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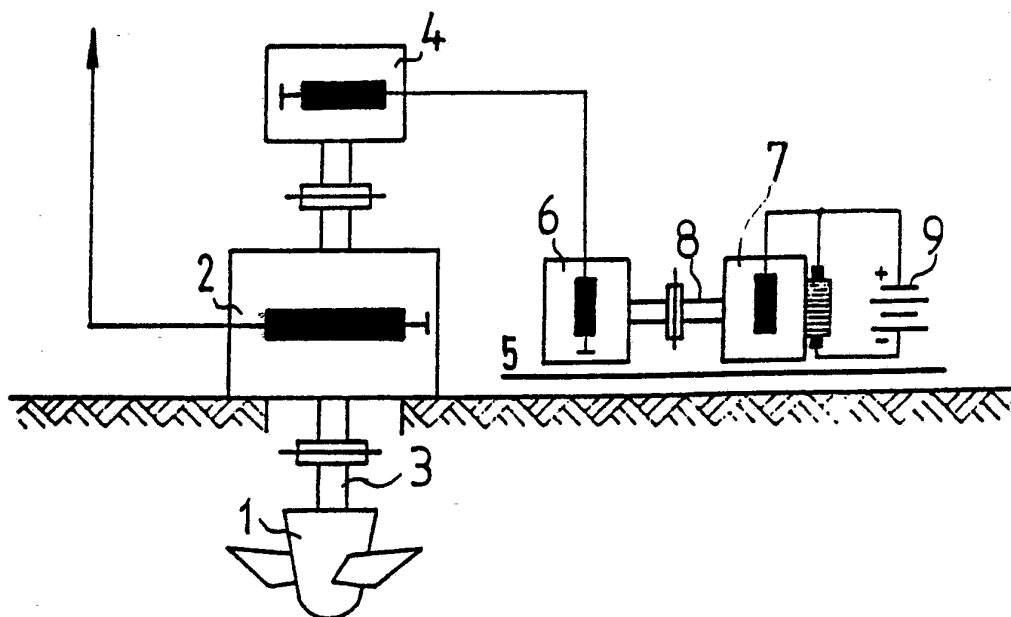
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(21) International Application Number: PCT/CS92/00001 (22) International Filing Date: 14 January 1992 (14.01.92) (71) Applicant (for all designated States except US): PASTOR, Zdeněk [CS/CS]; Palackého 425, 739 61 Třinec (CS). (72) Inventor; and (75) Inventor/Applicant (for US only): LEDR, Zdeněk [CS/CS]; Myslbekova 15, 169 00 Praha 6 (CS). (74) Agent: KANIA, František; Barvičova 23, 602 00 Brno (CS). (81) Designated States: AT, AU, BB, BG, BR, CA, CH, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MW, NL, NO, PL, RO, RU, SD, SE, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).	Published With international search report.	

(54) Title: APPARATUS FOR ELECTRICAL SPEED CONTROL OF A WATER TURBINE IN A SMALL HYDROELECTRIC POWER PLANT



(57) Abstract

The apparatus consists of an asynchronous machine (4) with dual squirrel cage of the Boucherot system, designed for the same synchronous speed as the generator (2). The stator winding of the asynchronous machine (4) is coupled to the winding of a synchronous machine (6), designed for the same rated frequency and the same rated voltage as the asynchronous machine (4). The shaft (8) of the synchronous machine (6) is coupled to the shaft (8) of the direct-current machine (7), to the armature of which is coupled the accumulator battery (9).

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Apparatus for electrical speed control of a water turbine in a small hydro - electric power plant

Background of the invention

5 The invention relates to an apparatus for electrical speed control of a water turbine in a small hydro - electric power plant, consisting of a simple water turbine with stationary blades, where the shaft of the water turbine is coupled to the shaft of the generator.

Known state of the art

10 In the small hydro - electric power plants of this type, where the speed control is achieved through a throttling of the water inlet toward the runner of the water turbine and where the water turbine drives either a synchronous generator or an independent asynchronous generator excited by a condenser
15 and provided by two oversaturated chokes, delta and star connected as is known in the art, difficulties occur in that when there is a change in the generator load, i.e. when there is a change in the water turbine load, great changes in the speed of the water turbine - generator arrangement occur,
20 ensued by big changes in frequency of a generated voltage, eventually in the value of said voltage itself.

The most unfavourable case is a switching off of the full load from the generator, when the full water flow speeds up the runner of the turbine up to 2 times till 2,5 times of the
25 rated speed. The known solution of this problem is an automatic connecting and disconnecting of an active resistance to the generator with the help of a complicated contact automatics, controlled by electronic circuits. Such a control is not very reliable and is susceptible to failures.

30 Brief summary of the invention

The disadvantages of the prior art are partly removed by an apparatus for electrical speed control of a water turbine

in a small hydro - electric power plant, consisting of a simple water turbine with stationary blades, where the shaft of the water turbine is coupled to shaft of the generator. The inventive idea of this solution consistsⁱⁿ that the shaft of the generator is coupled to the shaft of the asynchronous machine with a dual squirrel cage of the Boucherot system, designed for the same synchronous speed as the generator, where stator winding of said asynchronous machine is coupled to the winding of a synchronous machine designed for the same rated frequency and the same rated tension as said asynchronous machine, the shaft of said synchronous machine being coupled to the shaft of a direct - current machine, the armature of which is coupled to the accumulator battery.

The main advantage of the apparatus according to the invention is that it functions continuously and in a contactless manner, so that it ensures a no - failure operation.

Another advantage of this apparatus is that the synchronous machine and the direct - current machine can be designed for considerably higher rated speed than the generator and the asynchronous machine have at the same frequency, so that the set consisting of the synchronous machine and of the direct - current machine can have a considerably smaller dimensions.

Another advantage of this apparatus is that if a gearbox is inserted between the shafts of the generator and the asynchronous machine, the rated speed of the asynchronous machine can be higher than the rated speed of the generator, so that the asynchronous machine can be smaller than in case of fixed coupling of shafts of the generator and the asynchronous machine.

30 Brief description of the drawings

The apparatus will be more in detail explained according to enclosed drawings, where Fig. 1 shows an example of the invention and Fig 2 shows characteristics of the water turbine, of the asynchronous machine and of the set consisting of the

water turbine and the asynchronous machine.

Description of preferred embodiment

A small hydro -electric power plant according to Fig.1 consists of a simple water turbine 1 and of a generator 2, which are arranged with a common shaft 3, although in another embodiment thereof the shafts 3 of said water turbine 1 and said generator 2 could be coupled through a gearbox as well. Generator 2 can be either synchronous generator or an independent asynchronous generator. The shaft 3 is coupled to the shaft of an asynchronous machine 4, e.g. an asynchronous machine with a dual squirrel cage in the Boucherot system, designed for the same rated synchronous revolutions as said generator 2. On a base plate 6 a synchronous machine 6 and a direct - current machine 7 are arranged, the shafts 8 of which are coupled together. The winding of said asynchronous machine 4 is coupled in series with the winding of said synchronous machine 6. The winding of said direct - current machine 7 is coupled to an accumulator battery 9. Said synchronous machine 6 is designed for the same rated frequency and for the same rated voltage as the asynchronous machine 4. Exciter and control circuits of the generator, starter circuits for the accumulator battery 9 and other circuits known in the art and necessary for the work of different embodiments of the apparatus, but not directly connected with the inventive idea, are in this application not described.

During the full power of the water turbine 1 with the characteristics as shown in Fig. 2 by the first curve 10 and when the water turbine 1 has synchronous speed n_s and rated moment M_n , is the asynchronous machine 4 magnetized by the synchronous machine 6, which operates as a generator driven by the direct - current machine 7, said direct - current machine 7 operating as a motor, supplied from the accumulator battery 9.

With synchronous speed the asynchronous machine 4 provides a turning moment which equals zero. In case of a relief of the

generator 2, i.e. in case of relief of the water turbine 1 as well, the synchronous speed of the generator 2 as well as of the asynchronous machine 4 became super - synchronous and the asynchronous machine 4 begins^{to} work as an asynchronous generator, which begins to brake the water turbine 1 through its braking torque, the characteristics of which is shown in Fig. 2 as a second curve 20. At the same time the asynchronous machine supplies the power output into the supply, from which it is magnetized, i.e. into the synchronous machine 6, which begins to operate as a synchronous motor, driving a direct - current machine 7, which begins to operate as a direct current generator loading the accumulator battery 9.

The characteristics of the brake moment of the asynchronous machine 4 adds up with the characteristics of the water turbine 1, the resulting characteristics of the set consisting of the asynchronous machine 4 and of the water turbine 1 being shown as the third curve 30. From this curve it is clear that a big change of the torque moment, i.e. the big change of the load of the water turbine 1 or the generator 2 causes only very small change of the speed of the generator 2 and therefore the frequency of the generator 2 is only a little higher.

And analogically : When on the other hand the generator 2 is overloaded, the speed of the generator 2 and of the asynchronous machine 4 becomes lower and the asynchronous machine 4 begins to operate as an asynchronous motor driven by the synchronous machine 6, which begins to operate as a synchronous generator, driven by the direct - current machine 7, which is supplied from the accumulator battery 9.

The adding up of the characteristics of the water turbine 1 and of the asynchronous machine 4 gives again the characteristics of the whole set, which is shown for the state of overloading of the generator 2 in the bottom part of Fig. 2 by the third curve 30.

The characteristics of the said set must ensure only

small change of generator speed when a big change of the water turbine or generator load occurs. To achieve this it is necessary to ensure that the asynchronous machine 4 will have a big brake moment in its super - synchronous region and a big torque moment in its sub- synchronous region. These conditions are fulfilled by an asynchronous machine with a dual squirrel cage of the Boucherot system.

In one specific embodiment of the invention as a generator 2 an alternating - current generator with a power $P_2 = 100$ kVA, rated speed 750 revolutions/ min, $\cos \varphi = 0,8$ and efficiency $\eta = 0,85$ was used. Its power demand, i.e. the expected power output of the water turbine $P_1 = \frac{P_2}{\eta} = 94$ kW. The brake moment of the asynchronous machine during the generator speed $= 1,1 n_s$, where n_s is a synchronous speed, i.e. during the generator speed $750 \cdot 1,1 = 825$ revolutions/min, must equal to a driving moment of the water turbine at this speed. The value of this moment is $M = 975 \frac{P_1}{n_s} = 975 \frac{94}{750} = 122$ kpm. Because of the shape of the water turbine characteristics the brake power will be a little smaller and it could be assumed that the brake power $P_B \approx 90$ kW. This value is achieved at the transition point, the value of which is at least 2,2 times higher than the value of moment at the rated speed, i.e. $M_{\max} \geq 2,2 M_n$, so that the rated power of the asynchronous machine should be $90 : 2,2 = 41$ kW or less.

If there is a gearbox between the generator and the asynchronous machine with the ratio $1500 : 750 = 2$, it is possible to use a common asynchronous machine, the parameters of which are $P_n = 37$ kW, speed 1500 revolutions/min, $U = 380$ V, $f = 50$ Hz, $M_{\max} : M_n = 2,9$ and $I_n = 70$ A. The current is during the no - load operation only 40 % I_n , i.e. $I_{n1} = 28$ A. Synchronous machine magnetizes at the synchronous speed of the water turbine the asynchronous machine with the power $P_{SM1} = 3 \cdot 380 \cdot 28 \cdot 10^{-3} \approx 20$ kVA, but it must transmit a power of 90 kW into the direct - current machine.

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Of the power 90 kW from the asynchronous machine comes into the shaft of the synchronous machine with an efficiency $\eta = 0,906$ a power $P_{SM2} = 90 \text{ kW} \cdot 0,906 \approx 82 \text{ kW}$. When considering the overload capacity of the synchronous machine, a machine with a continuous rating of 50 kW will be sufficient. The direct - current machine, working as a dynamo, will have the power $P_{DCM} = 82 \text{ kW} \cdot \eta = 82 \text{ kW} \cdot 0,85 = 70 \text{ kW}$. When considering the overload capacity of the direct - current machine, a machine with the continuous rating of 50 kW will be sufficient. The proposed voltage of the accumulator battery being 120 V, the loading current into the battery will be $I_1 = 70 \text{ kW} : 120 \text{ V} = 580 \text{ A}$.

From what was here described follows that the apparatus for electrical speed control of a water turbine in a small hydro - electric power plant according to the invention is simple and ensures the braking of a water turbine through an asynchronous machine, where the energy gained by braking returns into the accumulator battery, from which it is consumed when the asynchronous machine goes over into the motor region and helps the water turbine.

The apparatus according to the invention could be used especially at the so called small energy suppliers with a power, which is lower than 1MW and at the so called micro-energy suppliers with a power, which is lower than 100 kW, where the using of water turbines with adjustable blades would not be economical, as they need complicated and expensive electrohydraulic control devices.

C L A I M S

1. An apparatus for electrical speed control of a water turbine in a small hydro - electric power plant, consisting of a simple water turbine with stationary blades, where the shaft of the water turbine is coupled to the shaft of the generator, characterized in that the shaft of the generator (2) is coupled^{to} the shaft of the asynchronous machine (4) with a dual squirrel cage of the Boucherot system, designed for the same synchronous speed as the generator (2), where stator winding of said asynchronous machine (4) is coupled to the winding of a synchronous machine (6) designed for the same rated frequency and the same rated tension as said asynchronous machine (4), the shaft of said synchronous machine (6) being coupled to the shaft of a direct - current machine (7), the armature of which is coupled to the accumulator battery.
2. An apparatus according to claim 1, characterized in that the coupling of shafts of said turbine and said generator is fixed.
3. An apparatus according to claim 1, characterized in that the coupling of shafts of said generator and said asynchronous machine is fixed.
4. An apparatus according to claim 1, characterized in that the coupling of shafts of said turbine and said generator is executed through a gearbox means.
5. An apparatus according to claim 1, characterized in that the coupling of shafts of said generator and said asynchronous machine is executed through a gearbox means.

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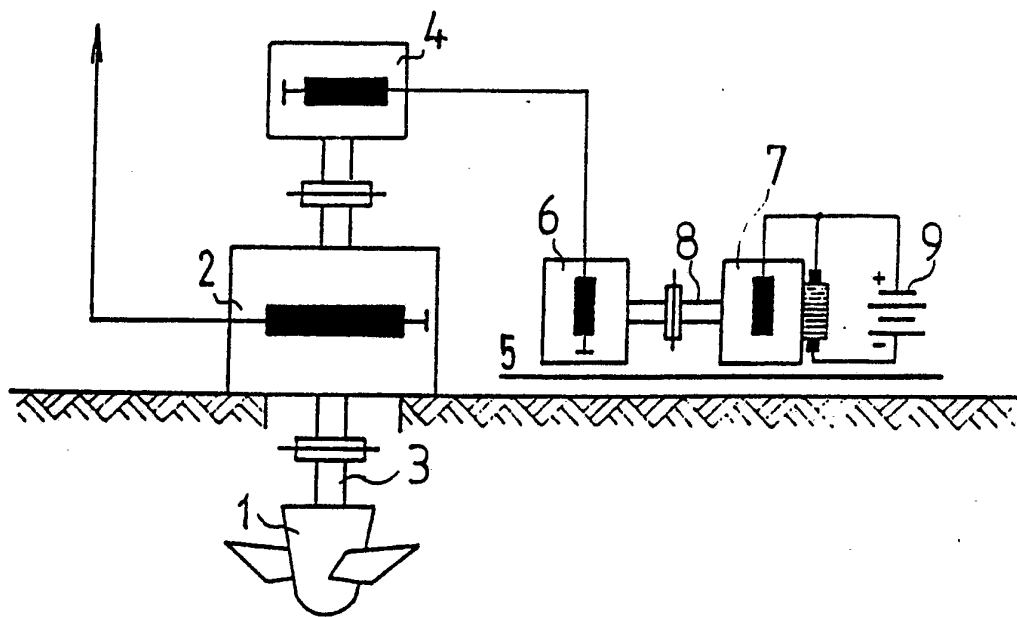


Fig. 1

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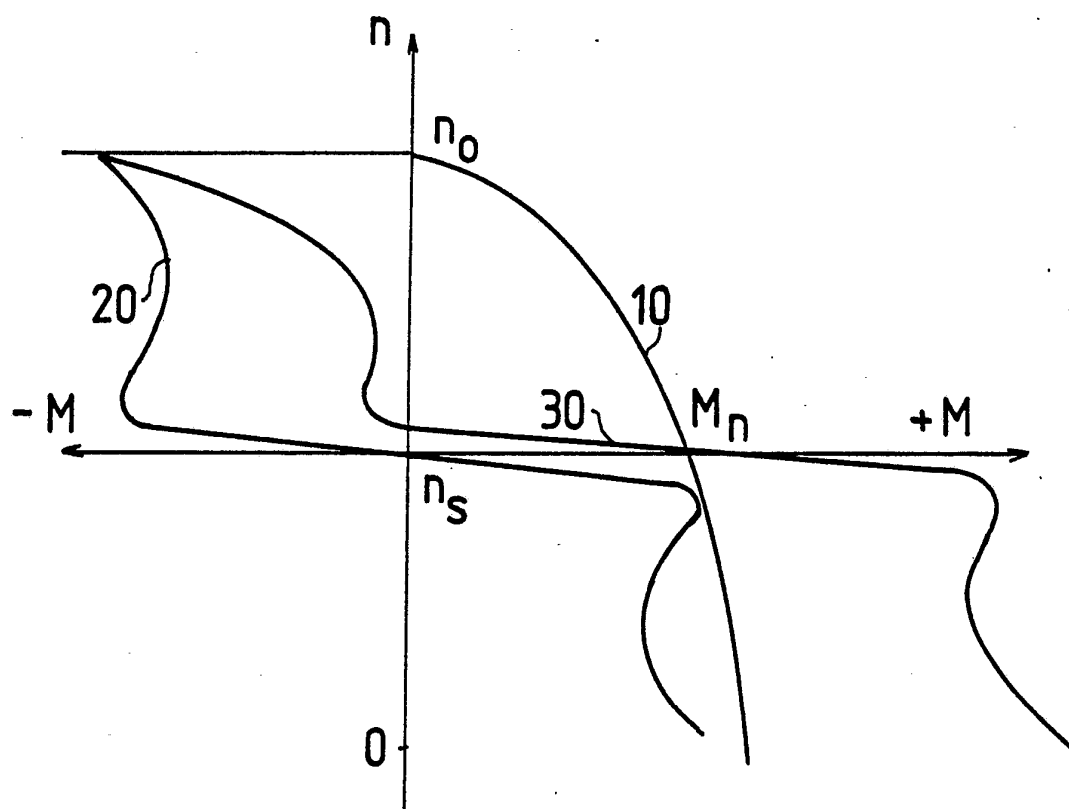
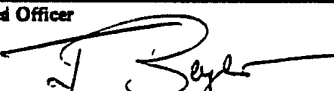


Fig. 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CS 92/00001

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.Cl. 5 H02P9/10		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	H02P ; H02K	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US,A,4 367 890 (F. SPIRK) 11 January 1983 see the whole document ---	1,2
A	DE,B,1 128 527 (SIEMENS-SCHUCKERTWERKE AG) 26 April 1962 see claim 1; figure 2 ---	1
A	DE,C,298 201 (AEG) 19 December 1915 see the whole document ---	1
A	US,A,4 219 768 (M. GOBAUD) 26 August 1980 see abstract; figure 1 ---	1
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IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
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**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. CS 9200001
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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		DE-A- 3037147	08-04-82
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DE-C-298201		None	

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		EP-A, B 0002981	11-07-79
