



(51) International Patent Classification:

G01R 31/34 (2006.01)

(21) International Application Number:

PCT/IB2016/053168

(22) International Filing Date:

29 May 2016 (29.05.2016)

(25) Filing Language:

Polish

(26) Publication Language:

English

(71) Applicants: APLISENS S.A. [PL/PL]; ul.Morelowa 7, 03-192 Warszawa (PL). MAST DR MARIAN STRACZYNSKI [PL/PL]; ul.Dzika 38, 97-0400 Belchatów (PL).

(72) Inventors: STRĄCZYŃSKI, Marian; ul.Dzika 38, 97-400 Belchatów (PL). NOWIŃSKI, Maciej; ul.Czapli 75, 44-114 Gliwice (PL). URBAŃSKI, Paweł; ul.Budryka 5/6, 97-400 Belchatów (PL).

(74) Agent: ADAMCZYK, Piotr; Kancelaria Patentowa Piotr Adamczyk, ul.Wilcza 70/8, 00-670 Warszawa (PL).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR,

HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD FOR DIAGNOSING TECHNICAL CONDITION OF SUBMERSIBLE PUMP UNIT

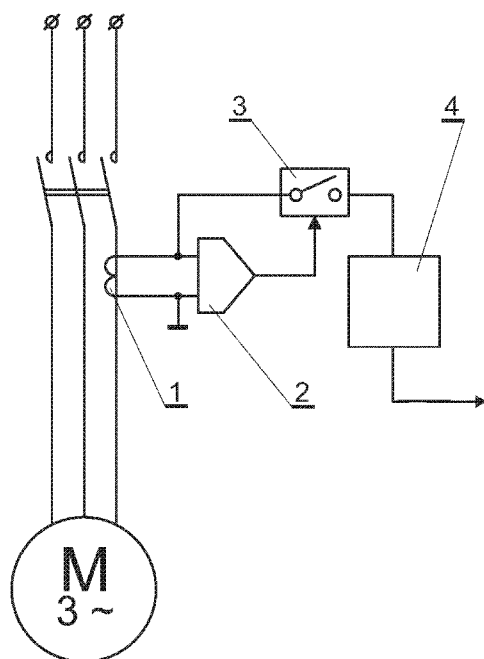


Fig.1

(57) Abstract: The invention consists in continuous monitoring of changes in the electrical current consumed by electric engine of a pump unit. In the continuous manner the effective values of the electric current drawn by the engine of the unit are determined at time intervals falling in subsequent cycles of alternating current powering this engine. On the basis of obtained effective values of the current the mean values of the current in successive acquisition periods of a length ranging from 1 to 100 minutes are determined. For each subsequent acquisition period the number of time intervals is recorded for which the determined value of the effective current exceeds the mean current consumption from the previous period by a predetermined amount of not less than 0.7 % of the mean value.



METHOD FOR DIAGNOSING TECHNICAL CONDITION OF SUBMERSIBLE PUMP UNIT

Technical Field

The object of the invention is a method for diagnosing the current technical condition of a submersible pump unit installed in deep-well and consisting of a submersible electric engine and a pump.

Background Art

Specification of the Polish patent No. 182760 discloses a diagnostic system of electric current for submersible pump unit based on a constant monitoring and analysis of changes in electric current consumed by an electric engine of the unit that appear already during the first stages of the unit damage. This publication, however, does not provide any teachings regarding tracking and analyzing of these changes.

Disclosure of Invention

The aim of the invention is to provide a simple and yet sufficiently accurate way for diagnosing the technical state of the system without a need for its periodic removal from the deep-wells.

This goal is met by the method according to the invention, consisting in constant monitoring of the changes in the electrical current consumed by the engine unit, wherein the values of the effective (RMS) electric current drawn by the engine unit are continuously determined at time intervals falling within the subsequent cycles of an alternating current powering this engine. On the basis of the determined

effective values, the mean value of current is calculated in successive data acquisition periods ranging from 1 to 100 minutes. In each subsequent period of acquisition the number of time intervals is recorded for which the evaluated effective value of the current exceeds the mean current consumption from the previous period by a predetermined value of not less than 0.7% of the mean value.

In one of embodiments of the invention, the effective value of the electric current is calculated for time intervals overlapping only with positive or only negative halves of the periodic cycle of the electric current.

In next embodiment of the invention, the length of successive acquisition periods, in which the mean value of current is defined, is in the range of 3 to 16 minutes and can be equal.

In yet another embodiment of the invention, the number of time intervals for given acquisition period is recorded for which the effective value of the current exceeds the mean current consumption from the previous acquisition period by an value of 1.5% to 5% of the mean value.

In yet another embodiment of the invention, for the registered intervals in the given acquisition period additionally the values by which the mean current is exceeded are also recorded, wherein on the basis of these values their total sum can be calculated.

The advantage of the invention lays in an accurate diagnosis of the technical state of the deep-well submersible system without the need for periodical removal of the system from deep-wells. This decidedly improves the quality of exploitation of submersible pumps and engines, enables the user an early detection of damage in pump unit working deep under water, and thus allows one for early prediction of failure, fixing of which always requires considerable financial outlays. Users thanks to diagnosis of the technical state, according to the invention method, can quickly eliminate the damaged deep-well submersible pump. The invention effectively optimizes operation of submersible pump units.

Brief Description of Drawings

The invention in an embodiment is described below in detail and presented on a drawings. Fig.1 shows a diagram of measurement system, and Fig.2 is

a graph showing the instantaneous excess of the mean power consumption in a single acquisition period.

Mode for Carrying out Invention

The invention was used for the diagnosis of deep-well submersible pump unit consisting of a submersible pump type UPA 200B-80/4D made by KSB SA and of three-phase electric engine of SM8-26 type with nominal power of 26 kW powered by a typical three-phase electric current of 50Hz frequency. The nominal capacity of the pump was 101 m³ per hour, and its nominal inlet suction was 65 m. The unit was built into a deep-well at a depth of 49,6 m in deep-well with a depth of 80 m and a diameter of 356 mm, drilled into the underground water reservoir. The discharge port of the pump was connected to a pipeline with a diameter of 150 mm, leading to the surface water reservoir. In the electric control cabinet, located in the vicinity of the surface reservoir, an contactor controlling the engine and diagnostic apparatus working according to the method of the invention were installed. The power consumed by the engine unit was measured using a known current transformer 1. The signal from the transformer was compared in comparator 2 with zero reference voltage. The comparator separated the time intervals in which the input signal of the transformer was positive or negative. Positive halves of the signal were cut off with analogue key 3, whereas the negative halves of the signal were transferred to the integration analogue-to-digital converter 4. In the analogue-to-digital converter 4 values of effective current were determined that were consumed by the units engine for each separated negative half of the current signal. On the basis of determined effective values for each negative half of the signal, the diagnostic device determined and recorded mean values of the current from each subsequent acquisition periods of adjustable length from 1 to 100 minutes. During each acquisition period the device recorded the number of negative signal halves for which the designated effective value of the mean current exceeded the value of the previous acquisition period by an adjustable value ranging from 0.7% to 5% of the mean value. Additionally, the diagnostic device is able to add up the total value of signals exceeding the mean current value. In the described above case, the mean current consumed by the engine

unit built into the deep-well was approximately 47 A. In the diagnostic device the acquisition length was set to 16 minutes and the registration threshold of exceeded mean current value was set to 0.7% of the mean, i.e. about 51 A. On the diagram in Fig.2 six registered episodes of exceeded current consumption are shown, with a total value of 17.5 A. On the basis of comparable data collected previously for similar pump units, it was assumed that the pump should be removed from the well and undergo an moderate repair, which was confirmed after removing the unit from the well and conducting technical check of the unit in a workshop. The value of the adjustable registration threshold of the exceeded mean current depends, among others, on the design of the pump and the engine power. The optimum for most used pump units of the acquisitions length ranges from 3 to 16 minutes. The described diagnostic device analyzed only the power consumption for the negative half of the measured signal, but according to the present invention one can use effective values of current determined for any constant time interval contained in the full spectrum of variation of the signal of the electric engine powering given unit, for example, the positive halves of signal or the full cycle of the signal. According to the invention the length of acquisition periods used can vary over time.

Claims

1. A method for diagnosing technical condition of submersible pump unit consisting in continuous monitoring of changes in electrical current consumed by engine of the unit, **wherein** values of the effective electric current consumed by the engine of the unit are continuously determined at time intervals falling within subsequent cycles of alternating current powering this engine, the mean values of the current are determined in periods contained in each acquisition period of a length ranging from 1 to 100 minutes, and during each subsequent acquisition period the number of time intervals is recorded for which the determined effective current value exceeds mean current consumption from the previous period by a predetermined amount not less than 0.7% of the mean value.
2. The method according to Claim 1, **wherein** the effective value of the electric current is determined at the time intervals overlapping only with positive or only with negative halves of the periodic cycle of the electric current.
3. The method according to Claim 2, **wherein** length of the subsequent acquisition periods, in which the mean value of current is determined, is within the range from 3 to 16 minutes.
4. The method according to Claim 1, 2 or 3, **wherein** length of the subsequent acquisition periods, in which the mean value of current is determined, are equal.
5. The method according to one of Claims from 1 to 4, **wherein** in given period of acquisition the number of time intervals is recorded for which the effective value of the current exceeds the mean current consumption from the previous period by a value ranging from 1.5% to 5 % of the mean value.

6. The method according to one of Claims from 2 to 5, **wherein** for the recorded time intervals in given acquisition period additionally the value by which the mean current is exceeded is registered.

7. The method according to Claim 6, **wherein** for the given acquisition period the sum of the recorded values exceeding the mean value is determined.

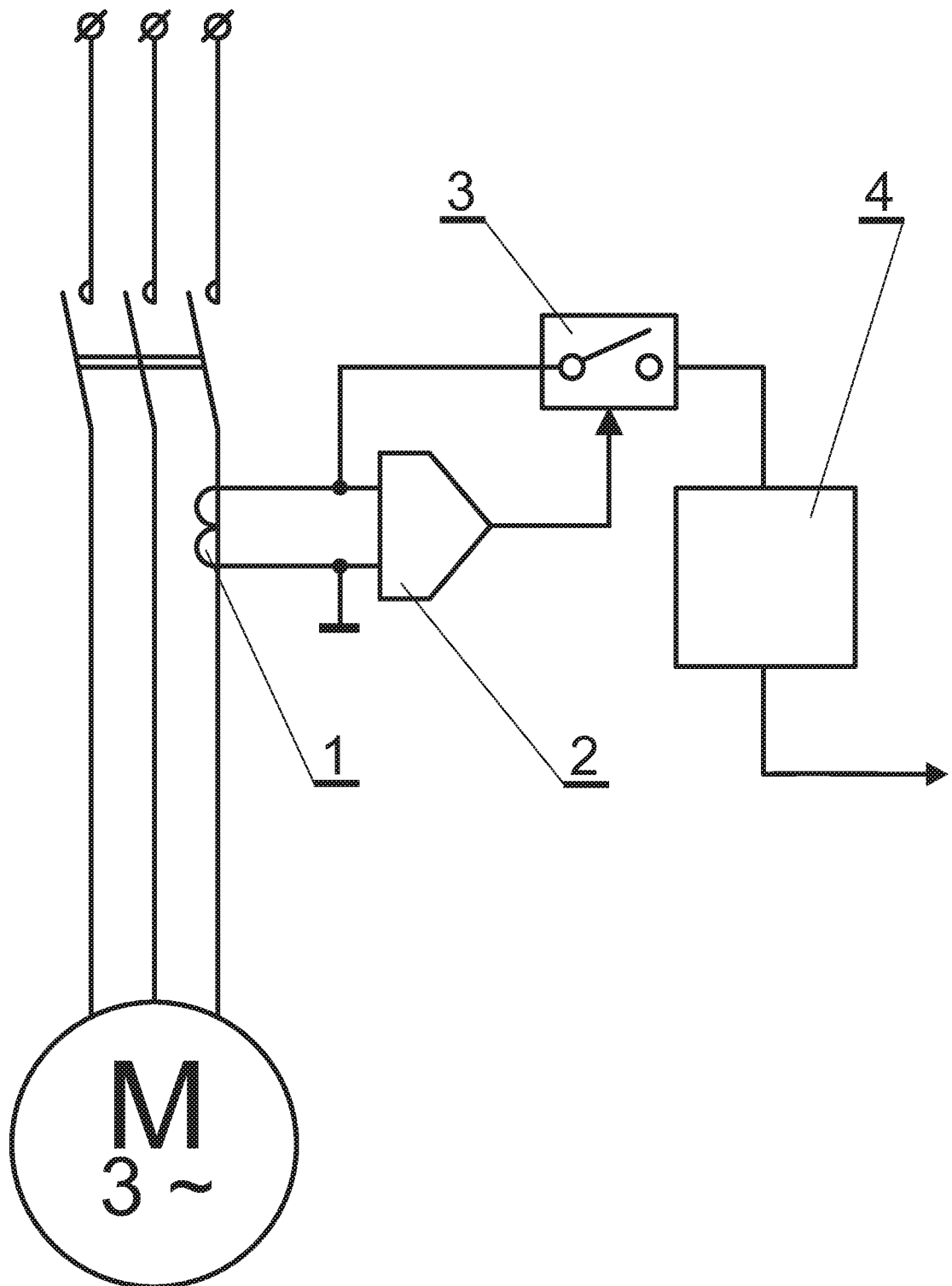


Fig.1

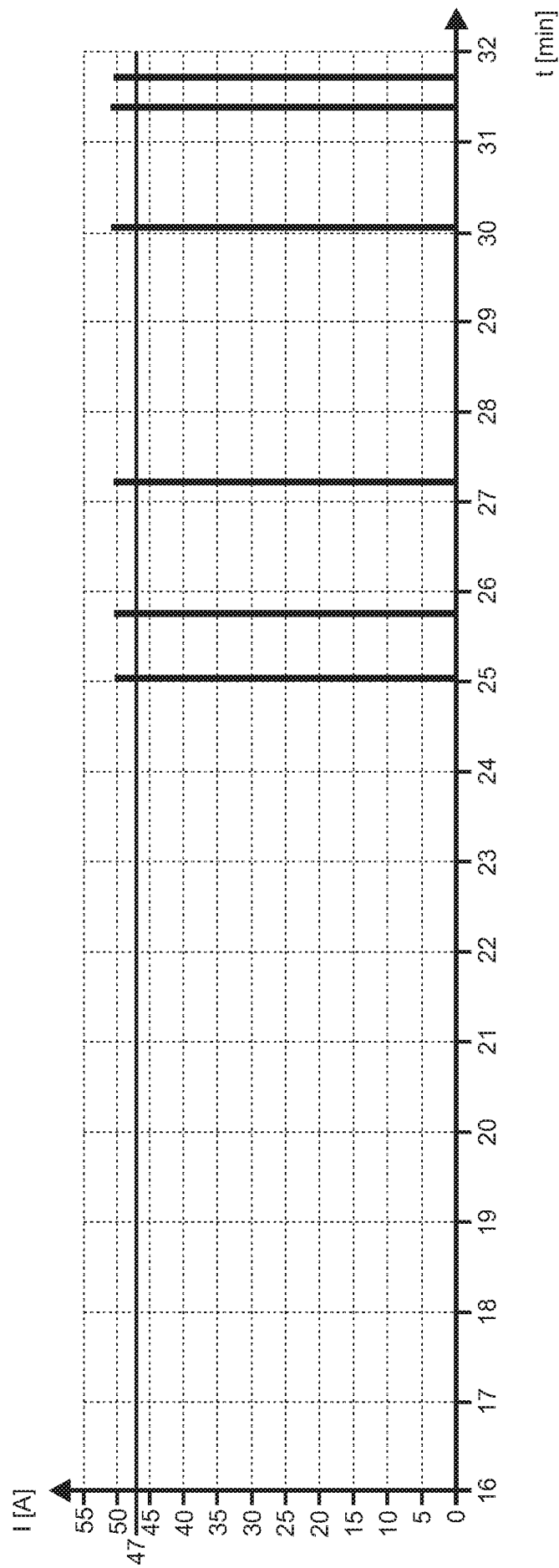


Fig.2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/053168

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R31/34
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 122 749 A (STANDARD TELEPHONES CABLES LTD) 18 January 1984 (1984-01-18) abstract page 1, line 110 - page 3, line 2; figures 1-3	1-7
X	----- US 2010/169030 A1 (PARLOS ALEXANDER GEORGE [US]) 1 July 2010 (2010-07-01) page 10, paragraph [0156] page 15, paragraph [0227] - page 16, paragraph [0247] figures 20-24 ----- -/--	1-7

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 January 2017

Date of mailing of the international search report

03/04/2017

Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bergado Colina, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/053168

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/171759 A2 (VASANI HIREN RAMANLAL [IN]) 21 November 2013 (2013-11-21) abstract page 3, line 27 - line 33 page 4, line 21 - page 6, line 36; figures 1-3 -----	1-7
X	DERRICK N ALCOCK: "Production Operation of Submersible Pumps with Closed-Loop Adjustable Speed Control", IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 43, no. 5, 1 September 1981 (1981-09-01), pages 481-489, XP011213018, ISSN: 0093-9994 abstract page 484, right-hand column -----	1-7
X	CHATTOPADHYAY SURAJIT ET AL: "Measurement of harmonic distortion and Skewness of stator current of induction motor at crawling in Clarke plane", IET SCIENCE, MEASUREMENT AND TECHNOLOGY, THE INSTITUTION OF ENGINEERING AND TECHNOLOGY, MICHAEL FARADAY HOUSE, SIX HILLS WAY, STEVENAGE, HERTS. SG1 2AY, UK, vol. 8, no. 6, 1 November 2014 (2014-11-01), pages 528-536, XP006050893, ISSN: 1751-8822, DOI: 10.1049/IET-SMT.2013.0082 the whole document -----	1-7
X	EP 1 418 339 A2 (EATON CORP [US]) 12 May 2004 (2004-05-12) abstract page 3, paragraph [0018] - page 6, paragraph [0031]; figures 1-3 -----	1-7
X	US 2008/067116 A1 (ANDERSON ROBB G [US] ET AL) 20 March 2008 (2008-03-20) abstract page 7, paragraph [0077] - page 17, paragraph [0180]; figures 1-23 -----	1-7
A	FR 2 875 962 A1 (SEB SA [FR]) 31 March 2006 (2006-03-31) abstract page 3, line 6 - page 5, line 29 page 6, line 22 - page 9, line 11; figures 1-3 ----- -/--	1-7

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2016/053168

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 487 642 A (DUFFETT-SMITH PETER JAMES [GB]) 1 August 2012 (2012-08-01) abstract page 8, line 23 - page 10, line 34; figures 1-3 -----	1-7
A	US 2015/355255 A1 (DAYAN PROSPER [IL]) 10 December 2015 (2015-12-10) abstract page 2, paragraph [0013] - paragraph [0016] page 3, paragraph [0031] - page 7, paragraph [0122]; figures 1-11 -----	1-7
A	US 2010/155057 A1 (ATHERTON ERIC J [GB]) 24 June 2010 (2010-06-24) abstract page 3, paragraph [0028] - page 4, paragraph [0037]; figures 1-6 -----	1-7
A	METWALLY ET AL: "Correlation between eddy currents and corrosion in electric submersible pump systems", INTERNATIONAL JOURNAL OF THERMAL SCIENCES, EDITIONS ELSEVIER, PARIS, FR, vol. 47, no. 6, 19 March 2008 (2008-03-19), pages 800-810, XP022542826, ISSN: 1290-0729, DOI: 10.1016/J.IJTHERMALSCI.2007.06.020 abstract page 802, left-hand column, last paragraph - right-hand column, paragraph first; figure 3; table 1 -----	1-7
A	WILLIAM D DICKSON ET AL: "Microcomputer Control of Variable Frequency Drives Using the Submersible Motor as an Instrument", IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 43, no. 4, 1 July 1982 (1982-07-01), pages 373-381, XP011213088, ISSN: 0093-9994 the whole document -----	1-7
A	WIDODO A ET AL: "Intelligent fault diagnosis system of induction motor based on transient current signal", MECHATRONICS, PERGAMON PRESS, OXFORD, GB, vol. 19, no. 5, 1 August 2009 (2009-08-01), pages 680-689, XP026136156, ISSN: 0957-4158, DOI: 10.1016/J.MECHATRONICS.2009.02.002 [retrieved on 2009-03-13] the whole document -----	1-7
	----- -/--	

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2016/053168

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WIEDENBRUG E ET AL: "Modern on-line testing of induction motors for predictive maintenance and monitoring", CONFERENCE RECORD OF THE 2001 ANNUAL PULP AND PAPER INDUSTRY TECHNICAL CONFERENCE. PORTLAND, OR, JUNE 18 - 22, 2001; [ANNUAL PULP & PAPER CONFERENCE], NEW YORK, NY : IEEE, US, 18 June 2001 (2001-06-18), pages 163-168, XP032139655, DOI: 10.1109/PAPCON.2001.952964 ISBN: 978-0-7803-6745-6 the whole document -----	1-7
A	EP 0 915 348 A2 (GEN ELECTRIC [US]) 12 May 1999 (1999-05-12) abstract page 4, paragraph [0013] - page 7, paragraph [0027]; figures 1-3 -----	1-7
A	US 3 976 919 A (VANDEVIER JOSEPH E ET AL) 24 August 1976 (1976-08-24) abstract column 2, line 47 - column 18, line 68; figures 1-5 -----	1-7
A	PL 182 760 B1 (STRACZYNSKI MARIAN [PL]; BARTNIK ZBIGNIEW [PL]; URBANSKI PAWEŁ [PL]) 28 February 2002 (2002-02-28) cited in the application the whole document -----	1-7
A	CN 203 730 347 U (XINJIANG TIANSHAN URANIUM INDUSTRY CO LTD CNNC) 23 July 2014 (2014-07-23) the whole document -----	1-7
A	FR 1 326 001 A (TAIT MFG CO THE) 3 May 1963 (1963-05-03) the whole document -----	1-7
A	CN 103 982 161 A (KELAMAYI BORUI TECHNOLOGY DEV CO LTD; KARAMAY THE ZTE PETROLEUM TECHNO) 13 August 2014 (2014-08-13) the whole document -----	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2016/053168

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
GB 2122749	A	18-01-1984	NONE	
US 2010169030	A1	01-07-2010	US 2010169030 A1 WO 2008148075 A1	01-07-2010 04-12-2008
WO 2013171759	A2	21-11-2013	NONE	
EP 1418339	A2	12-05-2004	CN 1499188 A EP 1418339 A2 US 2004090197 A1	26-05-2004 12-05-2004 13-05-2004
US 2008067116	A1	20-03-2008	CA 2685246 A1 EP 2156007 A1 US 2008067116 A1 US 2010150737 A1 US 2011106452 A1 US 2012195770 A1 US 2012283950 A1 WO 2008134278 A1	06-11-2008 24-02-2010 20-03-2008 17-06-2010 05-05-2011 02-08-2012 08-11-2012 06-11-2008
FR 2875962	A1	31-03-2006	EP 1794455 A1 FR 2875962 A1 US 2008092750 A1 WO 2006035171 A1	13-06-2007 31-03-2006 24-04-2008 06-04-2006
GB 2487642	A	01-08-2012	EP 2805399 A2 GB 2487642 A WO 2013108004 A2	26-11-2014 01-08-2012 25-07-2013
US 2015355255	A1	10-12-2015	NONE	
US 2010155057	A1	24-06-2010	US 2010155057 A1 WO 2010075227 A2	24-06-2010 01-07-2010
EP 0915348	A2	12-05-1999	DE 69833097 T2 EP 0915348 A2 JP 4012637 B2 JP H11235047 A US 5945802 A	31-08-2006 12-05-1999 21-11-2007 27-08-1999 31-08-1999
US 3976919	A	24-08-1976	CA 1054225 A DE 2625278 A1 IT 1060754 B NL 7605937 A US 3976919 A	08-05-1979 16-12-1976 30-09-1982 07-12-1976 24-08-1976
PL 182760	B1	28-02-2002	NONE	
CN 203730347	U	23-07-2014	NONE	
FR 1326001	A	03-05-1963	NONE	
CN 103982161	A	13-08-2014	NONE	