US012385362B2

(12) **United States Patent**
Hinderliter et al.

(10) **Patent No.: US 12,385,362 B2**
(45) **Date of Patent: *Aug. 12, 2025**

(54) **HIGH CAPACITY POWER STORAGE SYSTEM FOR ELECTRIC HYDRAULIC FRACTURING**

(71) Applicant: **U.S. Well Services, LLC**, Houston, TX (US)

(72) Inventors: **Brandon N. Hinderliter**, Houston, TX (US); **Jared Oehring**, Houston, TX (US); **Steven Riley**, Houston, TX (US)

(73) Assignee: **U.S. WELL SERVICES, LLC**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/092,619**

(22) Filed: **Jan. 3, 2023**

(65) **Prior Publication Data**

US 2023/0392479 A1 Dec. 7, 2023

Related U.S. Application Data

(63) Continuation of application No. 16/943,727, filed on Jul. 30, 2020, now Pat. No. 11,542,786.

(60) Provisional application No. 62/881,714, filed on Aug. 1, 2019.

(51) **Int. Cl.**

E21B 43/26	(2006.01)
E21B 41/00	(2006.01)
E21B 43/16	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 41/0085*** (2013.01); ***E21B 43/2607*** (2020.05); *E21B 43/16* (2013.01)

(58) **Field of Classification Search**

CPC E21B 43/2607; E21B 43/26

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,656,861	A	1/1928	Leonard
1,671,436	A	5/1928	Melott
2,004,077	A	6/1935	McCartney

(Continued)

FOREIGN PATENT DOCUMENTS

AU	734988	9/1997
AU	2011203353	7/2011

(Continued)

OTHER PUBLICATIONS

Fluid Power, Clean Fleet Reduces Emissions by 99% at Hydraulic Fracturing Sites, Jan. 11, 2005, 3 pages.

(Continued)

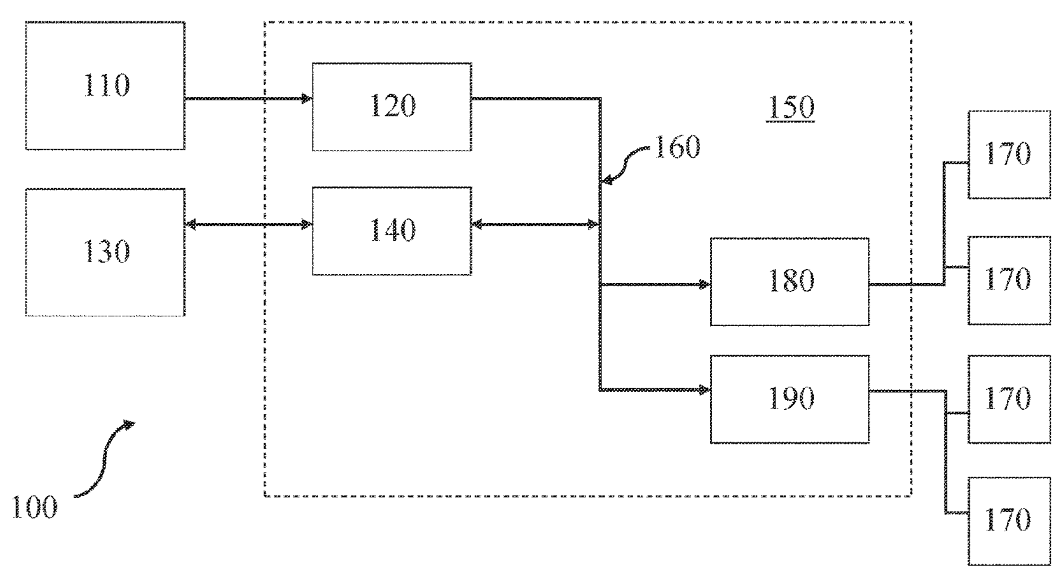
Primary Examiner — Kenneth L Thompson

(74) *Attorney, Agent, or Firm* — Abel Schillinger, LLP

(57) **ABSTRACT**

A system for powering electric hydraulic fracturing equipment, the system including a power storage system and electric powered hydraulic fracturing equipment in selective electrical communication with the power storage system. The system further includes at least one circuit breaker between the power storage system and the electric powered hydraulic fracturing equipment, the circuit breaker configured to facilitate or prevent electrical communication between the power storage system and the electric powered hydraulic fracturing equipment.

18 Claims, 8 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2,183,364	A	12/1939	Bailey
2,220,622	A	11/1940	Homer
2,248,051	A	7/1941	Armstrong
2,389,328	A	11/1945	Stilwell
2,407,796	A	9/1946	Page
2,416,848	A	3/1947	Rothery
2,610,741	A	9/1952	Schmid
2,753,940	A	7/1956	Bonner
2,976,025	A	3/1961	Pro
3,055,682	A	9/1962	Bacher
3,061,039	A	10/1962	Peters
3,066,503	A	12/1962	Fleming
3,302,069	A	1/1967	Webster
3,334,495	A	8/1967	Jensen
3,601,198	A	8/1971	Ahearn
3,722,595	A	3/1973	Kiel
3,764,233	A	10/1973	Strickland
3,773,140	A	11/1973	Mahajan
3,837,179	A	9/1974	Barth
3,849,662	A	11/1974	Blaskowski
3,878,884	A	4/1975	Raleigh
3,881,551	A	5/1975	Terry
3,978,877	A	9/1976	Cox
4,037,431	A	7/1977	Sugimoto
4,066,869	A	1/1978	Apaloo
4,100,822	A	7/1978	Rosman
4,151,575	A	4/1979	Hogue
4,226,299	A	10/1980	Hansen
4,265,266	A	5/1981	Kierbow et al.
4,411,313	A	10/1983	Johnson et al.
4,421,975	A	12/1983	Stein
4,432,064	A	2/1984	Barker
4,442,665	A	4/1984	Fick et al.
4,456,092	A	6/1984	Kubozuka
4,506,982	A	3/1985	Smithers et al.
4,512,387	A	4/1985	Rodriguez
4,529,887	A	7/1985	Johnson
4,538,916	A	9/1985	Zimmerman
4,601,629	A	7/1986	Zimmerman
4,676,063	A	6/1987	Goebel et al.
4,759,674	A	7/1988	Schroder
4,768,884	A	9/1988	Elkin
4,793,386	A	12/1988	Sloan
4,845,981	A	7/1989	Pearson
4,877,956	A	10/1989	Priest
4,922,463	A	5/1990	Del Zotto et al.
5,004,400	A	4/1991	Handke
5,006,044	A	4/1991	Walker, Sr.
5,025,861	A	6/1991	Huber et al.
5,050,673	A	9/1991	Baldridge
5,114,239	A	5/1992	Allen
5,130,628	A	7/1992	Owen
5,131,472	A	7/1992	Dees et al.
5,134,328	A	7/1992	Johnatakis
5,172,009	A	12/1992	Mohan
5,189,388	A	2/1993	Mosley
5,230,366	A	7/1993	Marandi
5,334,898	A	8/1994	Skybyk
5,334,899	A	8/1994	Skybyk
5,366,324	A	11/1994	Arlt
5,422,550	A	6/1995	McClanahan
5,433,243	A	7/1995	Griswold
5,439,066	A	8/1995	Gipson
5,517,593	A	5/1996	Nenniger
5,517,822	A	5/1996	Haws et al.
5,548,093	A	8/1996	Sato
5,590,976	A	1/1997	Kilheffer et al.
5,655,361	A	8/1997	Kishi
5,712,802	A	1/1998	Kumar
5,736,838	A	4/1998	Dove et al.
5,755,096	A	5/1998	Holleyman
5,790,972	A	8/1998	Kohlenberger
5,798,596	A	8/1998	Lordo
5,813,455	A	9/1998	Pratt et al.
5,865,247	A	2/1999	Paterson
5,879,137	A	3/1999	Yie
5,894,888	A	4/1999	Wiemers
5,907,970	A	6/1999	Havlovick et al.
5,950,726	A	9/1999	Roberts
6,007,227	A	12/1999	Carlson
6,035,265	A	3/2000	Dister et al.
6,059,539	A	5/2000	Nyilas
6,097,310	A	8/2000	Harrell et al.
6,116,040	A	9/2000	Stark
6,121,705	A	9/2000	Hoong
6,138,764	A	10/2000	Scarsdale et al.
6,142,878	A	11/2000	Barin
6,164,910	A	12/2000	Mayleben
6,167,965	B1	1/2001	Bearden
6,202,702	B1	3/2001	Ohira
6,208,098	B1	3/2001	Kume
6,254,462	B1	7/2001	Kelton
6,271,637	B1	8/2001	Kushion
6,273,193	B1	8/2001	Hermann et al.
6,315,523	B1	11/2001	Mills
6,321,860	B1	11/2001	Reddoch
6,442,942	B1	9/2002	Kopko
6,477,852	B2	11/2002	Dodo
6,484,490	B1	11/2002	Olsen
6,486,047	B2	11/2002	Lee et al.
6,491,098	B1	12/2002	Dallas
6,529,135	B1	3/2003	Bowers et al.
6,560,131	B1	5/2003	VonBrethorst
6,585,455	B1	7/2003	Petersen et al.
6,626,646	B2	9/2003	Rajewski
6,719,900	B2	4/2004	Hawkins
6,765,304	B2	7/2004	Baten et al.
6,776,227	B2	8/2004	Beida
6,786,051	B2	9/2004	Kristich
6,788,022	B2	9/2004	Sopko
6,802,690	B2	10/2004	Hansen
6,808,303	B2	10/2004	Fisher
6,857,486	B2	2/2005	Chitwood
6,931,310	B2	8/2005	Shimizu et al.
6,936,947	B1	8/2005	Leijon
6,985,750	B1	1/2006	Vicknair et al.
7,006,792	B2	2/2006	Wilson
7,011,152	B2	3/2006	Soelvik
7,082,993	B2	8/2006	Ayoub
7,104,233	B2	9/2006	Ryczek et al.
7,170,262	B2	1/2007	Pettigrew
7,173,399	B2	2/2007	Sihler
7,308,933	B1	12/2007	Mayfield
7,312,593	B1	12/2007	Streicher et al.
7,336,514	B2	2/2008	Amarillas
7,445,041	B2	11/2008	O'Brien
7,494,263	B2	2/2009	Dykstra et al.
7,500,642	B2	3/2009	Cunningham
7,525,264	B2	4/2009	Dodge
7,563,076	B2	7/2009	Brunet
7,581,379	B2	9/2009	Yoshida
7,660,648	B2	2/2010	Dykstra
7,675,189	B2	3/2010	Grenier
7,683,499	B2	3/2010	Saucier
7,717,193	B2	5/2010	Egilsson et al.
7,755,310	B2	7/2010	West et al.
7,795,830	B2	9/2010	Johnson
7,807,048	B2	10/2010	Collette
7,835,140	B2	11/2010	Mori
7,845,413	B2	12/2010	Shampine et al.
7,901,314	B2	3/2011	Salvaire
7,926,562	B2	4/2011	Poitzsch
7,949,483	B2	5/2011	Discenzo
7,971,650	B2	7/2011	Yuratich
7,977,824	B2	7/2011	Halen et al.
7,984,757	B1	7/2011	Keast
8,037,936	B2	10/2011	Neuroth
8,054,084	B2	11/2011	Schulz et al.
8,069,710	B2	12/2011	Dodd
8,083,504	B2	12/2011	Williams
8,091,928	B2	1/2012	Carrier
8,096,354	B2	1/2012	Poitzsch
8,096,891	B2	1/2012	Lochtefeld
8,139,383	B2	3/2012	Efraimsson

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,146,665 B2 4/2012 Neal
8,154,419 B2 4/2012 Daussin et al.
8,174,853 B2 5/2012 Kane
8,232,892 B2 7/2012 Overholt et al.
8,261,528 B2 9/2012 Chillar
8,272,439 B2 9/2012 Strickland
8,310,272 B2 11/2012 Quarto
8,322,239 B2 12/2012 Isono et al.
8,354,817 B2 1/2013 Yeh et al.
8,379,424 B2 2/2013 Grbovic
8,469,097 B2 6/2013 Gray
8,474,521 B2 7/2013 Kajaria
8,503,180 B2 8/2013 Nojima
8,506,267 B2 8/2013 Gambier et al.
8,534,235 B2 9/2013 Chandler
8,534,366 B2 9/2013 Fielder et al.
8,573,303 B2 11/2013 Kerfoot
8,596,056 B2 12/2013 Woodmansee
8,616,005 B1 12/2013 Cousino
8,616,274 B2 12/2013 Belcher et al.
8,622,128 B2 1/2014 Hegeman
8,628,627 B2 1/2014 Sales
8,646,521 B2 2/2014 Bowen
8,650,871 B2 2/2014 Gentile
8,692,408 B2 4/2014 Zhang et al.
8,727,068 B2 5/2014 Bruin
8,727,737 B2 5/2014 Seitter
8,727,783 B2 5/2014 Chen
8,760,657 B2 6/2014 Pope
8,763,387 B2 7/2014 Schmidt
8,774,972 B2 7/2014 Rusnak et al.
8,789,601 B2 7/2014 Broussard
8,789,609 B2 7/2014 Smith
8,795,525 B2 8/2014 McGinnis et al.
8,800,652 B2 8/2014 Bartko
8,807,960 B2 8/2014 Stephenson
8,838,341 B2 9/2014 Kumano
8,851,860 B1 10/2014 Mail
8,857,506 B2 10/2014 Stone, Jr.
8,874,383 B2 10/2014 Gambier
8,899,940 B2 12/2014 Leugemors
8,905,056 B2 12/2014 Kendrick
8,905,138 B2 12/2014 Lundstedt et al.
8,997,904 B2 * 4/2015 Cryer B60K 1/00 180/53.5
9,018,881 B2 4/2015 Mao et al.
9,051,822 B2 6/2015 Ayan
9,051,923 B2 6/2015 Kuo
9,061,223 B2 6/2015 Winborn
9,062,545 B2 6/2015 Roberts et al.
9,067,182 B2 6/2015 Nichols
9,080,412 B2 7/2015 Wetzel
9,103,193 B2 8/2015 Coli
9,119,326 B2 8/2015 McDonnell
9,121,257 B2 9/2015 Coli et al.
9,140,105 B2 9/2015 Pattillo
9,140,110 B2 9/2015 Coli et al.
9,160,168 B2 10/2015 Chapel
9,260,253 B2 2/2016 Naizer
9,324,049 B2 4/2016 Thomeer
9,340,353 B2 5/2016 Oren
9,353,593 B1 5/2016 Lu et al.
9,366,114 B2 6/2016 Coli et al.
9,410,410 B2 8/2016 Broussard et al.
9,450,385 B2 9/2016 Kristensen
9,475,020 B2 10/2016 Coli et al.
9,475,021 B2 10/2016 Coli et al.
9,482,086 B2 11/2016 Richardson et al.
9,499,335 B2 11/2016 McIver
9,506,333 B2 11/2016 Castillo et al.
9,513,055 B1 12/2016 Seal
9,534,473 B2 1/2017 Morris et al.
9,556,721 B2 * 1/2017 Jang E21B 47/06
9,562,420 B2 2/2017 Morris et al.
9,587,649 B2 3/2017 Oehring
9,611,728 B2 4/2017 Oehring
9,650,879 B2 5/2017 Broussard et al.
9,706,185 B2 7/2017 Ellis
9,728,354 B2 8/2017 Skolozdra
9,738,461 B2 8/2017 DeGaray
9,739,546 B2 8/2017 Bertilsson et al.
9,745,840 B2 8/2017 Oehring et al.
9,790,858 B2 10/2017 Kanebako
9,822,631 B2 11/2017 Ravi
9,840,897 B2 12/2017 Larson
9,840,901 B2 12/2017 Oehring et al.
9,841,026 B2 12/2017 Stinessen
9,863,228 B2 1/2018 Shampine et al.
RE46,725 E 2/2018 Case
9,893,500 B2 2/2018 Oehring
9,909,398 B2 3/2018 Pham
9,915,128 B2 3/2018 Hunter
9,932,799 B2 4/2018 Symchuk
9,945,365 B2 4/2018 Hernandez et al.
9,963,961 B2 * 5/2018 Hardin G05D 9/12
9,970,278 B2 5/2018 Broussard
9,976,351 B2 5/2018 Randall
9,995,218 B2 6/2018 Oehring
10,008,880 B2 6/2018 Vicknair
10,020,711 B2 7/2018 Oehring
10,036,238 B2 7/2018 Oehring
10,107,086 B2 10/2018 Oehring
10,119,381 B2 11/2018 Oehring
10,167,863 B1 1/2019 Cook
10,184,465 B2 * 1/2019 Enis F02C 6/16
10,196,878 B2 2/2019 Hunter
10,221,639 B2 3/2019 Romer et al.
10,227,854 B2 3/2019 Glass
10,232,332 B2 3/2019 Oehring
10,246,984 B2 4/2019 Payne
10,254,732 B2 4/2019 Oehring
10,260,327 B2 4/2019 Kajaria
10,280,724 B2 5/2019 Hinderliter
10,287,873 B2 5/2019 Filas
10,302,079 B2 5/2019 Kendrick
10,309,205 B2 6/2019 Randall
10,337,308 B2 7/2019 Broussard
10,371,012 B2 8/2019 Davis
10,378,326 B2 8/2019 Morris
10,393,108 B2 8/2019 Chong
10,407,990 B2 9/2019 Oehring
10,408,030 B2 9/2019 Oehring et al.
10,408,031 B2 9/2019 Oehring et al.
10,415,332 B2 9/2019 Morris et al.
10,436,026 B2 10/2019 Ounadjela
10,443,660 B2 10/2019 Harris
10,627,003 B2 4/2020 Dale et al.
10,648,270 B2 5/2020 Brunty et al.
10,648,311 B2 5/2020 Oehring et al.
10,669,471 B2 6/2020 Schmidt et al.
10,669,804 B2 6/2020 Kotrla
10,686,301 B2 6/2020 Oehring et al.
10,695,950 B2 6/2020 Igo et al.
10,711,576 B2 7/2020 Bishop
10,731,561 B2 8/2020 Oehring et al.
10,740,730 B2 8/2020 Altamirano et al.
10,753,153 B1 * 8/2020 Fischer H02J 7/0016
10,767,561 B2 9/2020 Brady
10,781,752 B2 9/2020 Kikkawa et al.
10,794,165 B2 10/2020 Fischer et al.
10,883,352 B2 * 1/2021 Headrick E21B 41/0085
10,988,998 B2 4/2021 Fischer et al.
10,989,180 B2 * 4/2021 Yeung F04B 17/05
11,022,526 B1 * 6/2021 Yeung F04B 17/05
11,359,462 B2 * 6/2022 Morris H02B 1/52
11,542,786 B2 * 1/2023 Hinderliter E21B 41/0085
2001/0000996 A1 5/2001 Grimland et al.
2002/0169523 A1 11/2002 Ross et al.
2003/0000759 A1 1/2003 Schmitz
2003/0056514 A1 3/2003 Lohn
2003/0079875 A1 5/2003 Weng
2003/0138327 A1 7/2003 Jones et al.
2004/0040746 A1 3/2004 Niedermayr et al.
2004/0045703 A1 3/2004 Hooper et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0102109	A1	5/2004	Cratty et al.
2004/0167738	A1	8/2004	Miller
2005/0061548	A1	3/2005	Hooper
2005/0116541	A1	6/2005	Seiver
2005/0201197	A1	9/2005	Duell et al.
2005/0274508	A1	12/2005	Folk
2006/0052903	A1	3/2006	Bassett
2006/0109141	A1	5/2006	Huang
2007/0125544	A1	6/2007	Robinson
2007/0131410	A1	6/2007	Hill
2007/0151731	A1	7/2007	Butler
2007/0187163	A1	8/2007	Cone
2007/0201305	A1	8/2007	Heilman et al.
2007/0204991	A1	9/2007	Loree
2007/0226089	A1	9/2007	DeGaray et al.
2007/0277982	A1	12/2007	Shampine
2007/0278140	A1	12/2007	Mallett et al.
2008/0017369	A1	1/2008	Sarada
2008/0041596	A1	2/2008	Blount
2008/0066911	A1	3/2008	Luharuka
2008/0095644	A1	4/2008	Mantei et al.
2008/0112802	A1	5/2008	Orlando
2008/0137266	A1	6/2008	Jensen
2008/0164023	A1	7/2008	Dykstra et al.
2008/0187444	A1	8/2008	Molotkov
2008/0208478	A1	8/2008	Ella
2008/0217024	A1	9/2008	Moore
2008/0257449	A1	10/2008	Weinstein et al.
2008/0264625	A1	10/2008	Ochoa
2008/0264649	A1	10/2008	Crawford
2008/0277120	A1	11/2008	Hickie
2008/0303469	A1	12/2008	Nojima
2009/0045782	A1	2/2009	Datta
2009/0065299	A1	3/2009	Vito
2009/0072645	A1	3/2009	Quere
2009/0078410	A1	3/2009	Krenek et al.
2009/0093317	A1	4/2009	Kajiwara et al.
2009/0095482	A1	4/2009	Surjaatmadja
2009/0101410	A1	4/2009	Egilsson
2009/0145611	A1	6/2009	Pallini, Jr.
2009/0153354	A1	6/2009	Daussin et al.
2009/0188181	A1	7/2009	Forbis
2009/0194273	A1	8/2009	Surjaatmadja
2009/0200035	A1	8/2009	Bjerkreim et al.
2009/0260826	A1	10/2009	Sherwood
2009/0308602	A1	12/2009	Bruins et al.
2010/0000508	A1	1/2010	Chandler
2010/0019574	A1	1/2010	Baldassarre et al.
2010/0038077	A1	2/2010	Heilman
2010/0038907	A1	2/2010	Hunt
2010/0045109	A1	2/2010	Arnold
2010/0051272	A1	3/2010	Loree et al.
2010/0132949	A1	6/2010	DeFosse et al.
2010/0146981	A1	6/2010	Motakef
2010/0172202	A1	7/2010	Borgstadt
2010/0250139	A1	9/2010	Hobbs et al.
2010/0293973	A1	11/2010	Erickson
2010/0300683	A1	12/2010	Looper
2010/0303655	A1	12/2010	Scekic
2010/0310384	A1	12/2010	Stephenson
2010/0322802	A1	12/2010	Kugelev
2011/0005757	A1	1/2011	Hebert
2011/0017468	A1	1/2011	Birch et al.
2011/0052423	A1	3/2011	Gambier
2011/0061855	A1	3/2011	Case et al.
2011/0079302	A1	4/2011	Hawes
2011/0081268	A1	4/2011	Ochoa et al.
2011/0085924	A1	4/2011	Shampine
2011/0110793	A1	5/2011	Leugemors et al.
2011/0166046	A1	7/2011	Weaver
2011/0194256	A1	8/2011	De Rijck
2011/0247831	A1	10/2011	Smith
2011/0247878	A1	10/2011	Rasheed
2011/0272158	A1	11/2011	Neal
2012/0018016	A1	1/2012	Gibson
2012/0049625	A1	3/2012	Hopwood
2012/0063936	A1	3/2012	Baxter et al.
2012/0067582	A1	3/2012	Fincher
2012/0085541	A1	4/2012	Love et al.
2012/0112757	A1	5/2012	Vrankovic et al.
2012/0127635	A1	5/2012	Grindeland
2012/0150455	A1	6/2012	Franklin et al.
2012/0152549	A1	6/2012	Koroteev
2012/0152716	A1	6/2012	Kikukawa et al.
2012/0205112	A1	8/2012	Pettigrew
2012/0205119	A1	8/2012	Wentworth
2012/0205400	A1	8/2012	DeGaray
2012/0222865	A1	9/2012	Larson
2012/0232728	A1	9/2012	Karimi et al.
2012/0247783	A1	10/2012	Berner, Jr.
2012/0255734	A1	10/2012	Coli et al.
2013/0009469	A1	1/2013	Gillett
2013/0025706	A1	1/2013	DeGaray et al.
2013/0051971	A1	2/2013	Wyse et al.
2013/0064528	A1	3/2013	Bigex
2013/0175038	A1	7/2013	Conrad
2013/0175039	A1	7/2013	Guidry
2013/0180722	A1	7/2013	Olarte Caro
2013/0189629	A1	7/2013	Chandler
2013/0199617	A1	8/2013	DeGaray
2013/0233542	A1	9/2013	Shampine
2013/0242688	A1	9/2013	Kageler
2013/0255271	A1	10/2013	Yu et al.
2013/0278183	A1	10/2013	Liang
2013/0284278	A1	10/2013	Winborn
2013/0284455	A1	10/2013	Kajaria et al.
2013/0299167	A1	11/2013	Fordyce
2013/0306322	A1	11/2013	Sanborn et al.
2013/0317750	A1	11/2013	Hunter
2013/0341029	A1	12/2013	Roberts et al.
2013/0343858	A1	12/2013	Flusche
2014/0000899	A1	1/2014	Nevison
2014/0010671	A1	1/2014	Cryer et al.
2014/0041730	A1	2/2014	Naizer
2014/0054965	A1	2/2014	Jain
2014/0060658	A1	3/2014	Hains
2014/0095114	A1	4/2014	Thomeer
2014/0096974	A1	4/2014	Coli
2014/0124162	A1	5/2014	Leavitt
2014/0127036	A1	5/2014	Buckley
2014/0138079	A1	5/2014	Broussard et al.
2014/0147310	A1	5/2014	Hunt
2014/0174691	A1	6/2014	Kamps
2014/0174717	A1	6/2014	Broussard et al.
2014/0205475	A1	7/2014	Dale
2014/0219824	A1	8/2014	Burnette
2014/0238683	A1	8/2014	Korach
2014/0246211	A1	9/2014	Guidry et al.
2014/0251623	A1	9/2014	Lestz et al.
2014/0255214	A1	9/2014	Burnette
2014/0277772	A1	9/2014	Lopez
2014/0290768	A1	10/2014	Randle
2014/0332199	A1	11/2014	Gilstad
2014/0379300	A1	12/2014	Devine
2015/0027712	A1	1/2015	Vicknair
2015/0053426	A1	2/2015	Smith
2015/0068724	A1	3/2015	Coli et al.
2015/0068754	A1	3/2015	Coli et al.
2015/0075778	A1	3/2015	Walters
2015/0078924	A1	3/2015	Zhang
2015/0083426	A1	3/2015	Lesko
2015/0097504	A1	4/2015	Lamascus
2015/0114652	A1	4/2015	Lestz
2015/0136043	A1	5/2015	Shaaban
2015/0144336	A1	5/2015	Hardin et al.
2015/0147194	A1	5/2015	Foote
2015/0159911	A1	6/2015	Holt
2015/0175013	A1	6/2015	Cryer et al.
2015/0176386	A1	6/2015	Castillo et al.
2015/0211512	A1	7/2015	Wiegman
2015/0211524	A1	7/2015	Broussard
2015/0217672	A1	8/2015	Shampine
2015/0225113	A1	8/2015	Lungu
2015/0233530	A1	8/2015	Sandidge

(56) **References Cited**

U.S. PATENT DOCUMENTS

2015/0252661	A1	9/2015	Glass
2015/0300145	A1	10/2015	Coli et al.
2015/0300336	A1	10/2015	Hernandez
2015/0314225	A1	11/2015	Coli et al.
2015/0330172	A1	11/2015	Allmaras
2015/0354322	A1	12/2015	Vicknair
2016/0006311	A1	1/2016	Li
2016/0032703	A1	2/2016	Broussard et al.
2016/0102537	A1	4/2016	Lopez
2016/0105022	A1	4/2016	Oehring
2016/0160889	A1	6/2016	Hoffman et al.
2016/0177675	A1	6/2016	Morris et al.
2016/0177678	A1	6/2016	Morris
2016/0186531	A1	6/2016	Harkless et al.
2016/0208592	A1	7/2016	Oehring
2016/0208593	A1	7/2016	Coli et al.
2016/0208594	A1	7/2016	Coli et al.
2016/0208595	A1	7/2016	Tang
2016/0221220	A1	8/2016	Paige
2016/0230524	A1	8/2016	Dumoit
2016/0230525	A1	8/2016	Lestz et al.
2016/0230660	A1	8/2016	Zeitoun et al.
2016/0258267	A1	9/2016	Payne et al.
2016/0265457	A1	9/2016	Stephenson
2016/0273328	A1	9/2016	Oehring
2016/0273456	A1	9/2016	Zhang et al.
2016/0281484	A1	9/2016	Lestz
2016/0290114	A1	10/2016	Oehring
2016/0290563	A1	10/2016	Diggins
2016/0312108	A1	10/2016	Lestz et al.
2016/0319650	A1	11/2016	Oehring
2016/0326853	A1	11/2016	Fred et al.
2016/0326854	A1	11/2016	Broussard
2016/0326855	A1	11/2016	Coli et al.
2016/0341281	A1	11/2016	Brunvold et al.
2016/0348479	A1	12/2016	Oehring
2016/0349728	A1	12/2016	Oehring
2016/0369609	A1	12/2016	Morris et al.
2017/0016433	A1	1/2017	Chong
2017/0021318	A1	1/2017	McIver et al.
2017/0022788	A1	1/2017	Oehring et al.
2017/0022807	A1	1/2017	Dursun
2017/0028368	A1	2/2017	Oehring et al.
2017/0030177	A1	2/2017	Oehring et al.
2017/0030178	A1	2/2017	Oehring et al.
2017/0036178	A1	2/2017	Coli et al.
2017/0036872	A1	2/2017	Wallace
2017/0037717	A1	2/2017	Oehring
2017/0037718	A1	2/2017	Coli et al.
2017/0043280	A1	2/2017	Vankouwenberg
2017/0051732	A1	2/2017	Hemandez et al.
2017/0074076	A1	3/2017	Joseph et al.
2017/0082033	A1	3/2017	Wu et al.
2017/0096885	A1	4/2017	Oehring
2017/0096889	A1	4/2017	Blanckaert et al.
2017/0104389	A1	4/2017	Morris et al.
2017/0114625	A1	4/2017	Norris
2017/0130743	A1	5/2017	Anderson
2017/0138171	A1	5/2017	Richards et al.
2017/0145918	A1	5/2017	Oehring
2017/0146189	A1	5/2017	Herman
2017/0159570	A1	6/2017	Bickert
2017/0159654	A1	6/2017	Kendrick
2017/0175516	A1	6/2017	Eslinger
2017/0204852	A1	7/2017	Barnett
2017/0212535	A1	7/2017	Shelman et al.
2017/0218727	A1	8/2017	Oehring
2017/0218843	A1	8/2017	Oehring
2017/0222409	A1	8/2017	Oehring
2017/0226838	A1	8/2017	Ciezobka et al.
2017/0226839	A1	8/2017	Broussard
2017/0226842	A1	8/2017	Omont et al.
2017/0234250	A1	8/2017	Janik
2017/0241221	A1	8/2017	Seshadri
2017/0259227	A1	9/2017	Morris et al.
2017/0292513	A1	10/2017	Haddad
2017/0302218	A1	10/2017	Janik
2017/0313499	A1	11/2017	Hughes et al.
2017/0314380	A1	11/2017	Oehring
2017/0314979	A1	11/2017	Ye
2017/0328179	A1	11/2017	Dykstra
2017/0369258	A1	12/2017	DeGaray
2017/0370639	A1	12/2017	Bardon et al.
2018/0028992	A1	2/2018	Stegemoeller
2018/0038216	A1	2/2018	Zhang
2018/0045331	A1	2/2018	Lopez
2018/0090914	A1	3/2018	Johnson et al.
2018/0156210	A1	6/2018	Oehring
2018/0181830	A1	6/2018	Luharuka et al.
2018/0183219	A1	6/2018	Oehring
2018/0216455	A1	8/2018	Andreychuk
2018/0238147	A1	8/2018	Shahri
2018/0245428	A1	8/2018	Richards
2018/0258746	A1	9/2018	Broussard
2018/0259080	A1	9/2018	Dale et al.
2018/0266217	A1	9/2018	Funkhouser et al.
2018/0266412	A1	9/2018	Stokkevag
2018/0274446	A1	9/2018	Oehring
2018/0284817	A1	10/2018	Cook et al.
2018/0291713	A1	10/2018	Jeanson
2018/0298731	A1	10/2018	Bishop
2018/0312738	A1	11/2018	Rutsch et al.
2018/0313677	A1	11/2018	Warren et al.
2018/0320483	A1	11/2018	Zhang
2018/0343125	A1	11/2018	Clish
2018/0363437	A1	12/2018	Coli
2018/0363640	A1	12/2018	Kajita et al.
2018/0366950	A1	12/2018	Pedersen et al.
2019/0003329	A1	1/2019	Morris
2019/0010793	A1	1/2019	Hinderliter
2019/0040727	A1	2/2019	Oehring et al.
2019/0055827	A1	2/2019	Coli
2019/0063309	A1	2/2019	Davis
2019/0100989	A1	4/2019	Stewart
2019/0112910	A1	4/2019	Oehring
2019/0119096	A1	4/2019	Haile
2019/0120024	A1	4/2019	Oehring
2019/0128080	A1	5/2019	Ross
2019/0128104	A1	5/2019	Graham et al.
2019/0145251	A1	5/2019	Johnson
2019/0154020	A1	5/2019	Glass
2019/0162061	A1	5/2019	Stephenson
2019/0169971	A1	6/2019	Oehring
2019/0178057	A1	6/2019	Hunter
2019/0178235	A1	6/2019	Coskrey
2019/0203567	A1	7/2019	Ross
2019/0203572	A1	7/2019	Morris
2019/0211661	A1	7/2019	Reckels
2019/0226317	A1	7/2019	Payne
2019/0245348	A1	8/2019	Hinderliter
2019/0249527	A1	8/2019	Kraynek
2019/0257462	A1	8/2019	Rogers
2019/0292866	A1	9/2019	Ross
2019/0292891	A1	9/2019	Kajaria
2020/0040878	A1	2/2020	Morris
2020/0047141	A1	2/2020	Oehring et al.
2020/0088152	A1*	3/2020	Alloin F03B 15/00
2020/0088202	A1*	3/2020	Sigmar E21B 43/26
2020/0194976	A1	6/2020	Benussi
2020/0205301	A1	6/2020	McGuire et al.
2020/0232454	A1	7/2020	Chretien
2020/0325760	A1	10/2020	Markham
2020/0350790	A1	11/2020	Luft et al.
2022/0090477	A1*	3/2022	Zhang F02C 7/24
2022/0127943	A1*	4/2022	El Tawy E21B 43/2607

FOREIGN PATENT DOCUMENTS

CA	2158637	9/1994
CA	2406801	11/2001
CA	2653069	12/2007
CA	2707269	12/2010
CA	2482943	5/2011
CA	3050131	11/2011

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

CA	2773843		10/2012
CA	2845347		10/2012
CA	2955706		10/2012
CA	2966672		10/2012
CA	3000322		4/2013
CA	2787814		2/2014
CA	2833711		5/2014
CA	2978706		9/2016
CA	2944980		2/2017
CA	3006422		6/2017
CA	3018485		8/2017
CA	2964593		10/2017
CA	2849825		7/2018
CA	3067854		1/2019
CA	2919649		2/2019
CA	2919666		7/2019
CA	2797081		9/2019
CA	2945579		10/2019
CN	101639059		2/2010
CN	20168751	U	12/2010
CN	101977016		2/2011
CN	201730812		2/2011
CN	201819992		5/2011
CN	201925157		8/2011
CN	202023547	U	11/2011
CN	202157824		3/2012
CN	102602322	A	7/2012
CN	202406331		8/2012
CN	202463670		10/2012
CN	202500735		10/2012
CN	202545207		11/2012
CN	103095209		5/2013
CN	104117308		10/2014
CN	102758604		12/2014
CN	104196613		12/2014
CN	205986303	U	2/2017
CN	108049999	A	5/2018
CN	112196508		1/2021
EP	3453827		3/2019
EP	3456915		3/2019
JP	2004264589		9/2004
JP	3626363		3/2005
JP	2008263774		10/2008
JP	2012-117371		6/2012
KR	20100028462		3/2010
RU	48205		9/2005
RU	98493		10/2010
RU	2421605		6/2011
WO	93/20328		10/1993
WO	98/53182		11/1998
WO	2008081368	A1	7/2008
WO	2008/136883		11/2008
WO	2009/023042		2/2009
WO	2009046280		4/2009
WO	2011/127305		10/2011
WO	2012/122636		9/2012
WO	2012/137068		10/2012
WO	2014177346		11/2014
WO	2016/144939		9/2016
WO	2016/160458		10/2016
WO	2018044307	A1	3/2018
WO	2018213925	A1	11/2018
WO	2019210417		11/2019

OTHER PUBLICATIONS

Gardner Denver—Well Servicing Pump Model GD-2500Q, GD-2500Q-HD, Quintuplex Pumps, GWS Fluid End Parts List, Jul. 2011, 39 pages.
Gardner Denver C-2500 Quintuplex Well Service Pump 2003, 2 pages.
Gardner Denver GD-2500 Quintuplex Well Service Pump, 2003, 2 pages.
Gardner Denver GD-2500Q Quintuplex Well Service Pump Operating and Service Manual, Aug. 2005, 46 pages.
Gardner Denver GD-2500Q Quintuplex Well Service Pump Power End Parts List, Apr. 2007, 15 pages.
Gardner Denver GD-2500Q Well Service Pump, 2 pages.
Gardner Denver Pumps, Stimulation/Fracturing Pumps, Gd 2500Q Quintuplex Pump, Oct. 14, 2019, http://www.gardnerdenver.com/en-us/pumps/quintuplex-pump-gd-2500q#menu, 7 pages.
Gardner Denver Well Servicing Pump Model C2500Q Quintuplex Operating and Service Manual, Apr. 2011, 46 pages.
George E. King, "Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells," Feb. 6-8, 2012, Society of Petroleum Engineers, 80 pages.
Goodwin, "High-voltage auxiliary switchgear for power stations," Power Engineering Journal, 1989, 10 pages.
Griswold 811, ANSI Process Pump, Installation, Operation, and Maintenance Manual, 60 pages.
Guffey, "Field testing of variable-speed beam-pump computer control," May 1991, SPE Production Engineering, pp. 155-160.
Honghua Group Customer Spreadsheet, 2 pages.
Honghua Group Limited, Complete Equipment and System Integrating by Using of Gas Power-gen and Power Grid and VFD System, 30 pages.
Honghua Group Limited, Is gas and electricity driven equipment the future trend for develop lithologic reservoirs, 2 pages.
Honghua Group, Honghua America, LLC, HHF—1600 Mud Pump, 2 pages.
Honghua Group, Honghua Shale Gas Solutions Power Point Slides, Feb. 2012, 41 pages.
International Search Report and Written Opinion dated Sep. 19, 2018 in related PCT Patent Application No. PCT/US2018/040683.
International Search Report and Written Opinion dated Jan. 2, 2019 in related PCT Patent Application No. PCT/US18/54542.
International Search Report and Written Opinion dated Jan. 2, 2019 in related PCT Patent Application No. PCT/US18/54548.
International Search Report and Written Opinion dated Dec. 31, 2018 in related PCT Patent Application No. PCT/US18/55913.
International Search Report and Written Opinion dated Jan. 4, 2019 in related PCT Patent Application No. PCT/US18/57539.
International Search Report and Written Opinion dated Mar. 5, 2019 in related PCT Patent Application No. PCT/US18/63970.
International Search Report and Written Opinion dated Feb. 15, 2019 in related PCT Patent Application No. PCT/US18/63977.
International Search Report and Written Opinion mailed Apr. 10, 2019 in corresponding PCT Application No. PCT/US2019/016635.
International Search Report and Writen Opinion mailed Sep. 11, 2019 in related PCT Application No. PCT/US2019/037493.
International Search Report and Writen Opinion mailed Nov. 26, 2019 in related PCT Application No. PCT/US19/51018.
International Search Report and Writen Opinion mailed Feb. 11, 2020 in related PCT Application No. PCT/US2019/055323.
International Search Report and Writen Opinion mailed Jan. 2, 2020 in related PCT Application No. PCT/US19/55325.
International Search Report and Writen Opinion mailed Jul. 22, 2020 in related PCT Application No. PCT/US20/00017.
International Search Report and Writen Opinion mailed Jun. 2, 2020 in related PCT Application No. PCT/US20/23809.
International Search Report and Writen Opinion Mailed Aug. 28, 2020 in PCT/US20/23821.
International Search Report and Writen Opinion mailed Jun. 23, 2020 in related PCT Application No. PCT/US20/23912.
International Search Report and Writen Opinion Mailed Sep. 3, 2020 in PCT/US2020/36932.
International Search Report and Writen Opinion mailed Nov. 24, 2020 in corresponding PCT Application No. PCT/US20/44274.
International Search Report and Writen Opinion mailed Dec. 14, 2020 in PCT/US2020/53980.
International Search Report and Writen Opinion mailed Feb. 3, 2021 in PCT/US20/58899.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Writen Opinion mailed Feb. 2, 2021 in PCT/US20/58906.
International Search Report and Writen Opinion mailed Feb. 4, 2021 in PCT/US20/59834.
International Search Report and Written Opinion mailed in PCT/US2020/066543 mailed May 11, 2021.
International Search Report and Written Opinion mailed in PCT/US20/67146 mailed Mar. 29, 2021.
International Search Report and Written Opinion mailed in PCT/US20/67523 mailed Mar. 22, 2021.
International Search Report and Written Opinion mailed in PCT/US20/67526 mailed May 6, 2021.
International Search Report and Written Opinion mailed in PCT/US20/67528 mailed Mar. 19, 2021.
International Search Report and Written Opinion mailed in PCT/US20/67608 mailed Mar. 30, 2021.
Irvine, "The use of variable frequency drives as a final control in he petroleum industry," 2000, IEEE, pp. 2749-2758.
Joanne Liou, Hunghua Group introduces 6,000-hp integrated shale gas system, Drilling Matters, May 21, 2012, 2 pages.
Jon Gates, ASME Hydraulic Fracturing Conference, Mar. 24, 2015, http://www.otrglobal.com/newsroom/cnotes/128720, 6 pages.
Karim, "Duel Fuel Diesel Engines," (2015), Taylor & Francis, pp. 62-63, Retrieved from https://app.knovel.com/hotlink/toc/id:kpDFDE0001/dual-fuel-diesel-engines/duel-fuel-diesel-engines.
Woodbury et al., "Electrical Design Considerations for Drilling Rigs," IEEE Transactions on Industry Applications, vol. 1A-12, No. 4, Jul. /Aug. 1976, pp. 421-431.
Non-Final Office Action mailed Sep. 20, 2019 in related U.S. Appl. No. 16/443,273.
Non-Final Office Action Mailed Oct. 5, 2020 in U.S. Appl. No. 16/443,273.
Non-Final Office Action mailed May 22, 2020 in related U.S. Appl. No. 16/458,696.
Non-Final Office Action mailed Jan. 4, 2021 in U.S. Appl. No. 16/522,043.
Non-Final Office Action mailed Jan. 29, 2021 in U.S. Appl. No. 16/564,185.
Non-Final Office Action mailed Dec. 6, 2019 in related U.S. Appl. No. 16/564,186.
Non-Final Office Action issued in U.S. Appl. No. 16/564,186 mailed Oct. 15, 2021.
Non-Final Office Action mailed Dec. 23, 2019 in related U.S. Appl. No. 16/597,008.
Non-Final Office Action mailed Jan. 10, 2020 in related U.S. Appl. No. 16/597,014.
Non-Final Office Action mailed Jul. 23, 2020 in related U.S. Appl. No. 16/597,014.
Non-Final Office Action mailed Jun. 29, 2020 in related U.S. Appl. No. 16/728,359.
Non-Final Office Action issued in U.S. Appl. No. 16/871,328 mailed Dec. 9, 2021.
Non-Final Office Action issued in U.S. Appl. No. 16/871,928 mailed Aug. 25, 2021.
Non-Final Office Action issued in U.S. Appl. No. 16/901,774 mailed Sep. 14, 2021.
Non-Final Office Action issued in U.S. Appl. No. 16/943,727 mailed Aug. 3, 2021.
Non-Final Office Action issued in U.S. Appl. No. 16/943,935 mailed Oct. 21, 2021.
Non-Final Office Action issued in U.S. Appl. No. 17/060,647 mailed Sep. 20, 2021.
Notice of Allowance issued in corresponding U.S. Appl. No. 14/622,532 dated Mar. 27, 2017.
Notice of Allowance for U.S. Appl. No. 15/202,085, dated May 1, 2019.
Notice of Allowance issued in corresponding U.S. Appl. No. 15/217,040 dated Mar. 28, 2017.
Notice of Allowance mailed Apr. 23, 2019 in corresponding U.S. Appl. No. 15/653,028.
Notice of Allowance and Notice of Allowability issued in U.S. Appl. No. 15/829,419 mailed Jul. 26, 2021.
Notice of Allowance mailed Jan. 9, 2020 in related U.S. Appl. No. 16/570,331.
Final Office Action mailed Oct. 20, 2020 in related U.S. Appl. No. 16/268,030.
Offshore Technology Conference, Houston, TX, Apr. 30-May 3, 2012, Honghua Group Brochure and Pictures, 12 pages.
Onyx Industries Inc., Stack Light Engineering Reference Guide, Sep. 23, 2012, first page only.
Pemberton, "Strategies for Optimizing pump efficiency and LCC performance: process pumps are the largest consumers of energy in a typical pulp and paper mill—boosting their efficiency is a new avenue to reduced plant operating costs," Jun. 2003, Paper Age. pp. 28-32.
R. Ikeda et al., "Hydraulic fracturing technique: pore pressure effect and stress heterogeneity," 1989, Int. J. Rock Mech. Min. Sci. & Geomech., vol. 26, No. 6, pp. 471-475.
R. Saidur, "Applications of variable speed drive (VSD) in electrical motors energy savings," 2012 , vol. 16, pp. 543-550.
Response to Non-Final Office Action dated Aug. 3, 2015 in related U.S. Appl. No. 13/679,689, 62 pages.
Robert B. Thompson, "Optimizing the production system using real-time measurements: a piece of the digital oilfield puzzle," Nov. 11-14, 2007, SPE Annual Technical Conference and Exhibition, Anaheim, CA, pp. 1-10.
S.K. Subramaniam, "Production Monitoring System for Monitoring the Industrial Shop Floor Performance," 2009, International Journal of Systems Applications, Engineering & Development, vol. 3, Issue 1, pp. 28-35.
Schlumberger, JET Manual 23, Jan. 31, 2007, 68 pages.
Steve Besore, MTU Detroit Diesel Inc., "How to select generator sets for today's oil and gas drill drigs: careful comparison and selection can improve performance and reduce costs," May 5, 2010, 4 pages, https://www.mtu-online.com/fileadmin/fm-dam/mtu-USA/mtuinnorthamerica/white-papers/WhitePaper_EDP.pdf.
Stewart & Stevenson, Stimulation Systems, 2012, 20 pages.
Stuart H. Loewenthal, Design of Power-Transmitting Shafts, NASA Reference Publication 1123, Jul. 1984, 30 pages.
TESS Record—Trademark for Clean Fleet registered Sep. 5, 2013, accessed Jan. 14, 2020, 2 pages.
TMEIC, TMEIC Industrial Motors Manual, 2012, 12 pages.
Toshiba 2011 Industrial Catalog, Drives, PAC, PLCs, 2011, 272 pages.
Toshiba H9 ASD Installation and Operation Manual, Mar. 2011, 287 pages.
Toshiba, G9 Brochure—G9 Series Adjustable Speed Drives, Jun. 2007, 6 pages.
Toshiba, Toshiba Q9 Asd Installation and Operation Manual, Apr. 2010, 233 pages.
U.S. Well Services, About U.S. Well Services, accessed Jan. 14, 2020, 14 pages.
U.S. Well Services, Game-changing hydraulic fracturing technology, reduces emissions by 99%: U.S. Well Services's patented clean fleet technology proven to cut emission, save fuel and allow for quieter operations on site, Oct. 1, 2014, 3 pages.
UK Power Networks—Transformers to Supply Heat to Tate Modern—from Press Releases May 16, 2013.
Unknown, "Andon (manufacturing)," last edited Sep. 8, 2019, https://en.wikipedia.org/w/index.php?title=Andon_(manufacturing)&oldid=914575778, 2 pages.
Unknown, "Improving the Drilling Cycle," Oilfield Technology, Dec. 2009, vol. 2, Issue 9, 5 pages.
Unknown, "U.S. Well Services for Antero Fracking," Oct. 3, 2014, HHP Insight, http://hhpinsight.com/epoperations/2014/10/u-s-well-services-for-antero-fracking/, 3 pages.
Unknown, Evolution Well Services advances fracturing operations with an electrically powered system, Calgary PR Newsire, Jun. 4, 2012, 2 pages.
Warren Electric Corp., Hydraulic heaters maintain fluid quality and consistency, Hydraulics & Pneumatics, Dec. 30, 2010, 12 pages.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion mailed Jul. 9, 2019 in corresponding PCT Application No. PCT/US2019/027584.
Kroposki et al., Making Microgrids Work, 6 IEEE Power and Energy Mag. 40, 41 (2008).
Linda Kane, Energy pipeline: US Well Services brings clean fleet to Weld County, Nov. 4, 2015, Greeley Tribute, 7 pages.
Louisiana State University, Petroleum alumnus and team develop mobile fracturing unit that alleviates environmental impact, LSU School of EE & CS, Nov. 2012, 2 pages.
Luis Gamboa, "Variable Frequency Drives in Oil and Gas Pumping Systems," Pumps & Systems, Dec. 17, 2011, https://www.pumpsandsystems.com/variable-frequency-drives-oil-and-gas-pumping-systems, 5 pages.
Mactec, Fract Test with VFDs Final Report Hydraulic Fracturing Pilot Test Results and Preliminary Full Scale Design United Nuclera Church Rock Facility, Dec. 23, 2003, 73 pages.
Morris et al., U.S. Appl. No. 62/526,869; Hydration-Blender Transport and Electric Power Distribution for Fracturing Operation; Jun. 28, 2018; USPTO; see entire document.
Nikolich, "Compressors, pumps, refrigeration equipment: improvement and specialization of piston pumps for oil and gas well-drilling and production operations," 1996, Chemcial and Petroleum Engineering, vol. 32, pp. 157-162.
Non-Final Office Action issued in corresponding U.S. Appl. No. 14/622,532 dated May 17, 2016.
Non-Final Office Action issued in corresponding U.S. Appl. No. 14/622,532 dated Aug. 5, 2015.
Non-Final Office Action issued in corresponding U.S. Appl. No. 14/881,535 dated Oct. 6, 2017.
Non-Final Office Action mailed May 20, 2020 in related U.S. Appl. No. 14/881,535.
Non-Final Office Action issued in U.S. Appl. No. 14/881,535 mailed Jul. 21, 2021.
Non-Final Office Action issued in corresponding U.S. Appl. No. 14/884,363 dated Sep. 5, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/145,414 dated Nov. 29, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/145,443 dated Feb. 7, 2017.
Non-Final Office Action mailed May 8, 2020 in related U.S. Appl. No. 15/145,443.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/145,491 on Sep. 12, 2016.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/145,491 dated May 15, 2017.
Non-Final Office Action dated Apr. 2, 2018 in related U.S. Appl. No. 15/183,387.
Non-Final Office Action issued Mar. 6, 2019 in related U.S. Appl. No. 15/183,387.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/217,040 dated Nov. 29, 2016.
Non-Final Office Action dated Oct. 4, 2018 in related U.S. Appl. No. 15/217,081.
Non-Final Office Action dated May 29, 2018 in related U.S. Appl. No. 15/235,716.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/235,788 dated Dec. 14, 2016.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/291,842 dated Jan. 6, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/293,681 dated Feb. 16, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/294,349 dated Mar. 14, 2017.
Non-Final Office Action dated Apr. 10, 2018 in related U.S. Appl. No. 15/294,349.
Non-Final Office Action mailed Aug. 19, 2019 in related U.S. Appl. No. 15/356,436.
Non-Final Office Action Mailed Oct. 26, 2020 in U.S. Appl. No. 15/356,436.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/486,970 dated Jun. 22, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/487,656 dated Jun. 23, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/487,694 dated Jun. 26, 2017.
Non-Final Office Action issued in corresponding U.S. Appl. No. 15/644,487 dated Nov. 13, 2017.
Non-Final Office Action dated Jul. 25, 2018 in related U.S. Appl. No. 15/644,487.
Non-Final Office Action mailed Sep. 3, 2019 in related U.S. Appl. No. 15/994,772.
Non-Final Office Action mailed Mar. 3, 2020 in related U.S. Appl. No. 16/152,695.
Non-Final Office Action mailed Oct. 2, 2019 in related U.S. Appl. No. 16/152,732.
Non-Final Office Action dated Dec. 12, 2018 in related U.S. Appl. No. 16/160,708.
Non-Final Office Action Mailed Aug. 31, 2020 in U.S. Appl. No. 16/167,083.
Non-Final Office Action issued Feb. 12, 2019 in related U.S. Appl. No. 16/170,695.
Non-Final Office Action issued Feb. 25, 2019 in related U.S. Appl. No. 16/210,749.
Non-Final Office Action issued in corresponding U.S. Appl. No. 16/268,030 dated May 10, 2019.
Non-Final Office Action Mailed Sep. 2, 2020 in U.S. Appl. No. 16/356,263.
Non-Final Office Action mailed Jun. 22, 2020 in related U.S. Appl. No. 16/377,861.
Non-Final Office Action mailed Oct. 11, 2019 in related U.S. Appl. No. 16/385,070.
Non-Final Office Action mailed Aug. 4, 2020 in related U.S. Appl. No. 16/385,070.
Non-Final Office Action mailed Jun. 29, 2020 in related U.S. Appl. No. 16/404,283.
Non-Final Office Action issued in U.S. Appl. No. 16/404,283 mailed Jul. 21, 2021.
"Heat Exchanger" (https://en.wikipedia.org/w/index.php?title=Heat_exchanger&oldid=89300146) Dec. 18, 2019 Apr. 2019 (Apr. 18, 2019), entire document, especially para (0001].
"Process Burner" (https://www.cebasrt.com/productsloii-gaslprocess-burner) 06 Sep. 6, 2018 (Sep. 6, 2018), entire document, especially para (Burners for refinery Heaters].
"Water and Glycol Heating Systems" (https://www.heat-inc.com/wg-series-water-glycol-systems/) Jun. 18, 2018 (Jun. 18, 2018), entire document, especially WG Series Water Glycol Systems.
ABB Group, MV Drive benefits for shale gas applications, Powerpoint, Apr. 2012, 16 pages.
ABB, ABB Drive Ware User's Guide, DriveWindow Light 2, Oct. 15, 2013, 45 pages.
ABB, ABB Drive Ware User's Manual, DriveWindow 2, Dec. 31, 2012, 604 pages.
ABB, ABB drives in chemical, oil and gas Medium voltage drives for greater profitability and performance, 2011, 16 pages.
ABB, ABB drives in power generation: medium voltage drives for more efficient and reliable plant operation, 2006, 12 pages.
ABB, Drive PC Tools: Startup and maintenance, DriveWindow Light, 2014, 2 pages.
ABB, Global Center of Excellence DC Drives: DriveWindow light upgrade for DC drives Used for DWL 2.95 and DC DriveAP, Dec. 4, 2018, 1 page.
ABB, Industry Brochure—ABB drives in chemical, oil and gas medium voltage drives for greater profitability and performance, 2008, 16 pages.
Albone, "Mobile Compressor Stations for Natural Gas Transmission Service," ASME 67-GT-33, Turbo Expo, Power for Land, Sea and Air, vol. 79887, p. 1-10, 1967.
Andrew Howard Nunn, "The feasibility of natural gas as a fuel source for modern land-based drilling," Dec. 2011, 94 pages.
ASME, Hydraulic Fracturing's Greener Tint, Jan. 11, 2018, 2 pages.
Borets, "Borets Oil Equipment," accessed Sep. 4, 2020, 150 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Business Wire, Hunghua Group showcases shale gas, offshore and land drilling solutions at the 2013 Offshore Technology Conference, May 6, 2013, 2 pages.
Canadian Office Action dated Mar. 2, 2018 in related Canadian Patent Application No. 2,833,711.
Canadian Office Action mailed May 30, 2019 in corresponding CA Application No. 2,833,711.
Canadian Office Action dated Jun. 22, 2018 in related Canadian Patent Application No. 2,886,697.
Canadian Office Action issued Sep. 8, 2020 in Canadian Application No. 2,928,707.
Canadian Office Action dated Apr. 18, 2018 in related Canadian Patent Application No. 2,928,711.
Canadian Office Action mailed Aug. 18, 2020 in related CA Application No. 2,933,444.
Canadian Office Action mailed Jan. 30, 2019 in related Canadian Patent Application No. 2,936,997.
Canadian Office Action mailed Oct. 1, 2019 in related Canadian Patent Application No. 2,936,997.
Canadian Office Action mailed Mar. 1, 2019 in related Canadian Patent Application No. 2,943,275.
Canadian Office Action mailed Aug. 17, 2020 in related CA Application No. 2,944,968.
Canadian Office Action issued Aug. 31, 2020 in Canadian Application No. 2,944,980.
Canadian Office Action dated Sep. 28, 2018 in related Canadian Patent Application No. 2,945,281.
Canadian Office Action mailed Jun. 20, 2019 in corresponding CA Application No. 2,964,597.
Canadian Office Action issued Sep. 22, 2020 in Canadian Application No. 2,982,974.
Canadian Office Action issued in Canadian Application No. 3,094,768 mailed Oct. 28, 2021.
Charlotte Owen, "Chinese company launches new fracking rigs," May 2, 2012, Oil & Gas Technology Magazine, 2 pages.
U.S. Appl. No. 61/472,861, Coli Patent Application, "Mobile, modular, electrically powered system for use in fracturing underground formations," filed Apr. 7, 2011, 28 pages.
Coli, Mobile, modular, electrically powered system for use in fracturing underground formations using liquid petroleum gas, Oct. 5, 2012, U.S. Appl. No. 61/710,393, 59 pages.
Dan T. Ton & Merrill A. Smith, The U.S. Department of Energy's Microgrid Initiative, 25 The Electricy J. 84 (2012), p. 84-94.
Discenzo, "Next Generation Pump Systems Enable New Opportunities for Asset Management and Economic Optimization," accessed Sep. 4, 2020, 8 pages.
Final Office Action issued in corresponding U.S. Appl. No. 14/622,532 mailed Dec. 21, 2015.
Final Office Action issued in corresponding U.S. Appl. No. 14/622,532 mailed Dec. 7, 2016.
Final Office Action issued in corresponding U.S. Appl. No. 15/145,491 dated Sep. 6, 2017.
Final Office Action issued in corresponding U.S. Appl. No. 15/145,491 mailed Jan. 20, 2017.
Final Office Action issued in corresponding U.S. Appl. No. 15/294,349 dated Jul. 6, 2017.
Final Office Action mailed Mar. 31, 2020 in related U.S. Appl. No. 15/356,436.
Final Office Action issued in corresponding U.S. Appl. No. 16/170,695 dated Jun. 7, 2019.
Final Office Action issued in corresponding U.S. Appl. No. 16/210,749 dated Jun. 11, 2019.
Final Office Action mailed Sep. 11, 2019 in related U.S. Appl. No. 16/268,030.
Final Office Action issued in U.S. Appl. No. 16/356,263 mailed Oct. 7, 2021.
Final Office Action mailed Jan. 11, 2021 in U.S. Appl. No. 16/404,283.
Final Office Action mailed Jan. 21, 2021 in U.S. Appl. No. 16/458,696.
Final Office Action mailed Feb. 4, 2021 in U.S. Appl. No. 16/597,014.
Finger, "Sandia National Handbook Laboratories Report: Slimhole handbook: procedures and recommendations for slimhole drilling and testing in geothermal exploration," Oct. 1999, 164 pages.

* cited by examiner

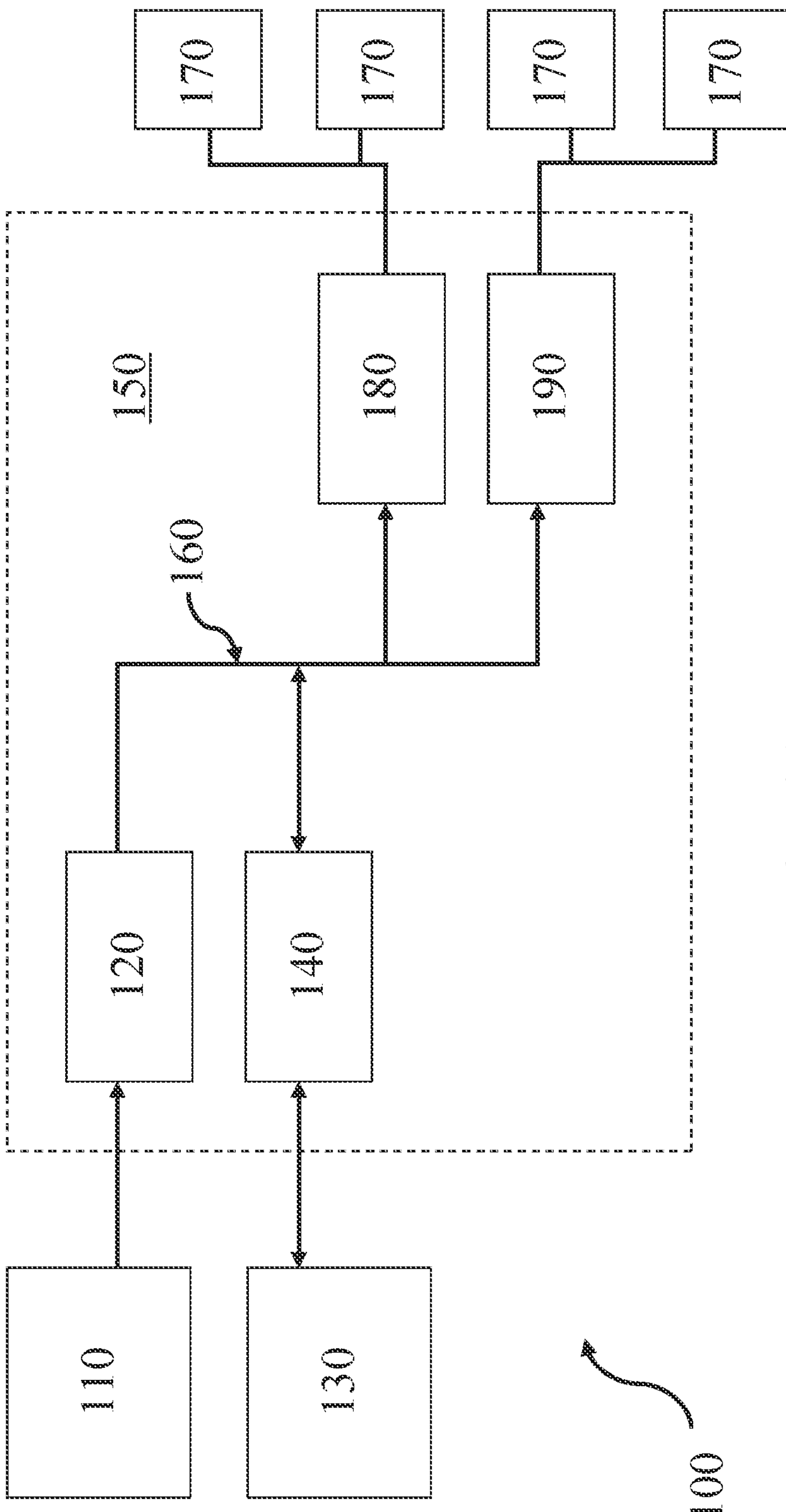


Fig. 1A

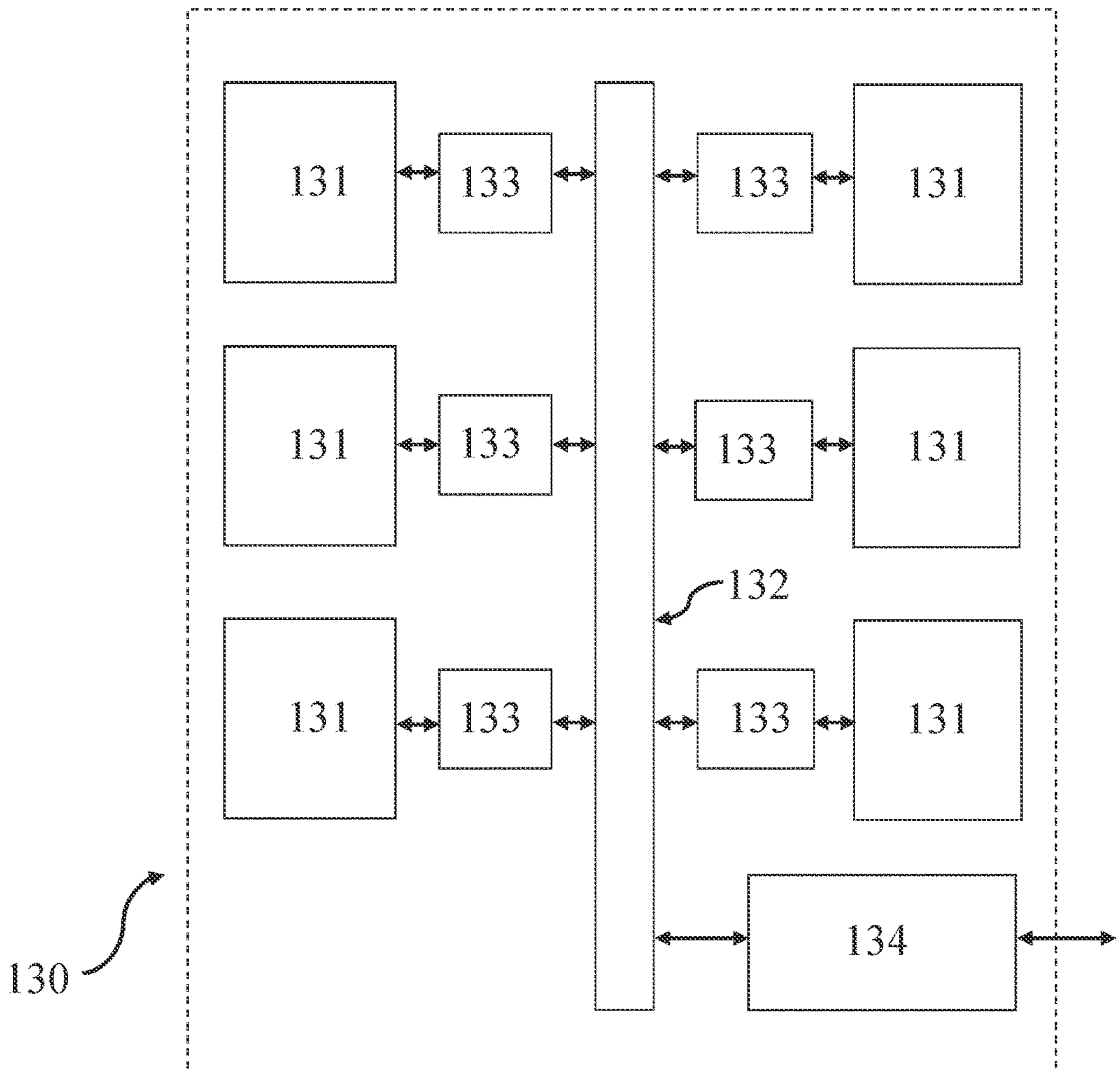


Fig. 1B

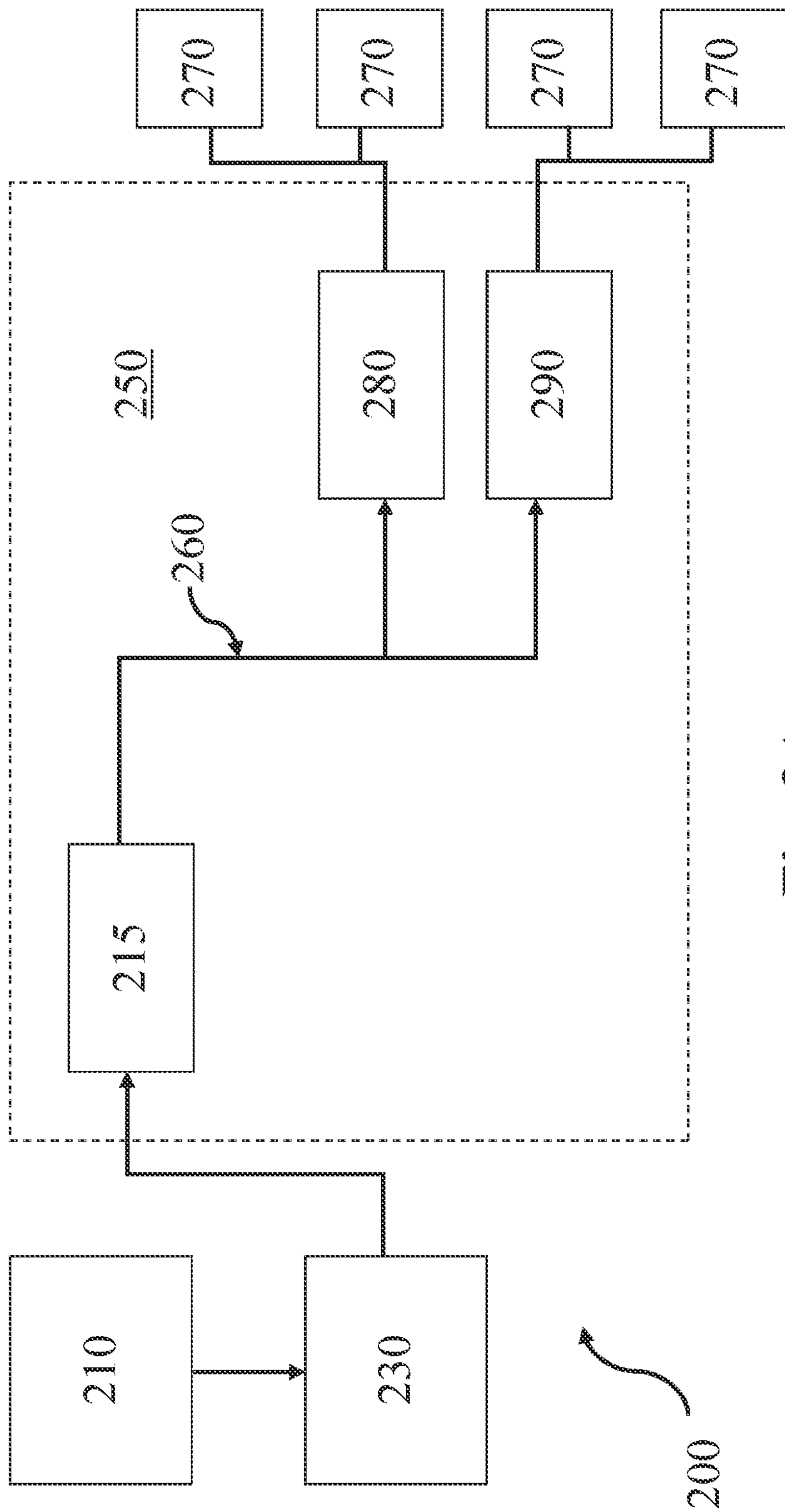


Fig. 2A

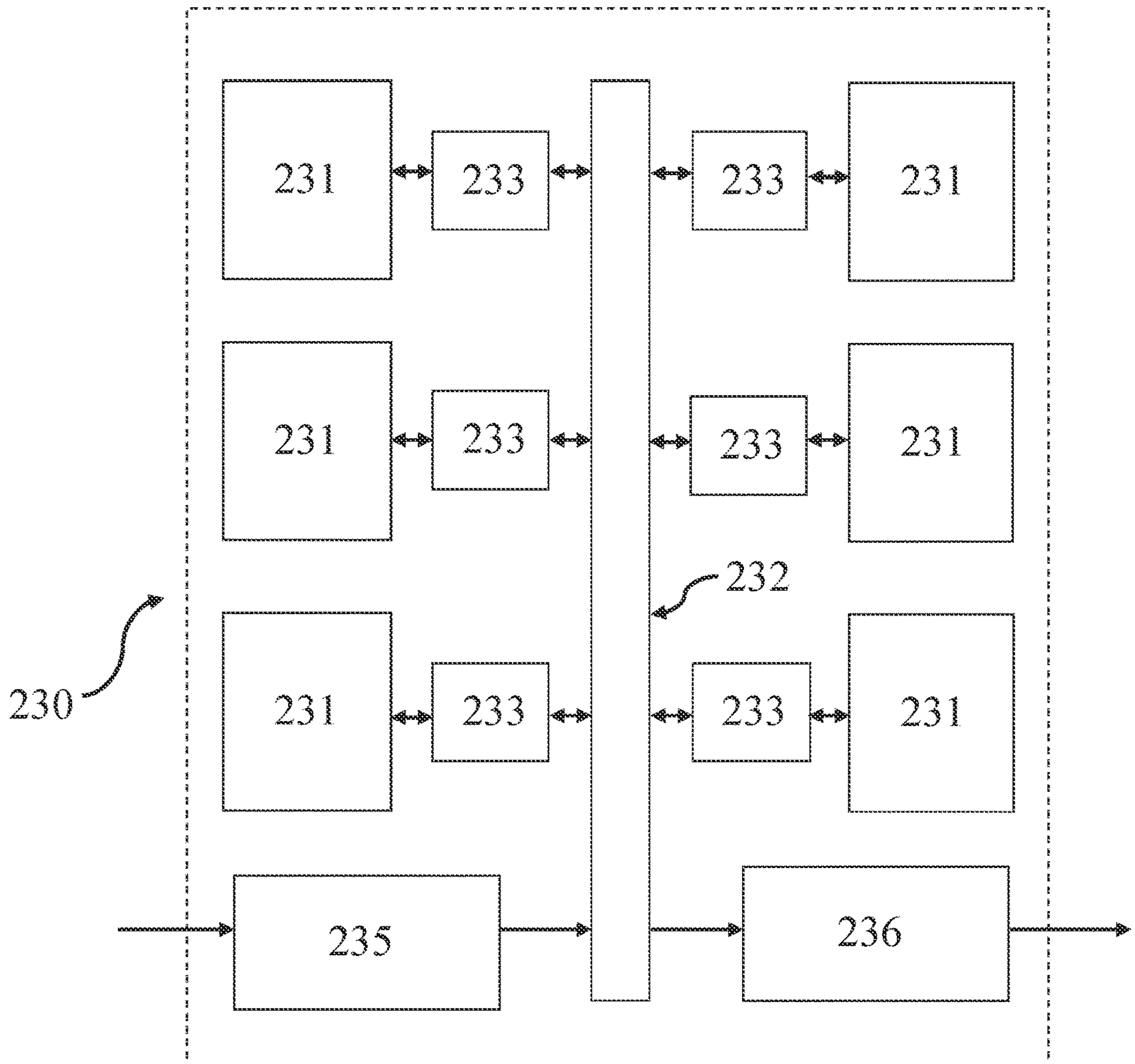


Fig. 2B

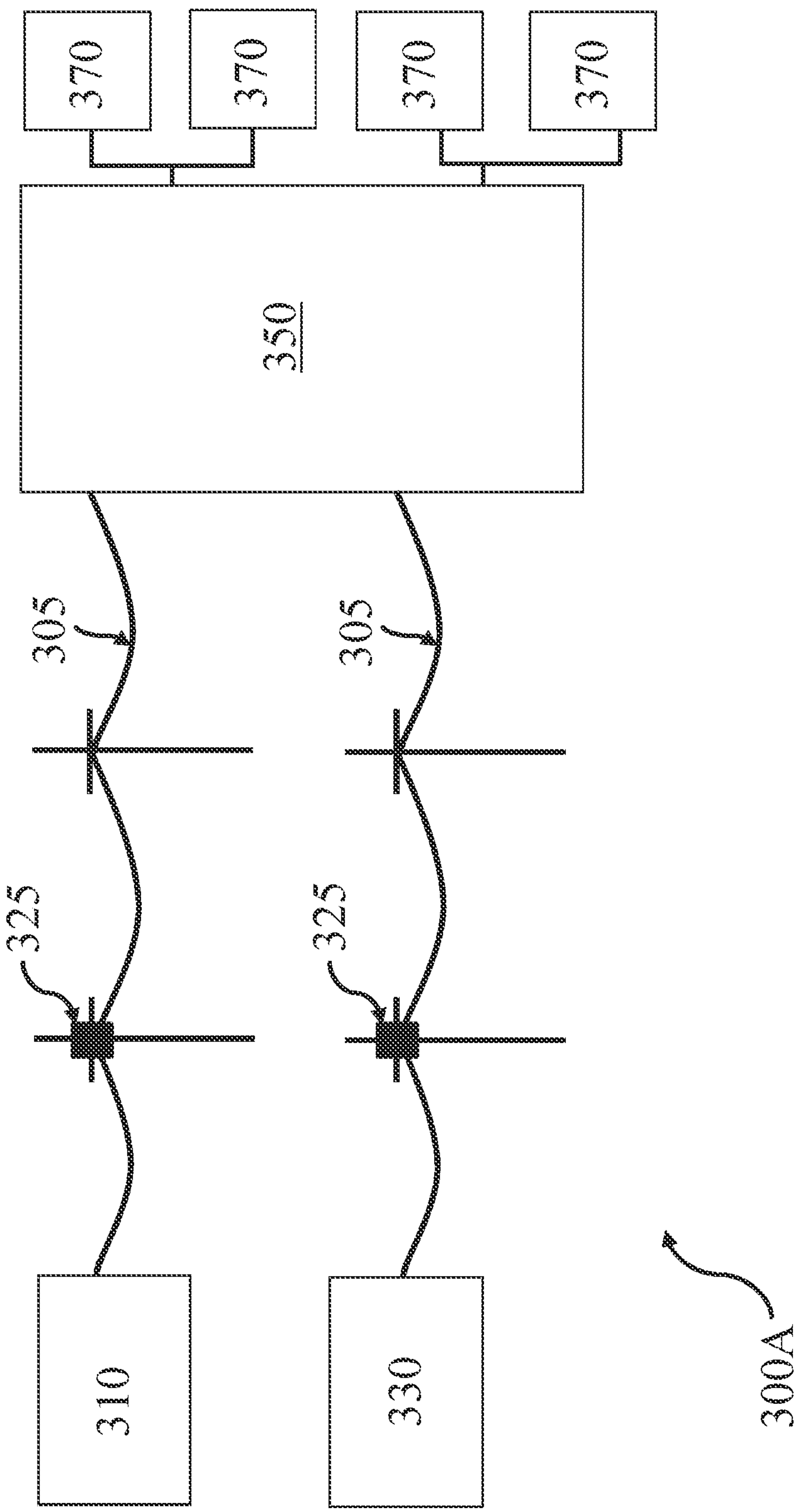


Fig. 3A

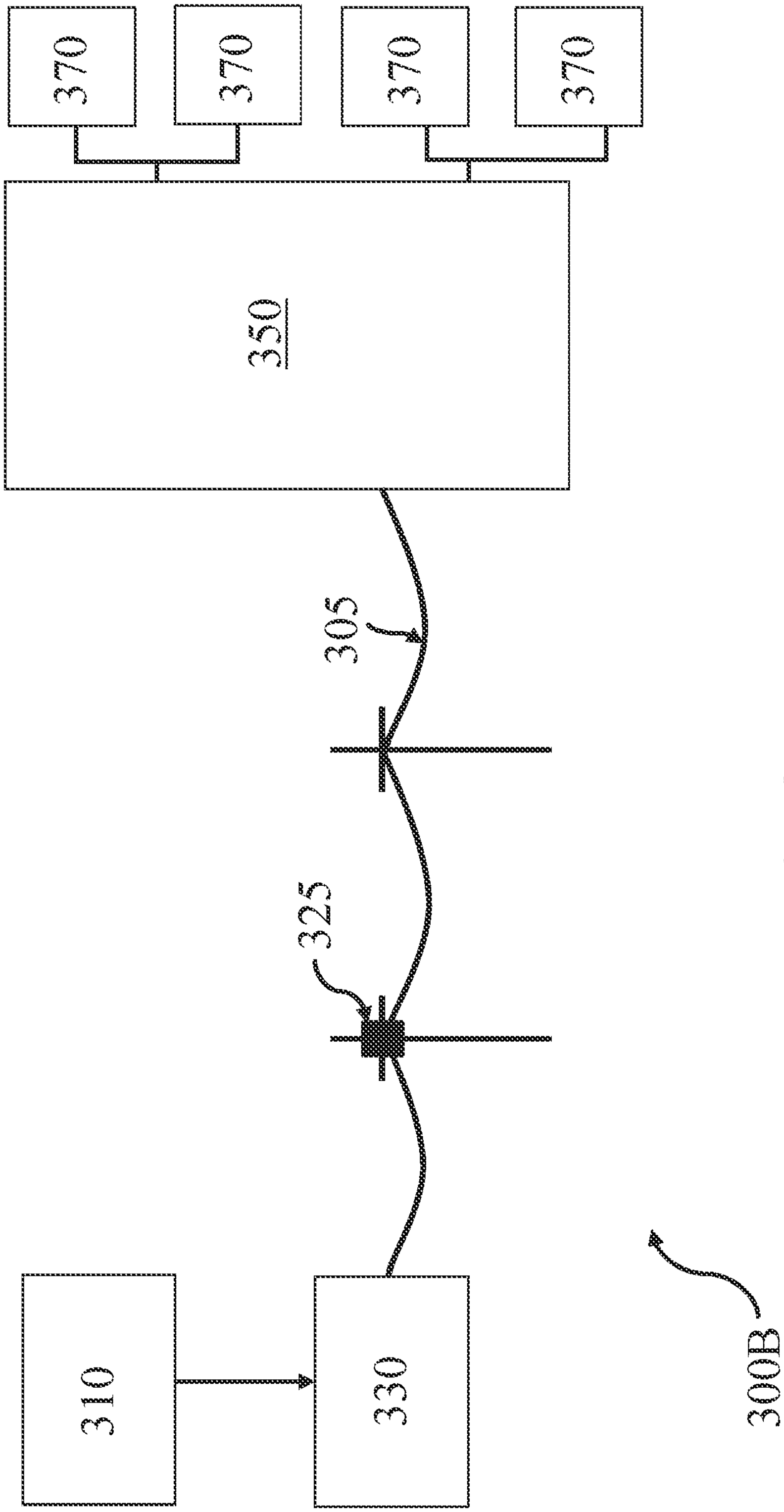


Fig. 3B

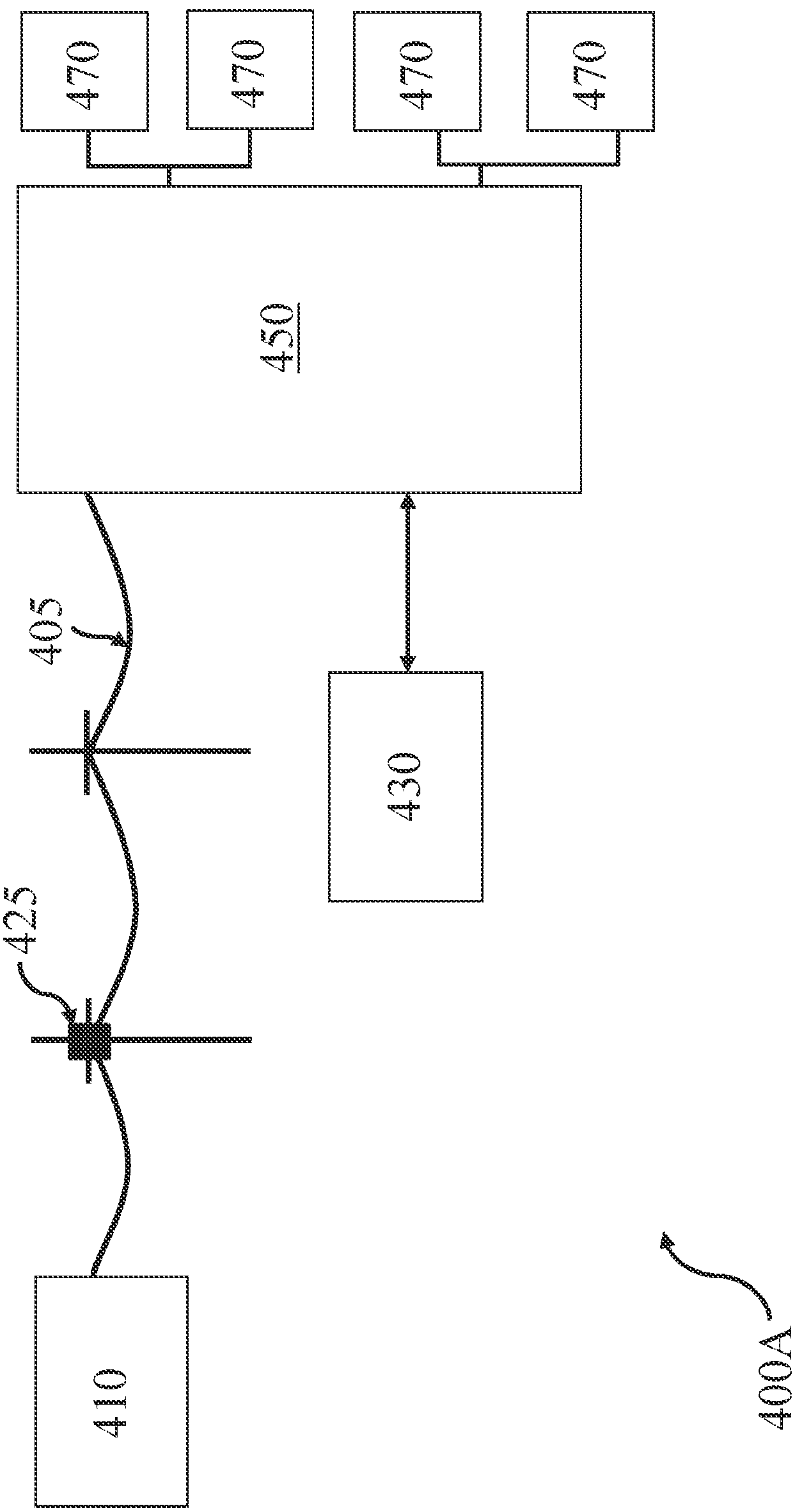


Fig. 4A

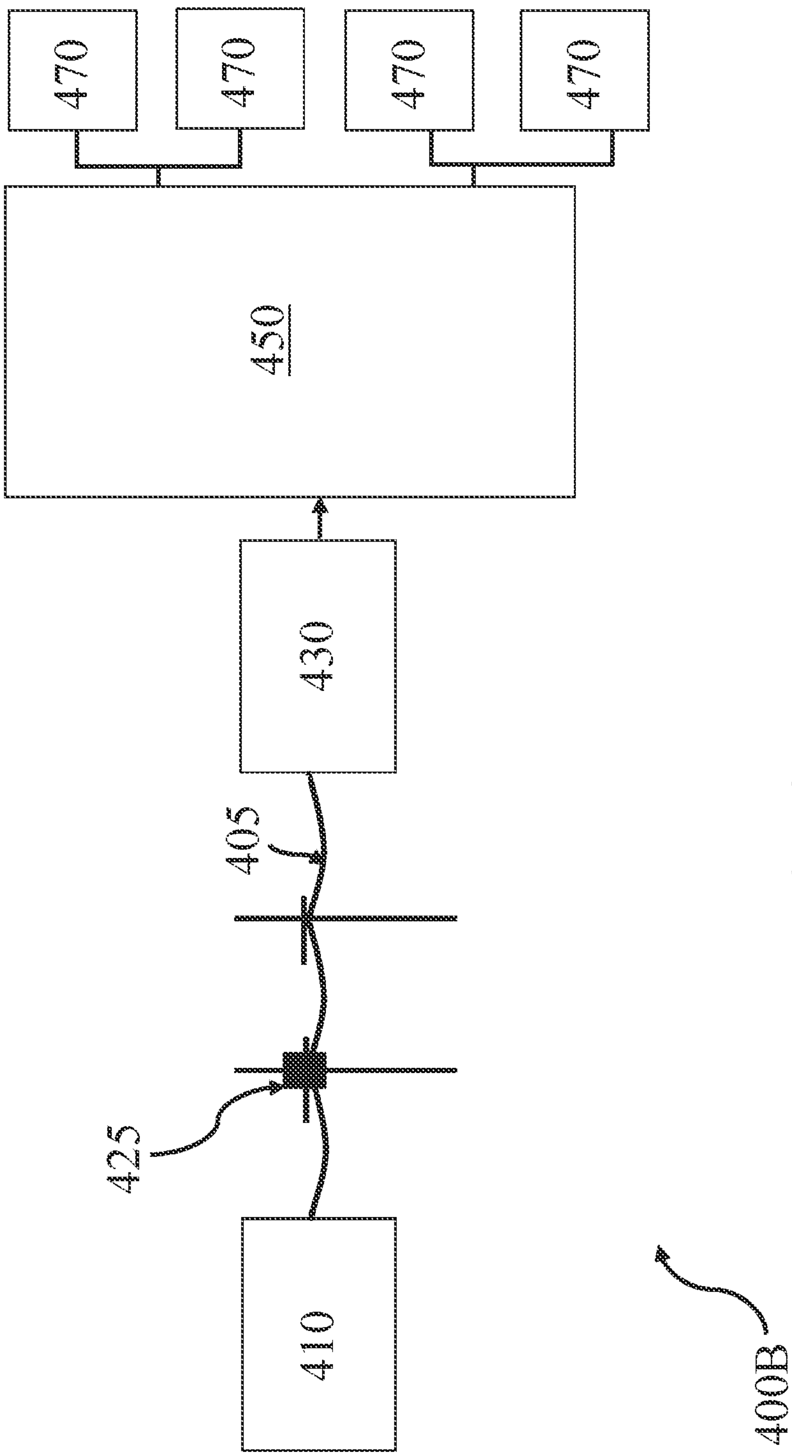


Fig. 4B

HIGH CAPACITY POWER STORAGE SYSTEM FOR ELECTRIC HYDRAULIC FRACTURING

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/943,727 filed Jul. 30, 2020, titled HIGH CAPACITY POWER STORAGE SYSTEM FOR ELECTRIC HYDRAULIC FRACTURING, now U.S. Pat. No. 11,542,786, issued Jan. 3, 2023, which claims priority to and the benefit of U.S. Provisional Application No. 62/881,174, filed Aug. 1, 2019, titled HIGH CAPACITY POWER STORAGE SYSTEM FOR ELECTRIC HYDRAULIC FRACTURING, the full disclosures of which are hereby incorporated herein by reference in their entirety for all intents and purposes.

BACKGROUND

1. Field of Invention

This invention relates in general to equipment used hydraulic fracturing operations, and in particular, to electricity storage at a hydraulic fracturing site.

1. Description of the Prior Art

Hydraulic Fracturing is a technique used to stimulate production from some hydrocarbon producing wells. The technique involves injecting hydraulic fracturing fluid into a wellbore at a pressure sufficient to generate fissures in the formation surrounding the wellbore. Hydrocarbons can then flow through the fissures to a production bore. The hydraulic fracturing fluid is typically injected into the wellbore using hydraulic fracturing pumps, which can be powered, in some cases, by electric motors. The electric motors can in turn be powered by generators.

Preserving and extending the life and durability of power generators at an electric hydraulic fracturing site is a priority. This objective, however, can be undermined by overloading power generation equipment. Such overloading reduces the life span of the equipment, and can also create a hazardous environment at a wellsite due to malfunctions and overheating in close proximity with other hydraulic fracturing equipment.

The fast response electricity storage system of the present technology is one viable option to assisting in power distribution, in particular at times when power generation equipment is overloaded. Not only does such a system provide a rapid and effective way to supply power when demand is high, but it also possesses other features that help provide continuous reliable power to hydraulic fracturing equipment.

SUMMARY

One embodiment of the present technology provides a hydraulic fracturing power system, including a power source, a power storage system, and electric powered hydraulic fracturing equipment in selective electrical communication with the power source, the power storage system, or both. The system further includes at least one circuit breaker between the power source, the power storage system, or both, and the electric powered hydraulic fracturing equipment, the circuit breaker having an open position that

opens an electric circuit between the electric powered hydraulic fracturing equipment and the power source, the power storage system, or both, and a closed position that closes the electric circuit.

In some embodiments, the power storage system can be at least one solid state battery selected from the group consisting of electrochemical capacitors, lithium ion batteries, nickel-cadmium batteries, and sodium sulfur batteries. Alternatively, the power storage system can be at least one flow battery selected from the group consisting of redox batteries, iron-chromium batteries, vanadium redox batteries, and zinc-bromine batteries. The at least one battery can be rechargeable.

In certain embodiments, the at least one circuit breaker can include a first circuit breaker and a second circuit breaker, the first circuit breaker electrically connected to the power source, and the second circuit breaker electrically connected to the power storage system. Each of the first circuit breaker and the second circuit breaker can be electrically connected to the electric powered hydraulic fracturing equipment via a common bus. Alternatively, the at least one circuit breaker can be a first circuit breaker, and both the power source and the power storage system can be electrically connected to the first circuit breaker.

In some embodiments, at least one of the power source and the power storage system can be electrically connected to the at least one circuit break via a power line. In addition, the power storage system can be mounted on a trailer. Furthermore, the at least one circuit breaker can be substantially enclosed in a switchgear housing.

Another embodiment of the present technology provides a system for powering electric hydraulic fracturing equipment, the system including a power storage system, electric powered hydraulic fracturing equipment in selective electrical communication with the power storage system, and at least one circuit breaker between the power storage system and the electric powered hydraulic fracturing equipment, the circuit breaker configured to facilitate or prevent electrical communication between the power storage system and the electric powered hydraulic fracturing equipment.

In certain embodiments, the power storage system can be at least one solid state battery selected from the group consisting of electrochemical capacitors, lithium ion batteries, nickel-cadmium batteries, and sodium sulfur batteries. Alternatively, the power storage system can be at least one flow battery selected from the group consisting of redox batteries, iron-chromium batteries, vanadium redox batteries, and zinc-bromine batteries.

In addition, certain embodiments of the technology can also include a power source. In such embodiments, the at least one circuit breaker can include a first circuit breaker and a second circuit breaker, the first circuit breaker electrically connected to the power source, and the second circuit breaker electrically connected to the power storage system. Alternatively, the at least one circuit breaker can be a first circuit breaker, and wherein both the power source and the power storage system are electrically connected to the first circuit breaker.

Some embodiments can include a power source, wherein at least one of the power source and the power storage system are electrically connected to the at least one circuit breaker via a power line, and wherein the at least one circuit breaker is substantially enclosed in a switchgear housing. Furthermore, the power source can be rechargeable. Alternatively, the power source can be electrically connected to the at least one circuit breaker via a power line, and the

power storage system can be located adjacent the switchgear housing and electrically coupled directly to the switchgear without a power line.

Additionally, yet another embodiment can include software in communication with the power storage system, the software configured to monitor the state of the power storage system and to integrate control of the power storage system with other features of the system for powering electric hydraulic fracturing equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The present technology will be better understood on reading the following detailed description of non-limiting embodiments thereof, and on examining the accompanying drawings, in which:

FIG. **1**A is a schematic diagram of a hydraulic fracturing power system according to an embodiment of the present technology;

FIG. **1**B is a schematic diagram of a power storage system as used in the embodiment of the hydraulic fracturing power system of FIG. **1**A;

FIG. **2**A is a schematic diagram of a hydraulic fracturing power system according to an alternate embodiment of the present technology;

FIG. **2**B is a schematic diagram of a power storage system as used in the embodiment of the hydraulic fracturing power system of FIG. **2**A;

FIG. **3**A is a schematic diagram of a hydraulic fracturing power system according to another alternate embodiment of the present technology;

FIG. **3**B is a schematic diagram of an alternate embodiment of the hydraulic fracturing power system of FIG. **3**A;

FIG. **4**A is a schematic diagram of a hydraulic fracturing power system according to yet another alternate embodiment of the present technology; and

FIG. **4**B is a schematic diagram of an alternate embodiment of the hydraulic fracturing power system of FIG. **4**A.

DETAILED DESCRIPTION OF THE INVENTION

The foregoing aspects, features and advantages of the present technology will be further appreciated when considered with reference to the following description of preferred embodiments and accompanying drawings, wherein like reference numerals represent like elements. In describing the preferred embodiments of the technology illustrated in the appended drawings, specific terminology will be used for the sake of clarity. The invention, however, is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

According to one embodiment of the technology, a fast response electricity storage, or power storage system (PSS) can be provided to supply power to the power generation equipment of an electric hydraulic fracturing fleet when demand is high or in the event of a generator failure. The PSS system can include either solid state batteries or flow batteries. Solid state batteries can include, for example, electrochemical capacitors, lithium ion batteries, nickel-cadmium batteries, and sodium sulfur batteries. In addition, solid state batteries can charge or discharge based on electricity usage, and such charging and discharging can be paired with a software system, to monitor the state of the batteries and control the charging and discharging of the batteries. Flow batteries can, for example, include redox, iron-chromium, vanadium redox, and zinc-bromine batteries, and can be rechargeable batteries that store electricity directly in an electrolyte solution and respond quickly as needed. The flow batteries can also be paired with software, and the software associated with the both solid state and flow batteries can be designed to integrate with an operator's existing system so that monitoring and control can be integrated with other functions.

FIG. **1**A shows a hydraulic fracturing power system **100** according to an embodiment of the present technology. The hydraulic fracturing power system **100** includes a power source **110**, which can be, for example, a generator, and which can feed a first circuit breaker **120**. As shown, the hydraulic fracturing power system **100** can further include a PSS **130** that can feed a second circuit breaker **140**. In some embodiments, both the first circuit breaker **120** and the second circuit breaker **140** can be housed in the same switchgear housing **150**, or trailer. Both the first circuit breaker **120** and the second circuit breaker **140** can be connected to a common bus **160**, which in some embodiments can be a large copper bar used to share power evenly to downstream equipment from upstream generators.

When the power source **110** is energized with both the first and second breakers **120**, **140** closed, hydraulic fracturing equipment **170** can be supplied power while the PSS **130** stores excess electricity. The hydraulic fracturing equipment can be hydraulic fracturing pumps, blenders data vans, wireline equipment, boost pumps, cranes, lighting, chemical trailers, etc. Once load requirements increase for the equipment **170**, the PSS **130** can release its stored power onto the common bus **160** in order to reduce the load on the power source **110**. The power source **110** and the PSS **130** can share the burden of supplying power during stages of high power demand until the end of the fracturing stage. Before the next fracturing stage begins, the PSS **130** can replenish stored electricity used previously until it is needed to discharge its power. This ability to recharge and discharge intermittently or continuously as needed ensures adequate power distribution to the system by the PSS **130** throughout an operation.

Also shown in FIG. **1**A are third circuit breaker **180** and fourth circuit breaker **190**. Each of the third and fourth circuit breakers **180**, **190** can be electrically connected to equipment **170**. In the embodiment shown in FIG. **1**A, each of the third and fourth circuit breakers **180**, **190** are shown connected to pieces of equipment **170**, such as, for example, two hydraulic fracturing pumps. In practice, however, the present technology contemplates any appropriate ratio of circuit breakers to equipment, including connecting each circuit breaker to a single piece of equipment, or connecting each circuit breaker to more than two pieces of equipment.

One advantage to the present technology is that it is a more efficient way of providing power at peak times than known systems, such as simply providing another generator on site. In addition, the entire PSS package can be much smaller than a second generator, thereby taking up less space on a pad. The storage system will also require significantly less rig up time due to having no fuel connections, crane lifts, or mechanical alignments.

FIG. **1**B is a schematic depiction of the PSS **130** of the embodiment of the hydraulic fracturing power system **100** of FIG. **1**A. The PSS **130** can include a plurality of battery banks **131**, each connected to a common PSS bus **132** via an optional battery bank circuit breaker **133**. The common PSS bus **132** is also connected to a PSS circuit breaker **134** which is in turn electrically connected to circuit breaker **140** in the switchgear housing **150**.

Each of the connections in the PSS **130**—between the battery banks **131** and battery bank circuit breakers **133**, the battery bank circuit breakers **133** and the common PSS bus **132**, the common PSS bus **132** and the PSS circuit breaker **134**, and the PSS circuit breaker **134** and the second circuit breaker **140**—are two way connections, as indicated by double headed arrows. This means that electricity flows in both directions between the various components. One advantage to this configuration is the ability of the battery banks **131** within the PSS **130** to constantly discharge and recharge as needed or allowed by the load demands of the system. Thus, when a heavy load is required, the PSS **130** can augment the power provided by power source **110** to help avoid overloading power source **110**. Conversely, when a light load is required, the PSS **130** can pull excess power from power source **110** to recharge battery banks **131**.

Referring now to FIG. **2**A, there is shown an alternate hydraulic fracturing power system **200** according to an alternate embodiment of the present technology, including a power source **210** and a PSS **230**. According to FIG. **2**, the PSS **230** can be connected to the power source **210** in series before feeding power to a circuit breaker **215** in the switchgear housing **250**. Upon reaching full capacity, the PSS **230** can disconnect internal batteries from the power source **210**, thereby allowing it to bypass straight to the switchgear system.

In the configuration shown in FIG. **2**A, the circuit breaker **215** will then act as a feeder breaker for two additional circuit breakers **280**, **290**. As shown, the circuit breaker **215** can be connected to circuit breakers **280**, **290** via common bus **260**. Circuit breaker **215** can be rated for higher amperage than circuit breakers **280**, **290**. Circuit breakers **280**, **290** are in turn connected to hydraulic fracturing equipment **270**. Each of the additional circuit breakers **280**, **290** can be electrically connected to equipment **270**. In the embodiment shown in FIG. **2**A, each of the additional circuit breakers **280**, **290** are shown connected to two pieces of equipment **270**, such as, for example, two hydraulic fracturing pumps. In practice, however, the present technology contemplates any appropriate ratio of circuit breakers to equipment, including connecting each circuit breaker to a single piece of equipment, or connecting each circuit breaker to more than two pieces of equipment.

FIG. **2**B is a schematic depiction of the PSS **230** of the embodiment of the hydraulic fracturing power system **200** of FIG. **2**A. The PSS **230** can include a plurality of battery banks **231**, each connected to a common PSS bus **232** via a battery bank circuit breaker **233**. The common PSS bus **232** is also connected to an incoming PSS circuit breaker **235** and an outgoing PSS circuit breaker **236**. Outgoing PSS circuit breaker **236** is in turn electrically connected to circuit breaker **215** in the switchgear housing **250**.

Many of the connections in the PSS **230**—between the battery banks **231** and battery bank circuit breakers **233**, and the battery bank circuit breakers **233** and the common PSS bus **232**—are two way connections, as indicated by double headed arrows. This means that electricity flows in both directions between the various components. One advantage to this configuration is the ability of the battery banks **231** within the PSS **230** to constantly discharge and recharge as needed. During a typical operation, power will discharge from the battery banks **231** to the circuit breaker **215** via the battery bank circuit breakers **233**, the common PSS bus **232**, and the outgoing PSS circuit breaker **236**. Simultaneously, or as needed, power from the power source will recharge the battery banks **231** via the incoming PSS circuit breaker **235**, the common bus **232**, and the battery bank circuit breakers **233**.

As shown in FIG. **3**A, in certain embodiments of the technology, the hydraulic fracturing power system **300**A can alternatively be powered by power transmission lines **305**, with the power source **310** and the PSS **330** providing parallel power to the switchgear **350**. In such an embodiment, the power source **310** and the PSS **330** can each be attached to circuit breakers within the switchgear housing, which are in turn connected to the hydraulic fracturing equipment **370**. This arrangement is similar to the embodiment shown in FIG. **1**A, except that the power source **310** and the PSS **330** can be located at a remote location. The configuration of the circuit breakers within the switchgear housing **350** can be substantially similar to that of circuit breakers **120**, **140**, **180**, **190** in the embodiment shown in FIG. **1**A. In addition, the PSS **330** can have a similar structure to that described above and shown in FIG. **1**B.

The arrangement shown in FIG. **3**A, including the use of power transmission lines **305**, could be beneficial if, for example, space at a well site is restricted, and power generation has to be stationed some distance from the pad. In such an embodiment, cables can be sized properly due to distance, and additional protection can be installed for safety reasons, such as three phase reclosers **325** (small circuit breakers placed at distribution poles to clear faults on cables that are running long distances). In the embodiment of FIG. **3**, the PSS **330** can be connected to the transmission lines for remote operations, but may still draw power from the power source **310**.

FIG. **3**B shows an embodiment of the hydraulic fracturing power system **300**B that shares characteristics of the embodiments of FIGS. **2**A and **3**A. That is, both the power source **310** and the PSS **330** are located at a remote location from the switchgear **350**, and they are connected to the switchgear **350** in series. One advantage to this embodiment is that it requires only one set of transmission lines **305** between the power source **310**/PSS **330** and the switchgear **350**. In this embodiment, the configuration of the circuit breakers within the switchgear housing **350** can be substantially similar to that of circuit breakers **215**, **280**, **290** in the embodiment shown in FIG. **2**A. In addition, the PSS **330** can have a similar structure to that described above and shown in FIG. **2**B.

In yet another embodiment, shown in FIG. **4**A, the hydraulic fracturing power system **400**A can include similar features to the embodiment shown in FIG. **3**A, including a power source **410** and a PSS **430**. Moreover, the power source **410** is connected to the switchgear **450** via power transmission lines **405**, and the power transmission lines can include safety features, such as reclosers **425**. In the embodiment of FIG. **4**A, the PSS **430** can also provide ancillary power. For example, if the power source **410** is a generator, and the generator shuts down during a fracturing stage, the PSS **430** can provide power to hydraulic fracturing equipment **470**, including pumps, in order to flush the well so that chemicals and sand previously being pumped through the well can be completely removed from the well.

FIG. **4**B shows an embodiment of the hydraulic fracturing power system **400**B that shares characteristics of the embodiments of FIGS. **2**A and **4**A. That is, the power source **410** is located at a remote location switchgear **350**, the PSS **430** is located at the well site, and the power source **410** and PSS **430** are connected to the switchgear **450** in series. One advantage to this embodiment is that the PSS **430** can provide power to the hydraulic fracturing equipment **470** even if the transmission lines **405** fail. Another advantage is that placing the PSS **430** at the wellsite allows for the provision of power at the wellsite without any local emissions or appreciative noise. In this embodiment, the configuration of the circuit breakers within the switchgear housing **450** can be substantially similar to that of circuit breakers **215**, **280**, **290** in the embodiment shown in FIG. **2**A. In addition, the PSS **430** can have a similar structure to that described above and shown in FIG. **2**B.

Another alternative embodiment of the present technology provides a hydraulic fracturing power system where the PSS can be used as black start for a power source that is a generator. Black starting is the process of supplying power to a generator that has been completely shut down to get it back up and running. Black start power can be used to power many different systems internal to a primary generator, including, for example, lighting, controls, blowers, cooling systems, lube pumps, oil pumps, starting motors, etc, until the generator is up and running and can provide its own power for these ancillary systems. Diesel generators can usually do this with battery power, but turbine generators require a larger power source, especially if gas compressors need to be operating before the engine can be fired. The configuration of the PSS relative to the switchgear and equipment in such a case can be similar to the embodiments shown in FIGS. **1**A-**4**B. If enough power is stored in the batteries, the PSS system could support black starting operations without the need for a smaller standby generator to act as the black start power source. However, it could also utilize an external power source, such as solar panels, to recharge the storage system.

Use of the PSS in hydraulic fracturing power system of the present technology provides numerous advantages over known systems, including load leveling, frequency regulation, power quality control, emergency power, black start power, load bank capabilities, equipment reduction, reduced maintenance, and a simplified fuel supply. Each of these features is discussed in detail herein below.

First, with regard to load leveling, the PSS of the present technology has the ability to store electricity in times of low demand, and then to release that electricity in times of high power demand. As applied to electric powered hydraulic fracturing, stages that require relatively less load can provide a time for the PSS to charge up, or store electricity. In addition, the PSS can charge between stages or at the beginning of stages before full pump rate is achieved. Thereafter, power can be released in the stages of higher load requirements. This helps in increasing the lifespan of a power generating asset by decreasing its workload.

With regard to frequency regulation, the PSS can charge and discharge in response to an increase or decrease of microgrid frequency to maintain stored electricity within prescribed limits. This increases grid stability. In other words, the PSS can ramp up or down a generating asset in order to synchronize the generator with microgrid operation.

With regard to power quality control, the PSS can protect downstream loads such as sensitive electronic equipment and microprocessor based controls against short-duration disturbances in the microgrid that might affect their operation.

With regard to emergency power, in the event of a generator failure (due to, for example, a mechanical fault, electric fault, or due to a fuel supply loss), the PSS can provide sufficient electric power to flush the wellbore. This feature can prevent a "screen out" where the loss of fluid velocity causes the proppant in the hydraulic fracturing fluid or slurry to drop out and settle in the wellbore. Such a screen out can plug off the perforations and cause several days of downtime to clear. A screen out is a major concern in hydraulic fracturing and is considered a failure. The PSS can allow an electric hydraulic fracturing fleet to properly flush the well by being able to power the electric blender as well as sufficient hydraulic fracturing pumps to displace the proppant-laden slurry completely into the formation without generator power.

With regard to black start power, normally a small generator can be used to provide power to ancillary systems such as heaters, blowers, sensors, lighting, programmable logic controllers, electric over hydraulic systems, and electric over air systems for the larger generators. Such a generator can also be used to power the starters for these larger generators, which are often electric starters with a variable frequency drive or soft starter, or can be hydraulic starters with electric motors powering the hydraulic pumps. If the PSS is properly charged, it can replace the black start generator to allow the larger generators (often turbines) to start from a black out condition.

With regard to load bank capabilities, the PSS can be used to test and verify generator performance during commissioning or after mobilization. It can also work for load rejections, to dissipate power during sudden shut downs, such as if the wellhead exceeds the maximum pressure and every frac pump needs to shut down simultaneously without warning.

With regard to equipment reduction, using an electricity storage system can allow electric fracturing operations to eliminate or reduce the use of a black start generator or supplemental generator, or a standby generator. Many times more than one large turbine generator is desired to provide power during peak demand during a hydraulic fracturing stage. Other times, a secondary generator can be held electrically isolated in standby in the event of a primary generator failure. Such secondary turbines can be replaced by the PSS, resulting in lower noise levels, less equipment on a pad, and faster mobilization times between well sites.

With regard to the reduced maintenance requirements, in some embodiments the PSS can be comprised of a solid state battery bank having very few moving parts. Thus, the PSS will require less maintenance than a generator utilizing a turbine or reciprocating engine.

With regard to the simplified fuel supply, in embodiments where the PSS is replacing a secondary or standby generator, the PSS will not require any fuel supply as it can be energized by a power grid. Therefore, any fuel connections for liquid or gas fuel can be removed from the system. This allows for a reduction in the number of connections and manifolds, as well as a reduction in the fuel volumes required during peak demand. In embodiments where the PSS replaces, for example, one of two turbines, all of the fuel equipment, hoses, and manifolding can be greatly reduced and simplified.

Although the technology herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present technology. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present technology as defined by the appended claims.

The invention claimed is:

1. A hydraulic fracturing power system, comprising:

a power source;

a power storage system;

an electric powered hydraulic fracturing pump in selective electrical communication with the power storage system; and

a circuit breaker between the power storage system and the electric powered hydraulic fracturing pump, the circuit breaker having an open position that opens an electric circuit between the electric powered hydraulic fracturing pump and the power storage system, and a closed position that closes the electric circuit, the circuit breaker varying between the open position and the closed position as required to power the electric powered hydraulic fracturing pump while the electric powered hydraulic fracturing pumps are in place at a wellsite, wherein the circuit breaker comprises a first circuit breaker, and the hydraulic fracturing power system further comprising:

a power source in selective electric al communication with the electric powered hydraulic fracturing pump, and

a second circuit breaker, wherein the second circuit breaker is electrically connected to the power source, and wherein the first circuit breaker is electrically connected to the power storage system.

2. The system of claim **1**, wherein the power storage system is at least one solid state battery selected from the group consisting of electrochemical capacitors, lithium ion batteries, nickel-cadmium batteries, and sodium sulfur batteries.

3. The system of claim **2**, wherein the power storage system is at least one flow battery selected from the group consisting of redox batteries, iron-chromium batteries, vanadium redox batteries, and zinc-bromine batteries.

4. The system of claim **3**, wherein the at least one solid state battery or the at least one flow battery is rechargeable.

5. The system of claim **1**, wherein each of the first circuit breaker and the second circuit breaker is electrically connected to the electric powered hydraulic fracturing pump via a common bus.

6. The system of claim **1**, wherein the circuit breaker comprises a first circuit breaker, and further comprising:

a power source in selective electrical communication with the electric powered hydraulic fracturing pump, wherein both the power source and the power storage system are electrically connected to the first circuit breaker.

7. The system of claim **1**, wherein the power storage system is electrically connected to the circuit breaker via a power line.

8. The system of claim **1**, wherein the power storage system is mounted to a trailer.

9. The system of claim **1**, wherein the circuit breaker is substantially enclosed in a switchgear housing.

10. A system for powering an electric hydraulic fracturing pump, comprising:

a power storage system having;

an electric powered hydraulic fracturing pump in selective electrical communication with the power storage system; and

a circuit breaker between the power storage system and the electric powered hydraulic fracturing pump, the circuit breaker configured to facilitate or prevent electrical communication between the power storage system and the electric powered hydraulic fracturing pump while the electric powered hydraulic fracturing pumps are in place at a wellsite, wherein the circuit breaker comprises a first circuit breaker, and further comprising:

a power source, and

a second circuit breaker, wherein the second circuit breaker is electrically connected to the power source, and the second circuit breaker is electrically connected to the power storage system.

11. The system of claim **10**, further comprising:

a power source, wherein both the power source and the power storage system are electrically connected to the circuit breaker, and the circuit breaker facilitates or prevents communication between the power storage system, the power source, and the electric powered hydraulic fracturing pump as required to power the electric powered hydraulic fracturing pump and maintain a charge in the power storage system.

12. The system of claim **11**, wherein at least one of the power source and the power storage system are electrically connected to the first circuit breaker or the second circuit breaker via a power line.

13. The system of claim **10**, wherein the circuit breaker is substantially enclosed in a switchgear housing.

14. The system of claim **13**, further comprising:

software in communication with the power storage system, the software configured to monitor a state of the power storage system and to integrate control of the power storage system with other features of the system for powering electric hydraulic fracturing equipment.

15. The system of claim **10**, wherein the power storage system is rechargeable.

16. The system of claim **10**, wherein the power source is electrically connected to the first circuit breaker via a power line, and wherein the power storage system is located adjacent a switchgear housing and electrically coupled directly to the switchgear housing without a power line.

17. A system for powering an electric hydraulic fracturing pump, comprising:

a power storage system having:

an electric powered hydraulic fracturing pump in selective electrical communication with the power storage system; and

a circuit breaker between the power storage system and the electric powered hydraulic fracturing pump, the circuit breaker configured to facilitate or prevent electrical communication between the power storage system and the electric powered hydraulic fracturing pump while the electric powered hydraulic fracturing pumps are in place at a wellsite, wherein the power storage system is at least one solid state battery selected from the group consisting of electrochemical capacitors, lithium ion batteries, nickel-cadmium batteries, and sodium sulfur batteries.

18. The system of claim **17**, wherein the power storage system is at least one flow battery selected from the group consisting of redox batteries, iron-chromium batteries, vanadium redox batteries, and zinc-bromine batteries.

* * * * *