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(54) **PUMP TURBINE INSTALLATION**

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(57) **ABSTRACT**

The invention relates to a pump turbine system, comprising

a turbine with a turbine impeller as well as a turbine spiral housing and a turbine suction pipe;

a pump with a pump impeller as well as a pump spiral housing and a pump suction pipe;

the two spiral housings are arranged to run in opposite directions;

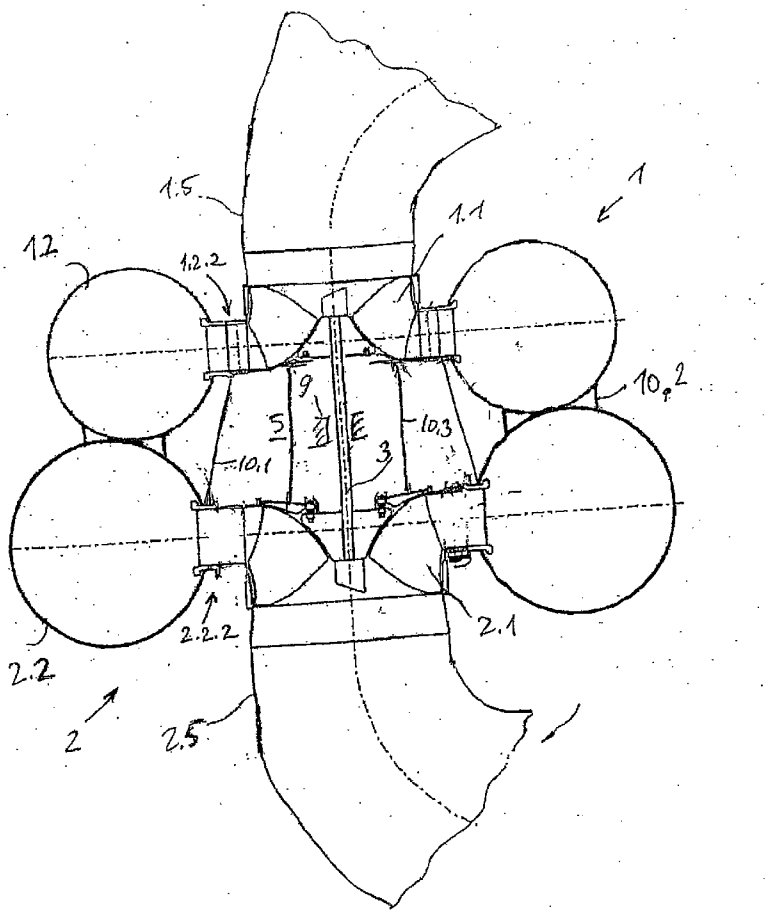
a shaft on which the turbine impeller and the pump impeller are non-rotatably arranged;

an electrical machine that is in drive communication with the shaft or can be brought into such communication;

the pressure lines of the two spiral housings open into a common pressure line;

both suction pipes are each connected to suction lines, with both suction lines opening into a common suction line; with

a separate shut-off element each being arranged in the suction lines.



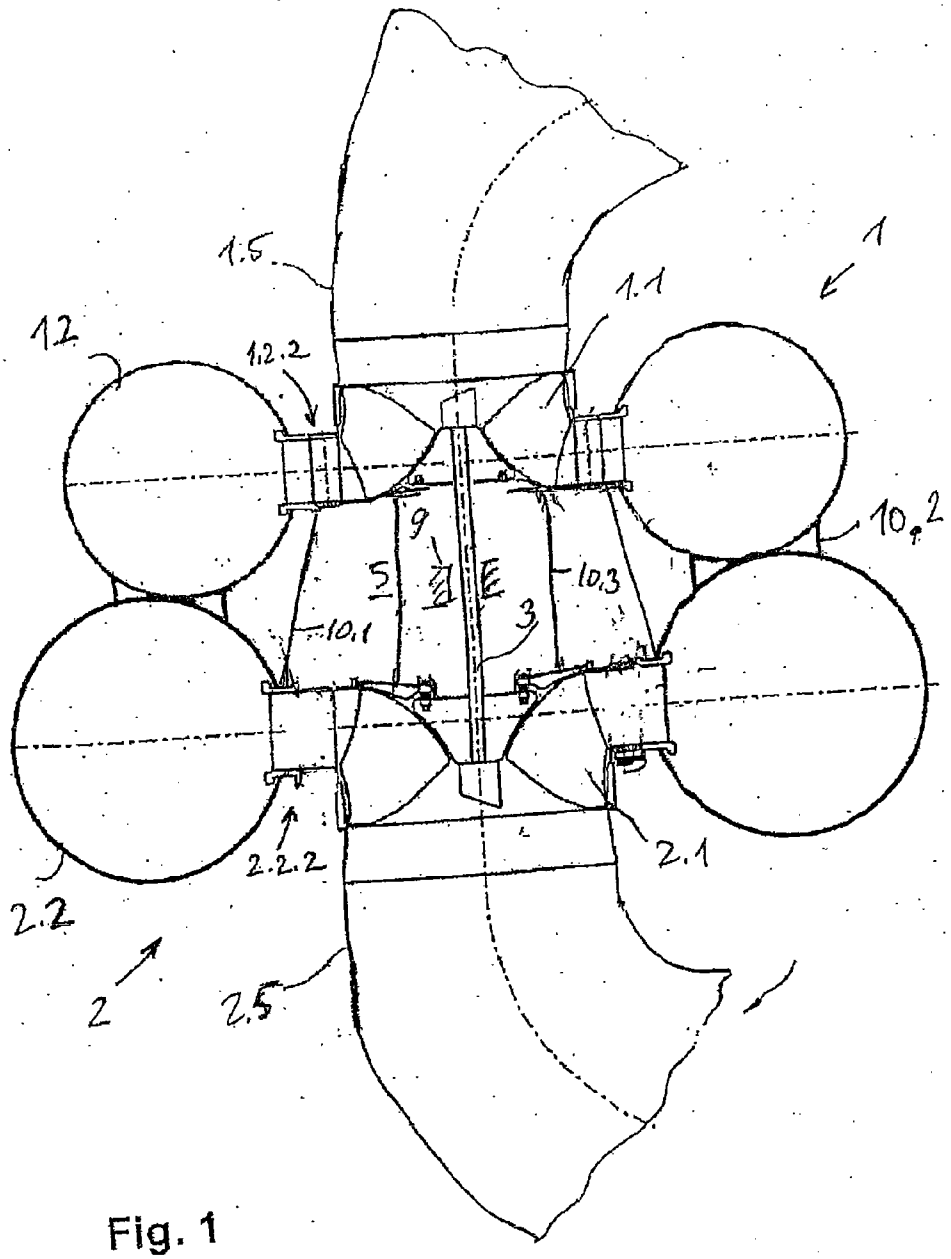


Fig. 1

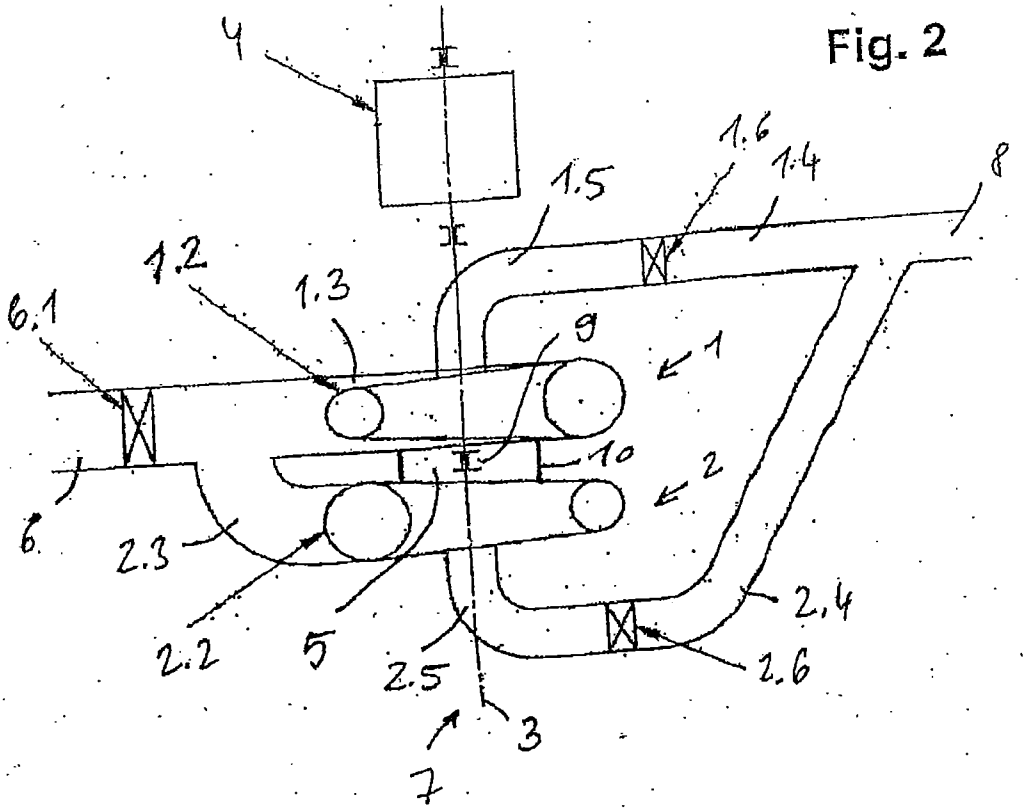

4
1.6
1.4
8
1.5
1.2
1.3
6.1
9
1
10
2
6
2.3
2.4
2.2
5
2.5
2.6
3
7

Fig. 2

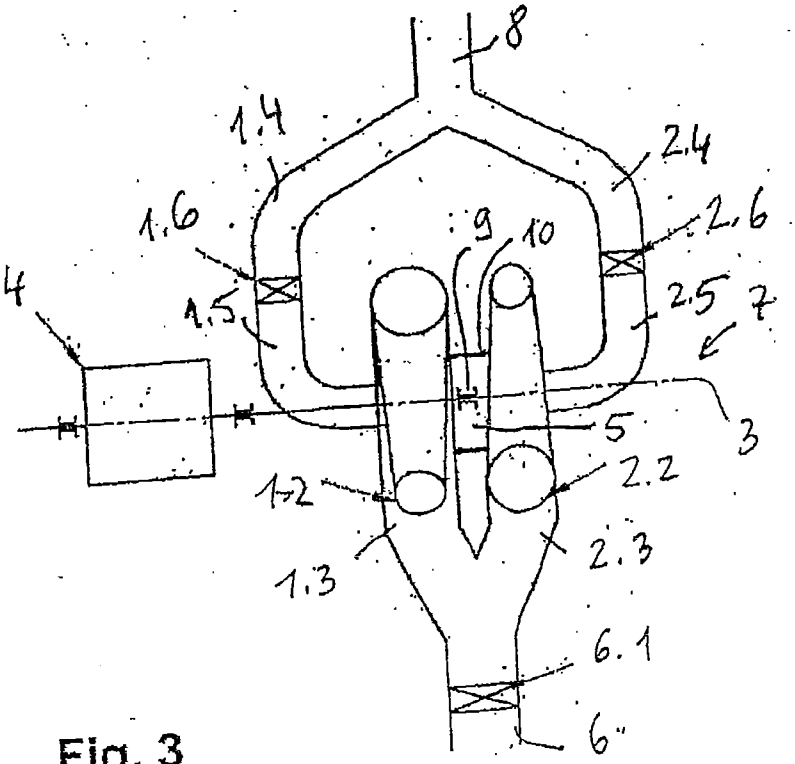

8
1.4
2.4
1.6
9
10
2.6
4
1.5
2.5
7
5
3
1.2
2.2
2.3
1.3
6.1
6"

Fig. 3

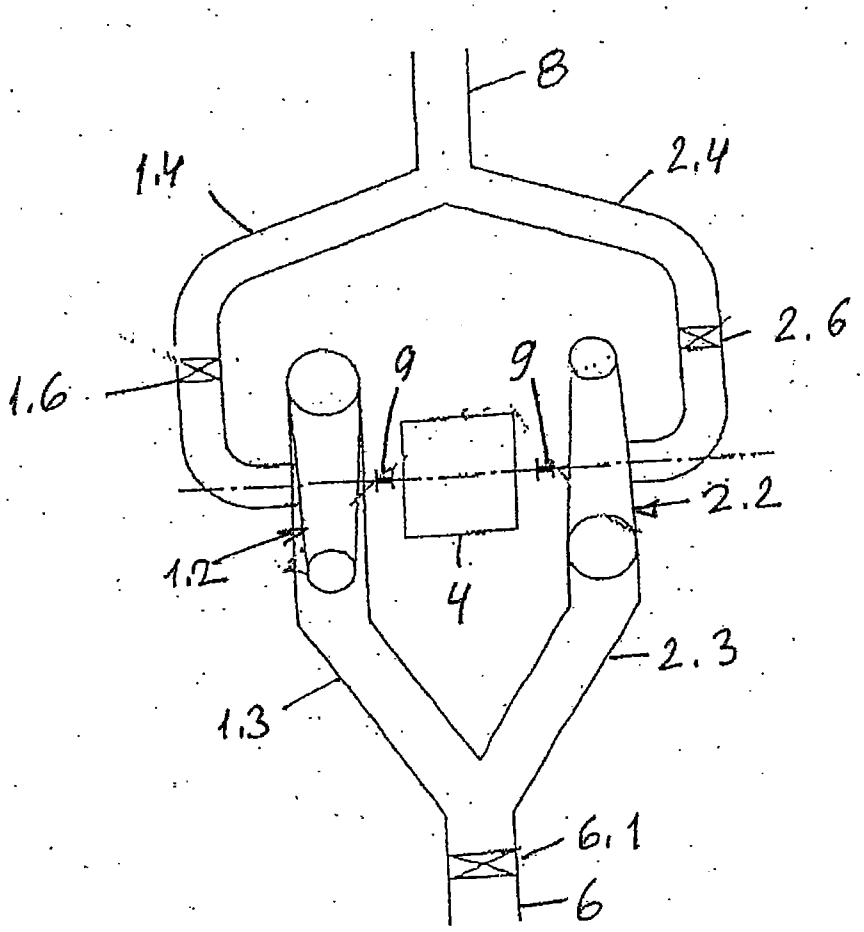


Fig. 4

PUMP TURBINE INSTALLATION

[0001] The invention relates to a pump turbine installation, comprising a turbine with a turbine impeller as well as a spiral turbine housing and a pump with a pump impeller, as well as a spiral pump housing. The pump and the turbine are or can be bought into a driving connection with an electric machine.

[0002] Francis or Perton turbines come into consideration as turbines. Moreover, the pump, as well as the turbine, can be constructed as a single stage or multistage device, so that combinations of a single stage turbine with a multistage pump or of multistage turbines with a single stage or multistage pump, are conceivable.

[0003] Pump turbine installation of pumped storage power plants have two modes of operations, namely a turbine mode and a pump mode. During the latter case, the pump pumps water from a lower basin into an upper basin and, for this purpose, is driven by an electric machine, which is in driving connection with the pump. The electric machine is supplied by a public electricity grid, that is, it is supplied with electric power.

[0004] On the other hand, in the case of a turbine operation, the water, which flows from the upper basin for the turbine into the lower basin, drives this turbine, which transfers a corresponding power to the electric machine. An electric machine converts the driving power into electric power and supplies a network. Accordingly, the electric machine, on the one hand, works as a generator and, on the other, as a motor. It is therefore also referred to as a motor-generator.

[0005] In contrast to the above-named generic pump turbine installation, reversible pump turbine installations have also become known, for which the turbine and the pump are formed by a common impeller, so that the common impeller is acted upon with water from the upper basin to produce electric power in the turbine operation and is driven by the electric machine in the pump operation.

[0006] Since such pumped storage power plants are used for equalizing load peaks in the network, the pump turbine must be able to supply turbine power as quickly as possible, in order to support the network or to be able to take up pump power quickly, in order to be used for primary network regulation. It is therefore desirable that the pump turbines of a pumped storage power plant can be shifted as quickly as possible into the pump operation and vice versa. This is a problem for the reversible pump turbines, which have been mentioned, since the direction of rotation of the shaft, on which the common impeller is seated, must be reversed for the change from a turbine operation to a pump operation and vice versa. This reversal of the direction of rotation requires a load change, which has a negative effect on the shaft and, with that, on the impeller, as well as on the other components, which are in driving connection therewith, such as, for example, the shaft of the motor-generator or the bearings of the shaft, which participate in supporting the shaft.

[0007] Because of the common impeller, reversible turbines can be operated only either as pumps or as turbines. However, this makes it difficult to control the output of such pump turbine installations as pumps.

[0008] Numerous attempts have been made to improve this load change in pump turbine installations, the disadvantages resulting therefrom and the power control. To some extent, these measures were successful. However, a further improvement in the duration of the operating change, as well as in avoiding load changes is desirable.

[0009] The invention is therefore based on the task of configuring a pump turbine installation of the type described above in such a manner, that the load change of the rotating components can be reduced. At the same time, it shall be possible to improve the power control of the pump turbine installation during the operation as a pump.

[0010] This objective was accomplished by the features of claim **1**.

[0011] Accordingly, the inventive pump turbine installations comprise a turbine with a turbine impeller as well as a spiral turbine housing, a pump with a pump impeller and a spiral pump housing. The two spiral housings are disposed opposite to one another. This means that the water flows in opposite directions relative to the two spiral housings.

[0012] One could also say that the cross-section of the spiral turbine housing decreases in the direction, in which the water is flowing, in the opposite direction to that of the pump spiral housing.

[0013] Furthermore, a shaft is provided, on which the turbine impeller and the pump impeller are disposed torque-proof and an electric motor is in or can be bought into a driving connection with the shaft. For example, the electric machine, which is constructed as a motor-generator, can be uncoupled from the shaft by means of a starting element such as a clutch.

[0014] In accordance with the invention, the pressure pipes of the two spiral housings discharge into a common pressure pipe.

[0015] In accordance with a further concept of the invention, a guide vane is disposed downstream from the turbine spiral housing for regulating the flow into the turbine impeller, the spiral turbine housing having a cross-member ring and a ring valve being disposed between the cross-member ring and the guide vane to block off the flow into the turbine impeller. This may, for example, be an axial valve or a cylindrical valve.

[0016] In accordance with a further concept of the invention, the spiral housing of the pump also has a cross-member ring. A ring valve also is disposed between the cross-member ring and the pump impeller and can be constructed as already explained for the turbine impeller.

[0017] Advantageously, a turbine suction pipe is disposed downstream from the turbine impeller and a pump suction pipe is disposed upstream from the pump impeller, the two suction pipes each having a separate shut-off device and the turbine suction pipe and the pump suction pipe discharging into a common suction line.

[0018] In contrast to the reversible pump turbines, the shaft of the inventive pump turbine installation always rotates in the same direction in the turbine operation as well as in the pump operation. By these means, the change in load resulting from a reversal in the direction of rotation of the shaft, is avoided, as a result of which there is distinctly less stress on the components, which are connected, and, accordingly, the construction may be much simpler.

[0019] Moreover, the inventive pump turbine installation makes a hydraulic short-circuit operation possible. This means that both hydraulic machines, that is, the pump as well as the turbine, can be operated simultaneously, as a result of which an even better control of the output of the pump turbine installation can be achieved during the operation of the pump.

[0020] The function of the ring valves described is to block off the pump or the turbine in combination with the shut-off devices in the suction lines, so that the latter can be emptied.

When only the turbine is in operation, the pump is emptied, so that the pump impeller revolves in air. On the other hand, when only the pump is in operation, the turbine is blocked off, so that the turbine impeller revolves in air. In a hydraulic short-circuit, water flows through the turbine impeller as well as through the pump impeller.

[0021] The invention is explained in greater detail by means of the drawing. In particular, the following is shown in the drawing:

[0022] FIG. **1** shows two hydraulic machines of the Francis construction, the one as turbine and the other as pump, in an axial section,

[0023] FIG. **2** shows a diagrammatic representation of a pump turbine installation of a first embodiment with a shaft extending in the vertical direction,

[0024] FIG. **3** shows a diagrammatic representation of a further embodiment of the pump turbine installation with a shaft, which is disposed in the horizontal direction and

[0025] FIG. **4** shows a diagrammatic representation of a third embodiment, for which there is an electric machine between the two spiral housings.

[0026] The pump turbine installation, shown in FIG. **1**, is constructed as follows. The turbine **1** comprises a turbine impeller **1.1**, comprising a plurality of impeller blades. The turbine impeller **1.1** is splined to a shaft **3** and the axis of rotation **7** of the latter is mounted rotatably. The turbine impeller **1.1** is surrounded by a spiral turbine housing **1.2**. In addition, a circle of guide vanes is disposed upstream from the turbine impeller **1.1**.

[0027] The turbine **1** has a suction pipe **1.5**. Said suction pipe is arranged downstream of the moving blades and comprises an inlet diffusor with an elbow attached thereto and a conduit in turn attached thereto such that the flow cross-section can be expanded in the flow direction of the water.

[0028] In the present case, a pump **2** is directly facing the turbine **1**. The latter means that the two hydraulic machines are arranged axially adjacent to each other and that no motor-generator is present between them. Here, the pump **2** is arranged below the turbine **1**.

[0029] The pump **2** has a similar design as the turbine **1**: the pump impeller **2.1** is likewise designed torsionally rigid with the shaft **3** and comprises a plurality of moving blades. The pump **2** comprises a separate pump spiral housing **2.2** hydraulically separated from the turbine spiral housing **1.2**, said pump spiral housing surrounding the pump impeller **2.1**.

[0030] The pump **2** likewise comprises a pump suction pipe **2.5** which can be designed similar to the one of the turbine **1**.

[0031] In the present case, the two spiral housings **1.2** and **2.2** are positioned directly above each other at a mutual distance. Here, the created intermediate space **5** is free of an electrical machine. In the present case, the intermediate space **5** is delimited by the spiral housings **1.2** and **2.2** facing each other. Both spiral housings **1.2** and **2.2** can be supported against each other by means of a supporting element.

[0032] The design of the supporting element can vary. In the present case, it has the shape of an envelope of a cone **10.1**. The envelope of a cone is supported against the traverse ring **1.2.2** of the turbine on the one hand and against the traverse ring **2.2.2** of the pump on the other hand. An additional support **10.2**, again ring-shaped, is present between the spiral housings **1.2** and **2.2**. As well, supports between the spiral housing of one machine and the traverse ring of the other machine would be conceivable.

[0033] An additional support **10.3** in the shape of a cylinder is present between the turbine lid and the pump lid. The support **10.3** has the advantage that it brings about an equilibrant of forces between the two machines. Moreover, a support between the traverse ring of one machine and the lid of the other machine can be considered.

[0034] As illustrated, the shaft **3** is positioned in a bearing **9**. The bearing **9** can be integrated in one of the supports **10.1** or **10.3**, respectively.

[0035] The following components can form a single component unit: the turbine spiral housing **1.2**, the pump spiral housing **2.2**, the supporting elements **10.1**, **10.2**, **10.3**, optionally also the traverse rings **1.2.2** and **2.2.2** as well as the bearing **9**. All three of the mentioned supporting elements **10.1**, **10.2**, **10.3** can be present, or only one of the supporting elements, or two of the supporting elements.

[0036] FIG. **2** shows a first embodiment of the pump turbine system according to the invention. As illustrated, a pressure line **1.3** is connected to the turbine spiral housing **1.2** as well as a pressure line **2.3** to the pump spiral housing **2.2**. Both pressure lines **1.3**, **2.3** open into a common pressure line **6** in which a common shut-off element **6.1** is present.

[0037] The common shut-off element **6.1** in the pressure line **6** preferably always remains open and is only closed for emergency closure or maintenance purposes. This has the advantage that the two spiral housings **1.1** and **2.2** are always pressurized with the same pressure; i.e., the upstream water pressure existing at the upper reservoir and are hence not exposed to frequent load changes.

[0038] Corresponding suction lines **1.4** and **2.4** are connected to the two suction pipes **1.5** and **2.5**. A separate shut-off element **1.6** and **2.6** each is arranged in the two suction lines **1.4** and **2.4**. Both suction lines **1.4** and **2.4** open into a common suction line **8**.

[0039] In the present case, an electrical machine **4** designed as motor-generator is in drive communication with the shaft **3**. Said machine is arranged above the turbine **1** and hence outside the intermediate space **5**, axially adjacent to the turbine **1**. This makes it possible to integrate a bearing **9** in the intermediate space **5**, which is delimited by the two spiral housings **1.2** and **2.2** as well as the supporting element **10**, said bearing serving for example as guide bearing or as combined thrust and guide bearing to support the shaft **3**. This further enhances the quiet running the shaft **3**.

[0040] FIG. **3** shows a further embodiment of the pump turbine system according to the invention based on FIG. **2**, whose arrangement has simply been turned to the left by 90 degrees, such that the rotational axis **3** runs in horizontal direction and the electrical machine **4** is arranged on the side next to the two hydraulic machines **1** and **2**. In so doing, essentially the same components are illustrated with the same reference numbers as those in FIG. **2**.

[0041] FIG. **4** shows a further embodiment in which the electrical machine **4** is arranged between the two spiral housings **1.2** and **2.2**, namely proaxially to these. The arrangement of the two spiral housings **1.2** and **2.2** as well as the electrical machine **4** can be strictly symmetrical.

[0042] Advantageously, both spiral housings **1.2** and **2.2** could be completely encased with concrete or arranged self-supporting, irrespective of the position of the shaft **3**. The intermediate space **5** can be designed large enough that a revision opening for maintenance of the two hydraulic machines is easily accessible.

[0043] The invention can be used for the following types of systems among others:

[0044] Single-stage turbine with single-stage pump.

[0045] Single-stage turbine with multi-stage pump.

[0046] Multi-stage turbine with single-stage pump.

[0047] Multi-stage turbine with multi-stage pump.

REFERENCE LIST

[0048] **1** Turbine

[0049] **1.1** Turbine impeller

[0050] **1.2** Turbine spiral housing

[0051] **1.2.1** Guide blade

[0052] **1.2.2** Traverse ring

[0053] **1.3** Pressure line

[0054] **1.4** Suction line

[0055] **1.5** Turbine suction pipe

[0056] **1.6** Shut-off element

[0057] **2** Pump

[0058] **2.1** Pump impeller

[0059] **2.2** Pump spiral housing

[0060] **2.2.2** Traverse ring

[0061] **2.3** Pressure line

[0062] **2.4** Suction line

[0063] **2.5** Pump suction pipe

[0064] **2.6** Shut-off element

[0065] **3** Shaft

[0066] **4** Electrical machine

[0067] **6** Pressure line

[0068] **6.1** Shut-off element

[0069] **7** Rotational axis

[0070] **8** Suction line

[0071] **9** Bearing

[0072] **10.1** Supporting element

[0073] **10.2** Supporting element

[0074] **10.3** Supporting element

1. A pump turbine system, comprising

a turbine (**1**) comprised of a turbine impeller (**1.1**), a turbine spiral housing (**1.2**) and a turbine suction pipe (**1.5**);

a pump (**2**) comprised of a pump impeller (**2.1**) a pump spiral housing (**2.2**) and a pump suction pipe (**2.5**);

two spiral housings (**1.2**, **2.2**) arranged to run in opposite directions of each other and further comprised of pressure lines (**1**,**3**, **2**,**3**), wherein said pressure lines (**1**,**3**, **2**,**3**) open into a common pressure line (**6**);

a shaft (**3**) on which the turbine impeller (**1.1**) and the pump impeller (**2.1**) are non-rotatably arranged;

an electrical machine (**4**) that is in drive communication with the shaft (**3**) or can be brought into such drive communication with the shaft (**3**);

each of said turbine suction pipe (**1.5**) and said pump suction pipe (**2.5**) are connected to a pair of suction lines (**1.4**, **2.4**), wherein both of said pair of suction lines (**1.4**, **2.4**) open into a common suction line (**8**);

a first shut-off element (**1.6**) being arranged in suction line (**1.4**);

a second shut-off element (**2.6**) being arranged in the suction lines (**2.4**);

the two spiral housings (**1.2**, **2.2**) together delimiting an intermediate space (**5**) and being directly supported by means of a supporting element;

a common shut-off element (**6.1**) being arranged in the pressure line (**6**);

a bearing (**9**) for supporting shaft (**3**) arranged in intermediate space (**5**); and

the common shut-off element (**6.1**) is embodied such that the two spiral housing (**1.1**, **2**,**2**) can be always pressurized with the same pressure.

2. (canceled)

3. (canceled)

4. (canceled)

5. (canceled)

6. (canceled)

7. (canceled)

8. (canceled)

9. (canceled)

10. The pump turbine system of claim **1**, wherein said supporting element is a cylindrical supporting ring or a supporting cone.

11. The pump turbine system of claim **1**, wherein said bearing (**9**) is a guide bearing or a combined thrust/guide bearing.

12. The pump turbine system of claim **1**, wherein the electrical machine (**4**) is positioned inside intermediate space (**5**) between the two spiral housings (**1.2**, **2.2**).

13. The pump turbine system of claim **1**, wherein the electrical machine (**4**) is positioned outside intermediate space (**5**) between the two spiral housings (**1.2**, **2.2**).

14. The pump turbine system of claim **1**, wherein:

the two spiral housings (**1.2**, **2.2**) are arranged at a definited axial distance from each other;

the two spiral housings (**1.2**, **2.2**) form a compact component unit; and

a first of the two spiral housings further comprises an outlet pipe that opens into an inlet pipe of a second of the two spiral housings.

15. The pump turbine system of claim **12**, wherein:

the two spiral housings (**1.2**, **2.2**) are arranged at a defined axial distance from each other;

the two spiral housings (**1.2**, **2.2**) form a compact component unit; and

a first of the two spiral housings further comprises an outlet pipe that opens into an inlet pipe of a second of the two spiral housings.

16. The pump turbine system of claim **13**, wherein:

the two spiral housings (**1.2**, **2.2**) are arranged at a defined axial distance from each other;

the two spiral housings (**1.2**, **2.2**) form a compact component unit; and

a first of the two spiral housings further comprises an outlet pipe that opens into an inlet pipe of a second of the two spiral housings.

17. A component unit for the pump turbine system of claim **1**, wherein said component unit comprises the two spiral housings (**1.2**, **2.2**) and at least one of supporting elements (**10.1**, **10.2**, **10.3**).

* * * * *