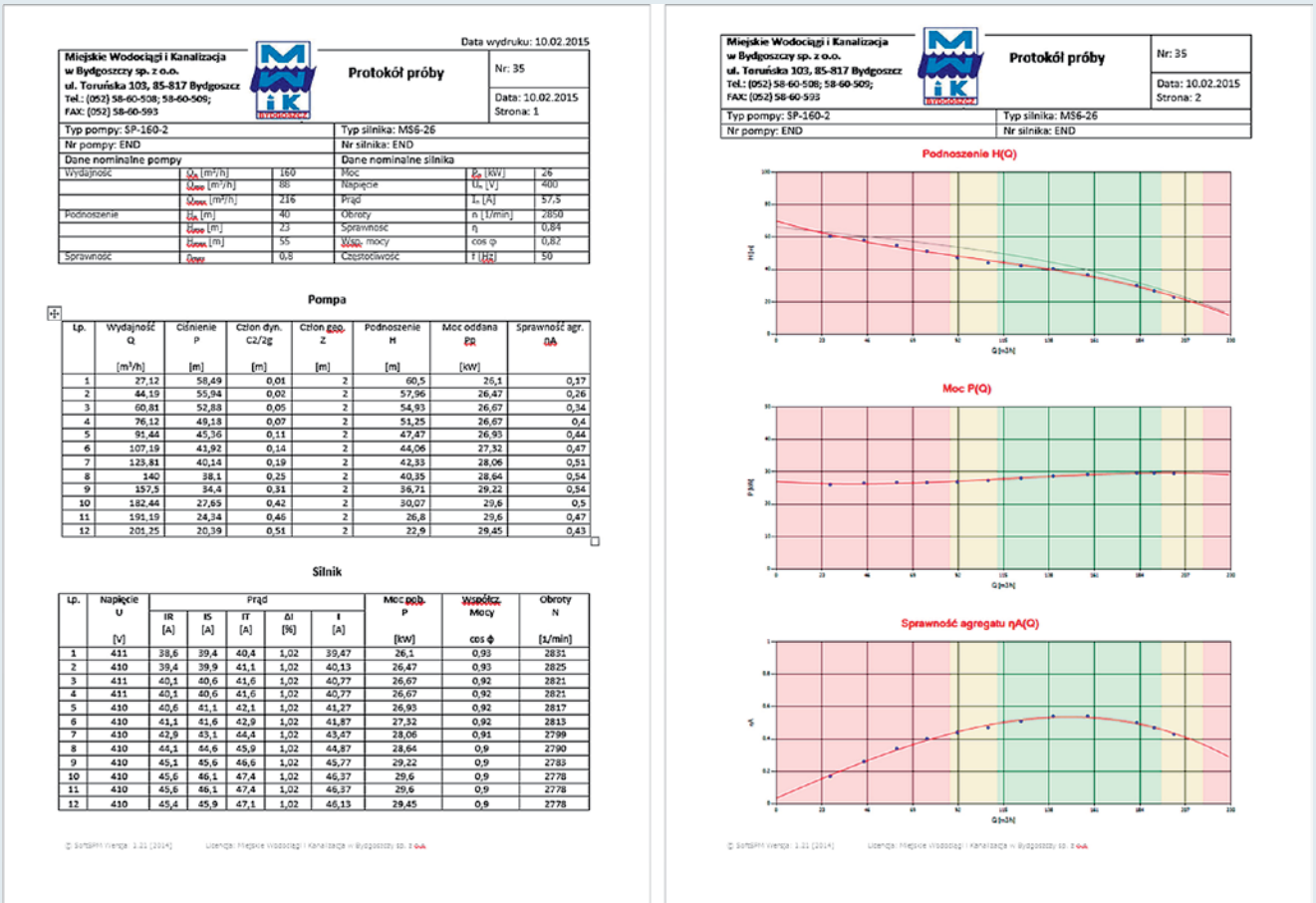
Picture 8.

table contains the pump's and submersible engine's catalogue specification as well as measurement data for particular measurement points determined by the computer program. The program indicated characteristics for the tested submersible pump and also gave the catalogue description for comparison – picture 9.

The indicated characteristics are in a "digitalised form", so as a consequence they might be used for further comparison and evaluation of the pump functioning in a well, e.g. in the **SoftSPM$_{BASIC}$** program. Users who exploit big systems of water intakes, and so possess dozens or hundreds of submersible pumps constantly used, often have their own organised maintenance management for those appliances. They carry out trials of new and repaired submersible pumps on their own trial station and select pumps to a specific pumping system on the basis of the determined characteristics. In the programs **SoftSPM$_{STD}$** and **SoftSPM$_{ENT}$** there is a mathematical model called a wizard of pump selection to the system, which allows the computer selection of a submersible pump to given operation conditions on the basis of real, measured on a trial station parameters. In the programs **SoftSPM$_{STD}$** and **SoftSPM$_{ENT}$** the digital characteristics of a given pump are automatically "moved" from trial stations directly to a computer mathematical model of the evaluation of a pumping system functioning for a given well. It is possible to visualise the functioning point of a pump which works in a well pumping system (patent RP) on the basis of its own characteristics measured before on the trial station.

FUNCTIONALITY

In **SPM$_{SYSTEM}$** the management of the operation of pumps and deep-water intakes is conducted from the possessed **SoftSPM** software level, which is configured in such a way so that it is possible to



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FAX: (052) 58-60-593

Protokół próby

Data wydruku: 10.02.2015
Nr: 35
Data: 10.02.2015
Strona: 1

Typ pompy: SP-160-2			Typ silnika: MS6-26		
Nr pompy: END			Nr silnika: END		
Dane nominalne pompy			Dane nominalne silnika		
Wydajność	Q_N [m³/h]	160	Moc	P_N [kW]	26
	Q_{min} [m³/h]	88	Napięcie	U_N [V]	400
	Q_{max} [m³/h]	216	Prąd	I_N [A]	57,5
Podnoszenie	H_N [m]	40	Obroty	n [1/min]	2850
	H_{min} [m]	23	Sprawność	η	0,84
	H_{max} [m]	55	Współ. mocy	cos φ	0,82
Sprawność	η_{pn}	0,8	Częstotliwość	f [Hz]	50

Pompa

Lp.	Wydajność Q [m³/h]	Ciśnienie P [m]	Człon dyn. C2/2g [m]	Człon geo. Z [m]	Podnoszenie H [m]	Moc oddana Pp [kW]	Sprawność agr. ηA
1	27,12	58,49	0,01	2	60,5	26,1	0,17
2	44,19	55,94	0,02	2	57,96	26,47	0,26
3	60,81	52,88	0,05	2	54,93	26,67	0,34
4	76,12	49,18	0,07	2	51,25	26,67	0,4
5	91,44	45,36	0,11	2	47,47	26,93	0,44
6	107,19	41,92	0,14	2	44,06	27,32	0,47
7	123,81	40,14	0,19	2	42,33	28,06	0,51
8	140	38,1	0,25	2	40,35	28,64	0,54
9	157,5	34,4	0,31	2	36,71	29,22	0,54
10	182,44	27,65	0,42	2	30,07	29,6	0,5
11	191,19	24,34	0,46	2	26,8	29,6	0,47
12	201,25	20,39	0,51	2	22,9	29,45	0,43

Silnik

Lp.	Napięcie U [V]	Prąd IR [A]	IS [A]	IT [A]	ΔI [%]	I [A]	Moc pob. P [kW]	Współcz. Mocy cos φ	Obroty N [1/min]
1	411	38,6	39,4	40,4	1,02	39,47	26,1	0,93	2831
2	410	39,4	39,9	41,1	1,02	40,13	26,47	0,93	2825
3	411	40,1	40,6	41,6	1,02	40,77	26,67	0,92	2821
4	411	40,1	40,6	41,6	1,02	40,77	26,67	0,92	2821
5	410	40,6	41,1	42,1	1,02	41,27	26,93	0,92	2817
6	410	41,1	41,6	42,9	1,02	41,87	27,32	0,92	2813
7	410	42,9	43,1	44,4	1,02	43,47	28,06	0,91	2799
8	410	44,1	44,6	45,9	1,02	44,87	28,64	0,9	2790
9	410	45,1	45,6	46,6	1,02	45,77	29,22	0,9	2783
10	410	45,6	46,1	47,4	1,02	46,37	29,6	0,9	2778
11	410	45,6	46,1	47,4	1,02	46,37	29,6	0,9	2778
12	410	45,4	45,9	47,1	1,02	46,13	29,45	0,9	2778

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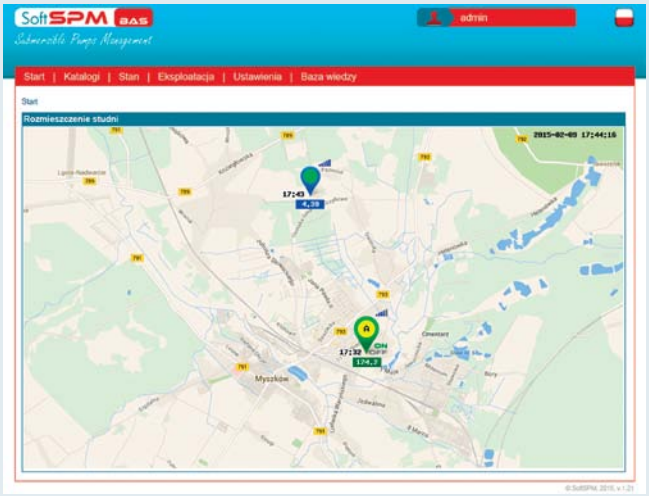
Protokół próby

Nr: 35
Data: 10.02.2015
Strona: 2

Typ pompy: SP-160-2	Typ silnika: MS6-26
Nr pompy: END	Nr silnika: END

Picture 9.

read the results of the objects' work assessment and their actual operation state during the first insight into the system work, i.e. on the as-built map. This task is performed in a following way: the well location is presented in a form of a pin icon called " a tear" (Picture). The colour of its border indicates the mode of the well functioning: green means that the submersible pump is on, red – the pump is off – picture 10.



Picture 10.

The submersible pump switching status is also confirmed by the inscription ON or OFF. In addition, the colour of the inner circle indicates the evaluation outcome of energy consumption of the submersible pump pumping system according to the following rule:

- **green** means optimal operation,
- **yellow** means work in a boundary area,
- **red** means uneconomic operation.

For instance, in case of control modes used to monitor the well functioning, there is the letter A or R provided. This means automatic work or manual control respectively.

The tanks location has been marked on a map. It is done in a similar way as in case of the wells location, although the pin con's border is blue. The colour of inner circle informs about the actual level of water in a tank:

- **green** means that the tank is filled up to the optimal level,
- **yellow** means that water level reached the boundary area,
- **red** means the warning level.

In addition, the actual value of the pump's work is provided underneath the well's pin con for a quick analysis. The measurement time is given above the con. The value of water level location is provided in the same way.

The user will have knowledge about the operational system state practically after the first glance at the map of objects location. In case of any alarm conditions either of the pumps functioning or tanks, appropriate marking and red inscriptions are placed on the map. There are visualised appropriate guidelines reflecting the figures concerning access of the GSM network, which are to illustrate the levels of those figures in points of the objects location.

Once the user clicks on the marked object, i.e. a well, they "go into" a deeper layer of the function analysis that reflects the results of a work of mathematical models which evaluate the current operation of the well pumping system – picture 11.

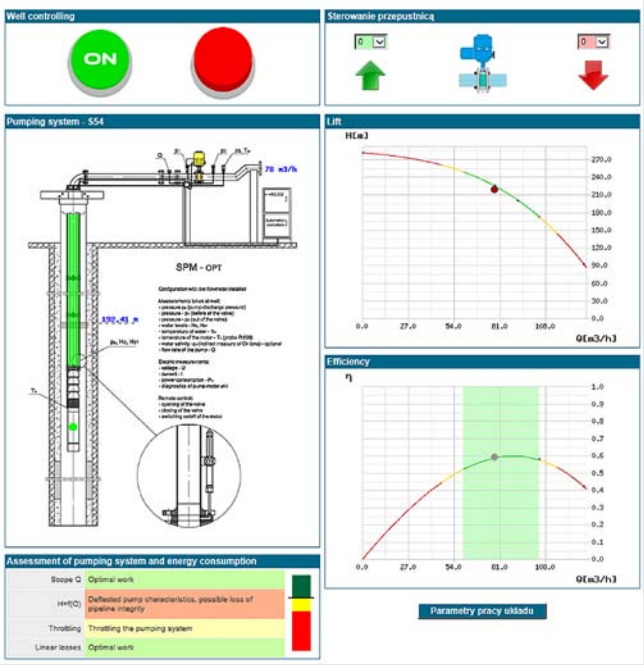
Picture 11.

The central and bottom part of the screen show results of performed analyses in mathematical models relating to evaluation of a pumping system operation. The evaluation is carried out by a computer on the basis of current figures of the hydraulic and electrical parameters transferred to the **SoftSPM** software from the SPM instrumentation and metering – picture 12.

The mathematical models of evaluation take into account:

- the point of a submersible pump location in an earlier determined optimal operation range,
- current strain of the **H = f (Q)** characteristic of the operating pump in a pumping system, along with leaktightness diagnostics of the pressure pipeline,
- the value of the current state of flow starving in the pumping system fittings,
- the value of the precisely defined line losses in the pump pressure pipeline,
- current level of pump system energy consumption.

The evaluation program sets out results for particular current measurement sets from the objects. For doing

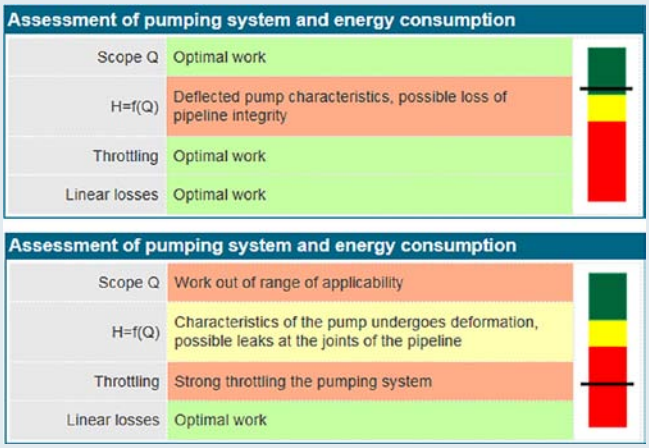


Picture 12.

so, the program uses encoded in mathemtical models evaluation criteria which take into account the system and mutual parametic dependance as well as some of its temporarily changeable courses. The results are presented in a text and graphic forms. Colours of the evaluation text backgrounds are evidence of their ranges according to the following principle:

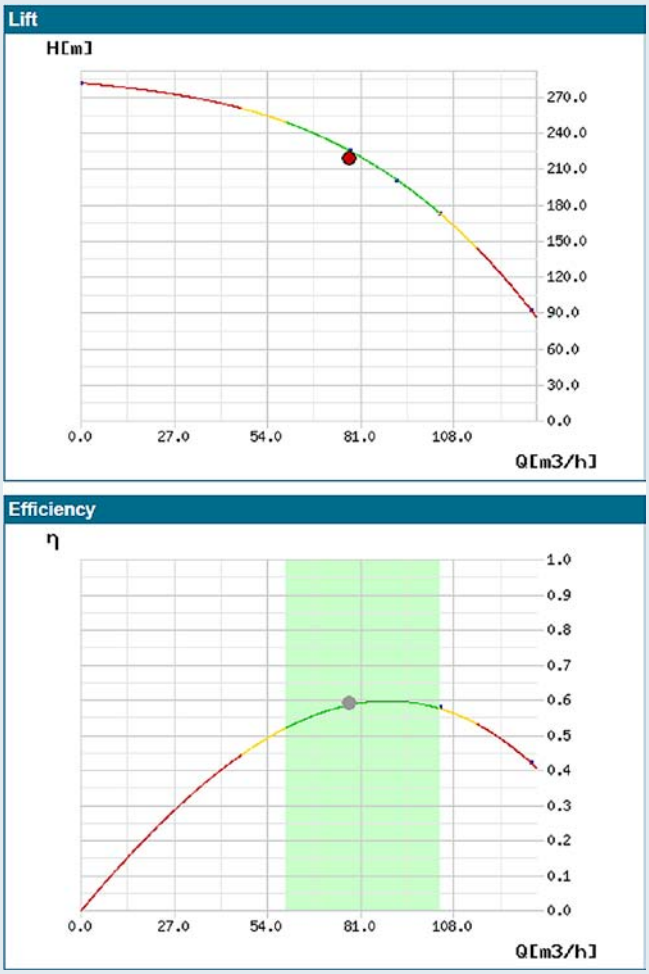
- **green** means optimal operation,
- **yellow** means work in a boundary area,
- **red** means uneconomic operation.

The picture 13 shows an example of the pumping system evaluation.



Picture 13.

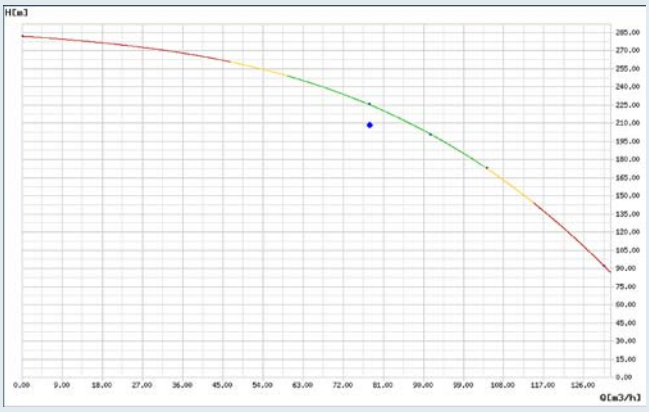
The scope of changes in the pumping system together with the so called stripe of its energy comsumption is easily noticeable. Picture shows a graphic illustration with the use of colours on the scheme of the pumping system construction. The colour of a pressure pipeline and throttle indicates the evaluation result for these elements of the system. This picture shows also the value of current pump efficiency and a current level of water in a well. Evaluation of a strain degree of the **H = f (Q)** characteristic is presented in a colour of the marked point of the pump's work exactly on the characteristic (Picture). Similarly to previous example, the colours used in the evaluation, i.e. green, yellow and red mean respectively: optimal work, the beginning of the characteristic strain and strained characteristic. In each case there is also information about the possible loss of the leaktightness of a pressure pump. Picture presents an evaluation view of the degree of the **H = f (Q)** characteristic as well as the location evaluation of the point of a pump's work against the background of the optimal pump use range – picture 14.



Picture 14.

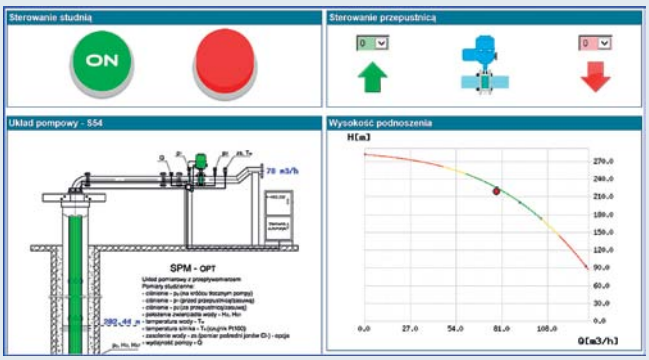
This chart shows that the pump works in an optimal use range, but its characteristic has been already strained. Pursuant to the principle applied in the system, if there is a need to check more precise evaluation, one should click on the object that they are interested in, and then

after choosing the characteristic with a coloured point of pump's work, they "go into" a deeper layer of the analysis that reflects the precise location of the point of work against the background of the actual pump characteristic from the trial station – picture 15.



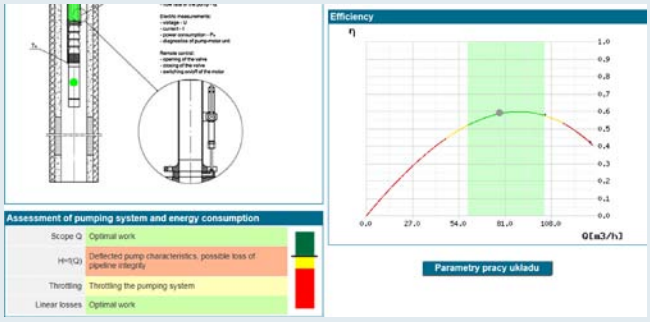
Picture 15.

The blue point shows the actual height of lifting the pump for given efficiency, i.e. the actual location of a work point on a new, changed characteristic. The analysis of the actual characteristic strain made by the mathematical model uses the pressure measurements taken by an integrated depth finder installed behind a discharge port of a submersible pump. The diagnostics method of a submersible pump and pumping system with the help of an integrated depth finder of pressure measurements is now the latest patented way of evaluation of the operating state of a pump together with the whole system. At the top of the evaluation screen there are panels for controlling the work of a submersible pump switch on/off a pump engine as well as panels for controlling e.g. the location of a throttle – picture 16.



Picture 16.

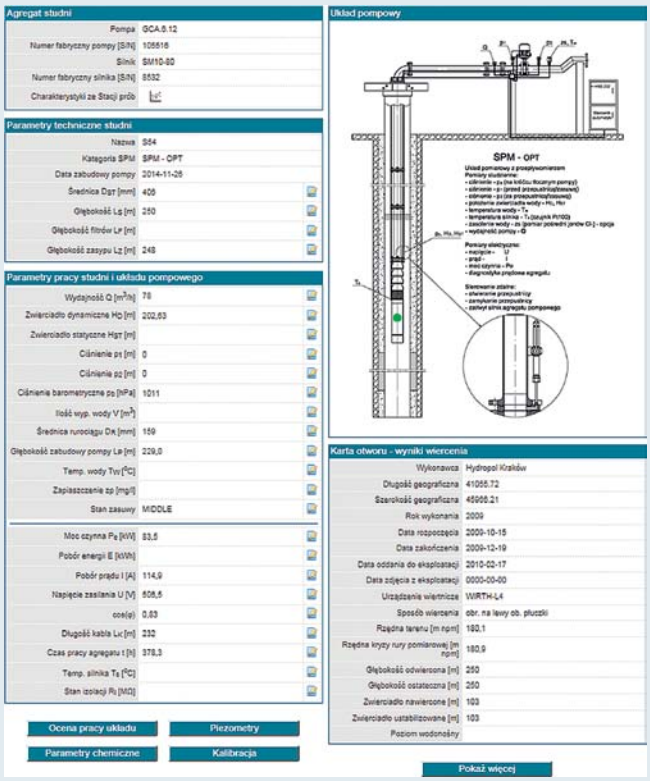
By clicking on „Operation system parameters" on the evaluation screen (picture), the user „enters" detailed data and parameters of the operation system and well – picture 17



Picture 17.

Data and parameters of the pumping system and well include information about a type of the pump and submersible engine together with the manufacturer's numbers and data coming from the protocol of pump's trials at a station as well as data referring to a well. There is also the following data given:

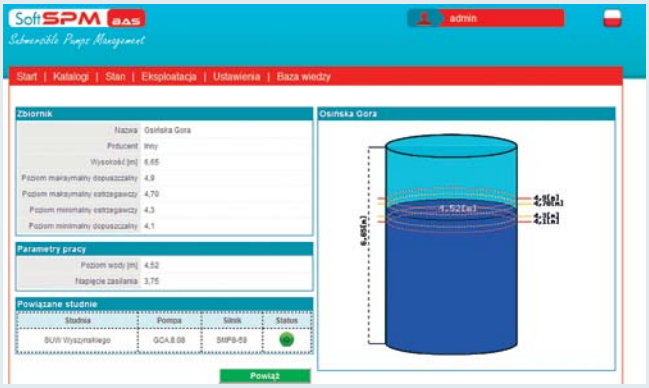
- a date of integration of a pump unit in a well pumping system together with installation data,
- information coming from the log of a well hole starting from the time of drilling a well, through the results of trial pumping, up to a set of operation parameters referring to the current operating of a pump,
- electrical parameters of a working submersible engine – picture 18.



Picture 18.

The picture shows a screen reflecting how the tank with water supplying a water-pipe network functions.

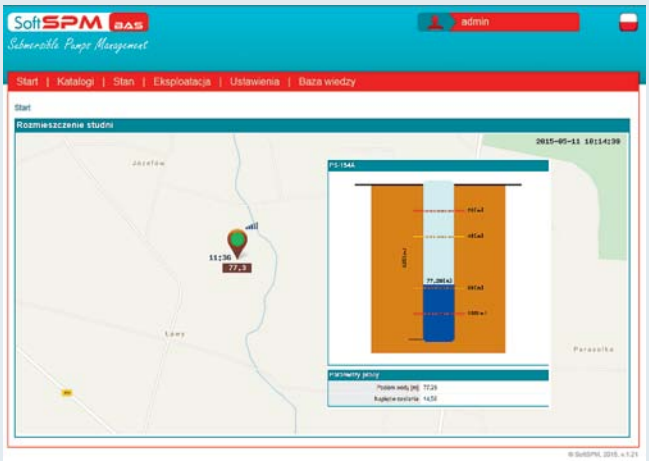
The filling degree of the tank has been graphically presented. The location of warning and alarm levels has been marked. The location values of the levels are provided next to a tank view. In the bottom part of a screen there is information given about wells providing water to a tank as well as whether these wells are on or off – picture 19.



Picture 19. The **SoftSPM** software allows practically free configuration of the control modes of water intakes functioning according to a ready or already configured by users algorithm of a work system.

The picture below presents the location of piezometric holes in the area. Similarly to the wells, the iezometers' location is shown with a pin con, though in this case its border is brown. The inner colour of the circle indicates the actual water level in the piezometer's pipe with the following division of colours – picture 20:

- **green** means the optimal water level,
- **yellow** indicates the value of water level location in the boundary area,
- **red** means the alarm water level in the piezometer.



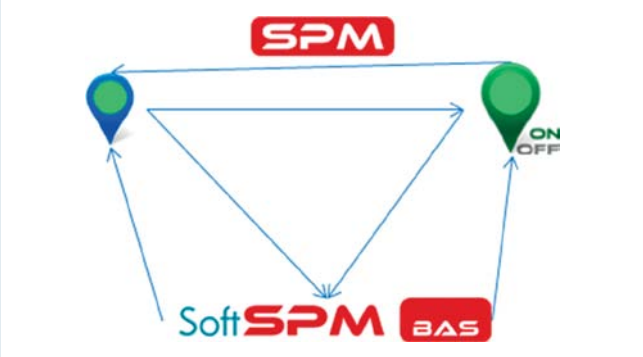
Picture 20.

Moreover, for a quick analysis, the actual value of the water level is provided underneath the piezometer's pin con and the time of measurement is provided right over it.

The **SPM$_{SYSTEM}$** has been equipped with a special version of the **SZ-21** controllers construction with a battery power supply, which cyclically measure and transmit the values of water level from piezometers. The controllers' power supply will be working up to 5 years and it depends on how often the data is transmitted from the piezometers.

The **SoftSPM** software allows practically free configuration of the control modes of water intakes functioning according to a ready or already configurated by users algorithm of a work system.

Taking into consideration modern, up-to-the-minute technologies relating to remote control and transfer of digital data, **SPM$_{SYSTEM}$** focuses mainly on the extensive use of the GSM network. In order to communicate between objects (**SZ-21** tank, **SZ-21** well, **SoftSPM** software) short text messages (so called sms) in digital mobile communication network are used. Each sms sent as a data source (from any "object") is confirmed by a return sms sent from the objects which received the data sorce message. This procedure guarantees high reliability. In case of lack of this mutual communication an appropriate alarm pops up, i.e. complete information about a kind and reason for the problem. The picture 21 shows an example of the communication scheme of controlling and providing information about the **SPM$_{SYSTEM}$** functioning.



Picture 21.

Each GSM network may be used. What is more, the use of antennas for strengthening the network signals facilitated raising the possibilities of controlling and tranfering data for communication via sms. Prior to the system implementation, appropriate measurements of signals are carried out. The **SZ-21** and **SIMATIC S7 1200** single-purpose system controllers have been configurated in such a way, so that the control and data transfer technologies may function mainly via sms. This configuration, besides fast performance in weak network coverage, considerably re-

duces the costs of system maintenance, and as a result, has influence on operation costs of the whole system. It is obvious that software of local controllers needs more developed and complex algorithms which guarantee constant supervision over the object. The controller "sends" an sms only in a situation which evokes reaction from the "higher" program located on the user's server or on the publicly available server at www.softspm.com. The described design structure and technology of the **SoftSPM** software cannot determine the distance between the server and a given object. Moreover, sms "delivery" from and to the server takes no more than several minutes, so the reaction of the "higher" program is almost immediate. Similarly, the same happens if we turn on or off the pump engine via the server, or we remotely change other parameters, e.g. the inverter's work frequency, location of a throttle, etc. **SPM$_{SYSTEM}$** has in its knowledge base and in construction of complex mathematical models a set of detailed procedures of how to react in case of any possible to foresee states of pumping systems work. With the passage of time, these bases sistematically expand and, as a result, the system optimizes by itself the functioning of particular work algorithms. If a user has any number of wells or many tanks connected with developed pipeline networks, the **SoftSPM** software allows to configure almost any structure of the objects control which are beyond the GSM network coverage. If the objects are clearly located beyond the GSM network coverage, the system configuration chooses other media of access, such as radio, cables, fiber optic cables, etc.

THE CLOUD

The Cloud in the SaaS model, in which the user pays monthly subscription costs and the system itself is hosted on the **SDC** (SoftSPMData Center) servers. This is the model of the **SoftSPM** system distribution which makes the software, infrastructure and the whole application development platform installed and maintained on the servers in the softspm.com domain available to the users (the functional scope depends on the version purchased: **SoftSPM$_{BAS}$**, **SoftSPM$_{STD}$**, **SoftSPM$_{ENT}$**). In the Cloud model (SaaS) użythe user doesn't have to instal the complete information system. In order to establish connection with the cloud, the Internet browser is enough – picture 22.

The operating principle involves transfer of the whole burden of IT service provision (data, software or computing power) to the server and guarantee that the

Picture 22.

clients' computers will be provided with constant access. Owing to this, their safety doesn't depend on what happens to the client's computer, and the speed of the process is the result of the server computing power. It is enough to log in from any computer which is connected to the Internet to take advantage of the profits that the cloud computing may offer.

METERING

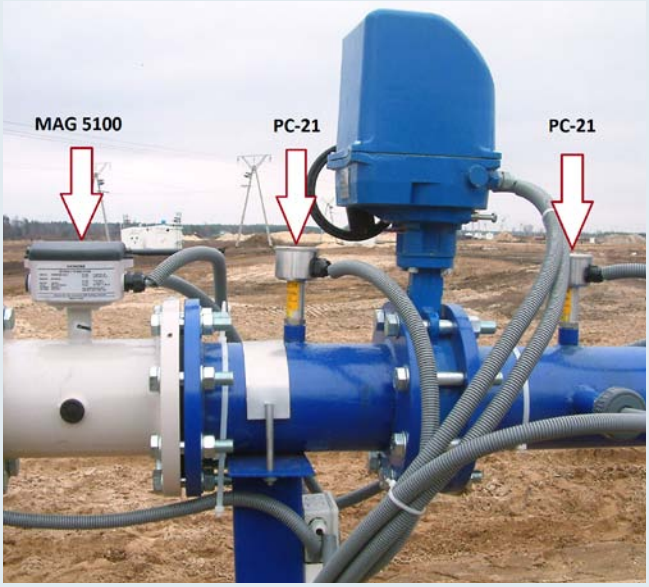
CONSTRUCTION

SPM$_{SYSTEM}$ has three versions of instrumentation and metering of wells – **SPM$_{MIN}$**, **SPM$_{BASE}$** oraz **SPM$_{OPT}$**. Each version is based on the latest dedicated solutions, which include among others the integrated depth finder for measuring the pressure inside and outside the submersible pump pressure pipeline, installed under water behind a pressure discharge of the pump. This depth finder allows precise determination of the balance of flow losses in the pumping system, including determination of linear flow losses in the pipeline, in which the submersible pump works. Based on the measured values of the pressure inside and outside of the submersible pump pipeline just behind a discharge, the mathematical models of the system allow precise mapping of the location of a submersible pump operating point on its characteristics, and thus diagnose (RP patent) the current technical condition of the working pump and submersible engine. The picture 23 shows the integrated pressure measurement depth finder at the moment of its installation in the submersible pump's pressure pipeline.

The **PC-21** pressure transducers, which are installed in each **SPM** metering version, measure the pressure before and behind the throttle. In the **SPM$_{BASE}$** and **SPM$_{OPT}$** versions there is an electromagnetic flowmeter installed (e.g. MAG 5100 or PEM-1000). The picture below shows the already installed metering for the **SPM$_{OPT}$** metering version – picture 24.

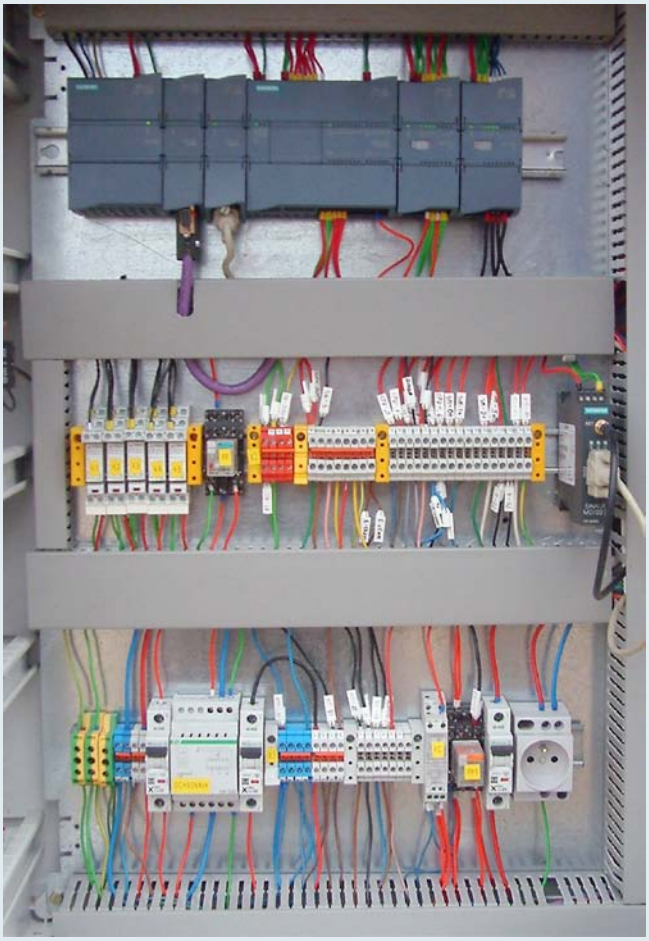
The **SGP-21** depth finders, the **PC-21** pressure transducers and the **MAG 5100** or **PEM-1000** flowmeters

Picture 23.



Picture 24.

are made in the versions dedicated to **SPM$_{SYSTEM}$**, which guarantee high functioning reliability. Depending on the quality of the pumped medium, this metering has been made of various materials – duplex including. The depth finders and the pressure transducers may freely program measuring scopes in the HART system. The metering is powered and it cooperates with two kinds of controllers, which in the basic version, by the GSM network in the SMS technology, cooperate with a level of the **SoftSPM** software chosen by the user. The **SZ-21** dedicated controller made by APLISENS S.A. cooperates with the **SPM$_{MIN}$**, **SPM$_{BASE}$** metering versions. In turn, **SIMATIC S7 1200** made by SIEMENS cooperates with the **SPM$_{OPT}$** version. The controllers possess its own resident software, which they implement in the set and temporarily changeable measuring cycles and enable the control of operation of the pumping units and other instrumentation – turn on/off the pump's engine, inverters, valves, diagnostics, etc. What is more, they enable the transfer of the so called object's security signals. According to the needs, the individually programmed algorithms of controlling the pumping system are activated locally or from a higher **SoftSPM** program located on the server. **SPM$_{SYSTEM}$** gathers in its knowledge base and in the construction of complex mathematical models a number of precise procedures in the operation modes of pumping systems possible to foresee. With the passage of time, these bases systematically extend, and by this the system in itself optimises the functioning of each work algorithm. If the user has any number of wells and many tanks connected with each other by an extended pipeline network, the system metering allows to configure practically every structure of control of the objects located within the GSM network. In case when the objects are clearly located



Picture 25.

beyond the GSM network, the system configuration chooses other media of access, like radio, cables, fibre optic cables, etc. The picture below shows the construction of an example automatics cabinet for the **SPM$_{OPT}$** version – picture 25.

The **SZ-21** controller may also monitor the water level in the tanks or piezometers.

The metering in **SPM$_{SYSTEM}$** includes also the trial stations of pumps and submersible engines. The **SPM$_{TEST}$** version compiles the metering and also embraces the pressure transducers and electromagnetic flowmeters mentioned before. Additionally, for the **SPM$_{TEST}$** version, there are the **KDP-1** concentrators and the **ST-1** transmission controller of special construction produced – picture 26.

Picture 26.

The picture below shows the metering of 3 chains of measuring the submersible pumps efficiency ranging from 0,5 m3/h to 360 m3/h with the view of the computer from the controlling position and the view of concentrators – picture 27.

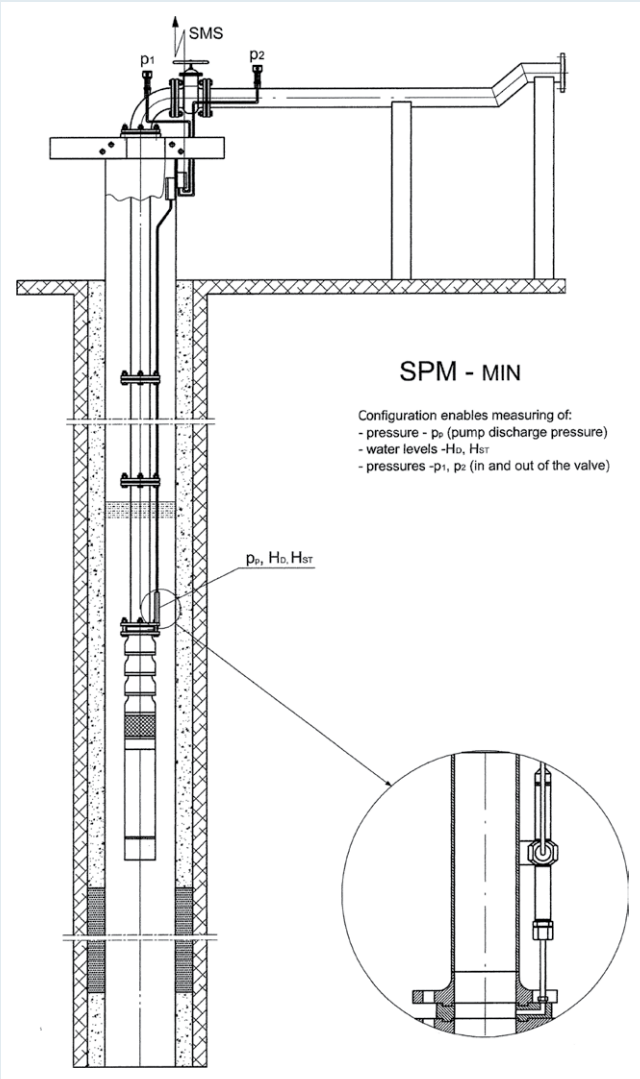
Picture 27.

SPM$_{MIN}$

The attached diagram shows the integration of the devices and metering for the "minimum" version – **SPM$_{MIN}$** . In this pumping system it is possible to control the pump unit and the well – picture 28.

Measurement parameters:

- **Well measurements**:
  - pp pressure in the discharge port of a submersible pump (under water),



Picture 28.

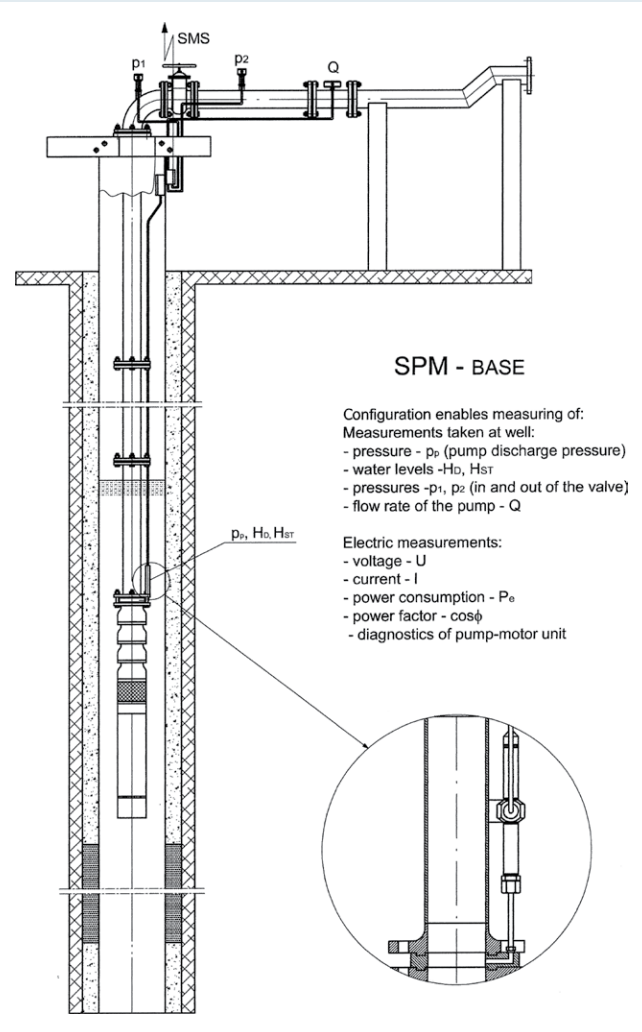
  - Hst, Hd – static or dynamic water level in the well,
  - p1 and p2 pressure (before and behind the throttle),
- **remote control**:
  - switching on/off of the pump engine.

The **SPM$_{MIN}$** version is the cheapest metering version of wells, but allows to determine in a mathematical and computer way the parameters of functioning of the pumping system. Moreover, it allows to make evaluation models of energy consumption. This version can be used in pumping systems, in which the liquid has or does not have traces of mechanical impurities, i.e. mainly sand. The quality of pumped water is akin to the quality of drinking water. The accuracy of mathematically determined pump efficiency is dependent on the steepness of the **H = f (Q)** characteristics. The accuracy class is between 0,5–1,5. A more advanced version of the system (e.g. **SPM$_{BASE}$**) should be used for pumps with extremely flat characteristics. In the

SPM_{MIN} version the metering of the pumping system of the well works together with a **SZ-21** controller that records and transmits measurement data to the **SoftSPM** central program. The controller may turn on or off the pump's engine both from the **SoftSPM** program and when it works in the so called 'distributed system' from the signal coming from the other controller.

SPM_{BASE}

The diagram below shows the integration of devices and metering for the "base" version – **SPM_{BASE}** – picture 29.



Picture 29.

In this version, the following parameters are measured:

- **Well measurements**:
  - pp pressure at the discharge port of a submersible pump (under water),
  - Hst, Hd – static or dynamic water level in a well,
  - p1 and p2 pressure (before and behind a throttle),
  - pump efficiency Q;
- **Electrical measurements**:
  - supply voltage U,
  - power consumption I,
  - active power consumption Pe,
  - power factor cos Ø,
  - power diagnostics;
- **Remote control**:
  - switching on/off of the pump engine.

The binary signal which might be activated by unauthorised people (so called the security signal) is transmitted from each object.

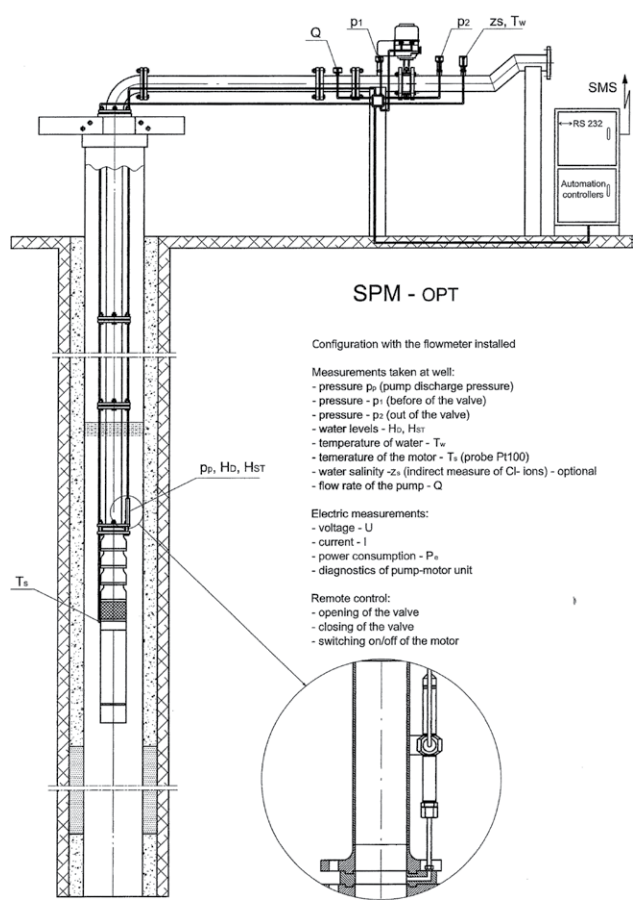
SPM_{BASE} is the most common version used in water intakes. It does not require any restrictions in terms of the pumped medium quality. This version provides high accuracy of measurements of the hydraulic parameters in the pumping system – the class of measurements is below 0.5. Similarly to the **SPM_{MIN}** version, **SPM_{BASE}** also works with the **SZ-21** controller that records and transmits measurement data to the **SoftSPM** central program. The controller may turn on or off the pump's engine both from the **SoftSPM** program and when it works in the so called 'distributed system' from the signal coming from the other controller.

SPM_{OPT}

The diagram below shows the optimum version, i.e. **SPM_{OPT}** – picture 30.

In this version the following parameters are measured:

- **Well measurements**:
  - pp pressure at the discharge of a submersible pump (under water),
  - Hst, Hd – static or dynamic water level in a well,
  - p1 and p2 pressure (before and behind a throttle),
  - pump efficiency Q,
  - water temperature Tw,
  - engine temperature Ts – sensor PT-100,
  - water salinity zs;
- **Electrical measurements**:
  - supply voltage U,
  - power consumption I,
  - active power consumption Pe,
  - power factor cos Ø,
  - power diagnostics.
- **Remote control**:
  - opening/closing of the valve,



Picture 30.

– increase/reduction of the engine speed – the inverter,
– switching on/off of the pump engine,

The binary signal which might be activated by unauthorised people (so called the security signal) is transmitted from each object.

The signals from the control and measurement equipment are brought to the automatics cabinet which contains the specially programmed **SIMATIC S7 1200** controller – picture 31. This controller cooperates with the **SoftSPM** software usually via the GSM network (sms) or GPRS. There are also other methods of data transfer possible: fiber optic cables, radio, WI-FI, telecommunication cables etc.

The controllers possess its own resident software, which they implement in the set and temporarily changeable measuring cycles and enable the control of operation of the pumping units and other instrumentation – turn on/off the pump's engine, inverters, valves, diagnostics etc. What is more, they enable the transfer of the so called object's security signals. According to the needs, the individually programmed algorithms of controlling the pumping system are activated locally or from a higher **SoftSPM** program located on the server.

SPM_{TEST}

The **SPM_{TEST}** version embraces the pressure transducers and electromagnetic flowmeters mentioned before. In the **SPM_{TEST}** version, there are the **KDP-1** concentrators and the **ST-1** transmission controller of special construction used – picture 32.

Based on measurements of submersible pump efficiency and a pressure measurement in a determined measurement pipeline cross-section, the pump flow **H = f (Q)** characteristic defined. This characteristics is compared to the real rotational speed. Measurements are carried out for various degrees of the pump starving, i.e. for different measurement points. The number

Picture 31.

Picture 32.

of these points has been calculated in such a way, so that it is possible to assess with high accuracy the following characteristics: **H = f (Q)**, **η = f (Q)**, **Pp = f (Q)**. In fact, only the trials performed at trial stations of submersible pump units allow to define and verify the proper course of pumps characteristics.

THE SPM_{SYSTEM} AUTOMATICS CABINETS

The **SPM_{SYSTEM}** automatics cabinets are used in the **SPM_{BASE}**, **SPM_{OPT}** and **SPM_{TEST}** metering versions. Cabinets, in order to be used in wells, are adapted to work in the open terrain in temperature ranging from -25°C to +65°C and in closed spaces, e.g. in buildings. The view of the SZA-2.1. SPM equipped cabinet, which supports the **SPM_{OPT}** metering for the maximum scope of measurements taken outside in temperature ranging from -25°C to +65°C, has been shown in the picture 33.

Picture 33.

Picture 34.

The view of the **SZA-1.2. SPM** automatics cabinet supporting the **SPM_{OPT}** metering for a basic scope of measurements, located in the building of the intake, has been shown in the picture 34.

The automatics cabinets for the **SPM_{TEST}** metering version are adapted to the individual project of trial stations each time. The view below refers to a station

Picture 35.

with 3 chains of measuring the efficiency of pumps and power of engines to 75 kW – picture 35.

BENEFITS

The full configuration of **SPM_{SYSTEM}**, regardless of which levels of the **SoftSPM** software are applied or what the metering or instrumentation version of the SPM well is, provides the user with the following benefits:

- **Economic**:
  - the optimisation of energy consuming during the operation of well pumping systems – reduction the electricity fee,
  - the increase of reliability of the pumping units used,
  - the possibility of any financially planned configuration of the scope of the **SoftSPM** software level as well as the choice of compatible SPM metering and instrumentation versions,
  - the possibility of gradual – steady system implementation, convertibility with the previous SEGAP system,
  - the possibility to use the service of the **SoftSPM** Cloud Comuting (Clouds) in the SaaS model,
  - the possibility to use the special lease system of the implemented and working SPM metering and instrumentation with its purchase after 36 months.
- **Installation and motion**:
  - simple, modular construction of the SPM well metering and instrumentation,
  - the freely programmed measuring ranges of pressure transducers and depth finders – the HART system,
  - the high operating accuracy and reliability of measuring devices and controllers.

SALES SYSTEM

The **SPM_{SYSTEM}** sale model takes into accounts both technical and economic conditions, which may refer to the client (a user). This is because the client is supposed to have a quick and simple access to both the **SoftSPM** software and the SPM metering sets. The sale model refers to software, metering and instrumentation of the well pumping systems.

- **The SoftSPM software – for all levels in options:**
  - the **SoftSPM** Cloud Comuting servise (Clouds) in the **SaaS** model (**S**ale **a**s **a S**ervice), in which the user monthly pays the subscription and the system is hosted on the SDC (SoftSPM Data Center) servers. The client uses the standard functionalities (their range depends on the version purchased: **$SoftSPM_{BAS}$**, **$SoftSPM_{STD}$**, **$SoftSPM_{ENT}$**) via the Internet;
  - the **Hosting** model – each individual implementation is dedicated to a specified user. The system itself is installed on the SDC (SoftSPM Data Center) servers and it is accessible via the Internet;
  - the **Client's** model – similarly to the hosting model, the system is directly adjusted to the user's needs and the system itself is installed on the servers indicated by the client.
- **The SPM metering and instrumentation:**
  - The purchase of any **SPM** metering and instrumentation version is single and includes installation and launching;
  - The lease of metering and instrumentation for the **SPM_{MIN}**, **SPM_{BASE}** versions with supervision over the installation and launching for 36 months with the possibility to purchase the sets for the price of the 36th rental fee on condition that the previous 35 rental fees are paid;
  - The joint mixed system of partial purchase of sets and the partial lease, according to the client's needs and financial possibilities.