



(12) **United States Patent**  
**Ben-Yaacov et al.**

(10) **Patent No.:** **US 9,127,866 B2**  
(45) **Date of Patent:** **\*Sep. 8, 2015**

(54) **HYBRID HEATING SYSTEM**

(71) Applicant: **PHOEBUS ENERGY LTD.**, Raanana (IL)

(72) Inventors: **Yoav Ben-Yaacov**, Even Yehuda (IL); **Harold Weiner**, Jerusalem (IL); **Shalom Lampert**, Maalot (IL)

(73) Assignee: **PHOEBUS ENERGY LTD.**, Petah Tikva

(\* ) 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.: **14/053,183**

(22) Filed: **Oct. 14, 2013**

(65) **Prior Publication Data**

US 2014/0102124 A1 Apr. 17, 2014

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 13/105,921, filed on May 12, 2011, now Pat. No. 8,600,563, which is a continuation-in-part of application No. PCT/IL2009/001088, filed on Nov. 18, 2009.

(60) Provisional application No. 61/115,561, filed on Nov. 18, 2008.

(51) **Int. Cl.**

**F25B 29/00** (2006.01)  
**F24D 11/02** (2006.01)  
**F24D 12/02** (2006.01)  
**F24D 19/10** (2006.01)

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

CPC ..... **F25B 29/00** (2013.01); **F24D 11/0228**

(2013.01); **F24D 12/02** (2013.01); **F24D 19/1039** (2013.01); **F24D 19/1048** (2013.01); **Y02B 10/70** (2013.01); **Y02B 30/126** (2013.01); **Y02B 30/14** (2013.01)

(58) **Field of Classification Search**

None  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,465,588 A \* 11/1995 McCahill et al. .... 62/127  
7,231,775 B2 \* 6/2007 Dilk et al. .... 62/235  
8,600,563 B2 \* 12/2013 Ben-Yaacov et al. .... 700/278

\* cited by examiner

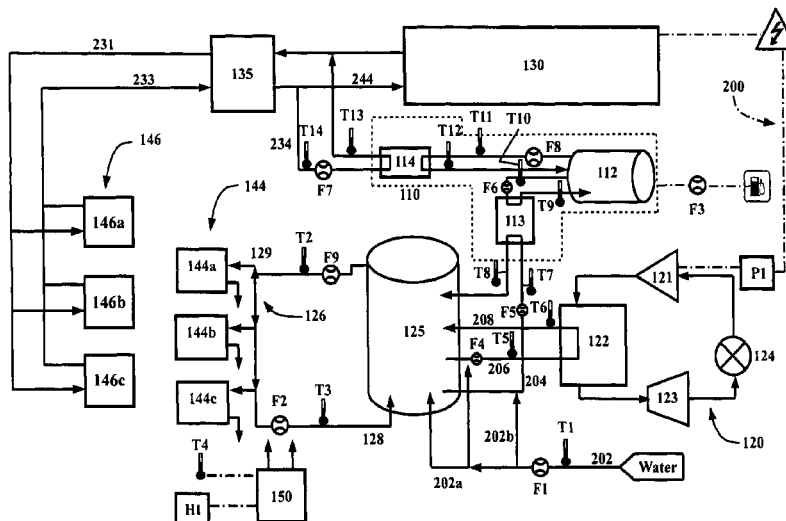
*Primary Examiner* — Sean Shechtman

(74) *Attorney, Agent, or Firm* — Marc Van Dyke

(57) **ABSTRACT**

Hybrid heating system including: a heat pump water heating system; sensors, for measuring a system parameter; an input arrangement providing cost data pertaining to a first power cost for supplying power to the heat pump system, and to cost information pertaining to a second power cost for operating a conventional heating system; a processor storing criteria specifying when to operate the heat pump and conventional systems, the processor receiving and processing: cost data; cost information; system parameter data; flow information on a heat exchange system circulation arrangement, and heat pump system power consumption information and concurrently operating, upon demand, the heat pump system and a chiller system in opposite heating modes; wherein, when the chiller system operates in a cooling mode, the processor processes the cost data and information, system parameter data, and flow and power consumption information, and controls the systems based on the criteria.

**20 Claims, 4 Drawing Sheets**





US009464414B2

(12) **United States Patent**  
**Shapira**

(10) **Patent No.:** **US 9,464,414 B2**  
(45) **Date of Patent:** **Oct. 11, 2016**

- (54) **HOUSEHOLD ELECTRONIC MIXING-VALVE DEVICE**
- (71) Applicant: **SMARTAP A.Y LTD**, Haifa (IL)
- (72) Inventor: **Yuval Shapira**, Haifa (IL)
- (73) Assignee: **SMARTAP A.Y LTD.**, Hamesila, Nesher (IL)

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

(21) Appl. No.: **14/012,379**

(22) Filed: **Aug. 28, 2013**

(65) **Prior Publication Data**  
US 2014/0069516 A1 Mar. 13, 2014

**Related U.S. Application Data**

(63) Continuation-in-part of application No. PCT/US2012/026678, filed on Feb. 27, 2012, and a continuation-in-part of application No. 13/204,805, filed on Aug. 8, 2011.

- (51) **Int. Cl.**  
**G05D 23/19** (2006.01)  
**E03C 1/04** (2006.01)  
**E03C 1/05** (2006.01)  
**F16K 11/00** (2006.01)  
**G05D 23/13** (2006.01)

- (52) **U.S. Cl.**  
CPC ..... **E03C 1/04** (2013.01); **E03C 1/055** (2013.01); **F16K 19/006** (2013.01); **G05D 23/1393** (2013.01); **Y10T 137/2499** (2015.04); **Y10T 137/2529** (2015.04); **Y10T 137/776** (2015.04); **Y10T 137/87684** (2015.04)

- (58) **Field of Classification Search**  
CPC ..... E03C 1/04; E03C 1/055; F16K 19/006; G05D 23/1393; Y10T 137/2499; Y10T 137/2521; Y10T 137/2529; Y10T 137/776; Y10T 137/87684  
USPC ..... 137/100, 101.19, 606, 487; 236/12.12  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,055,389	A *	9/1962	Brunner	137/487
3,776,265	A *	12/1973	O'Connor, Jr.	137/487.5
3,875,955	A *	4/1975	Gallatin et al.	137/14
4,061,155	A *	12/1977	Sopha	137/85
4,277,832	A *	7/1981	Wong	364/510
4,420,811	A *	12/1983	Tarnay et al.	700/285
4,674,678	A *	6/1987	Knebel et al.	236/12.12
4,693,415	A *	9/1987	Sturm	236/12.12
4,694,512	A *	9/1987	Knebel et al.	4/668
4,756,030	A *	7/1988	Juliver	4/668
4,796,651	A *	1/1989	Ginn et al.	137/8
5,033,671	A *	7/1991	Shiba et al.	236/12.12
5,190,068	A *	3/1993	Philbin	137/8

(Continued)

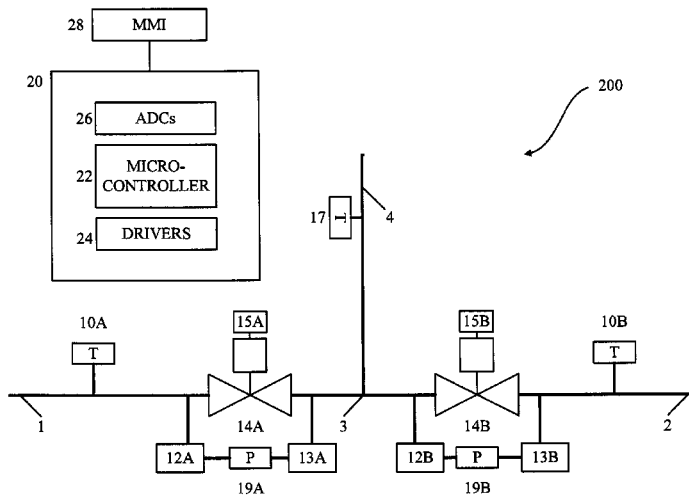
*Primary Examiner* — William McCalister

(74) *Attorney, Agent, or Firm* — Marc Van Dyke

(57) **ABSTRACT**

A household electronic mixing-valve faucet for controlling a temperature of a mixed stream discharging from the faucet, including: (a) a faucet body; (b) a controller; (c) a first powered valve fluidly connected to the hot water flowpath; (d) a second powered valve fluidly connected to the cold water flowpath; (e) an arrangement adapted to determine extents of opening of the valves; (f) temperature sensors, operative to sense a temperature of fluids within the hot and cold water flowpaths; and pressure sensors; the controller adapted to maintain a difference between an actual temperature of the mixed stream and a setpoint temperature thereof within a particular range.

**12 Claims, 8 Drawing Sheets**



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

(10) **Patent No.:** **US 10,290,433 B2**  
(45) **Date of Patent:** **May 14, 2019**

(54) **PLASTIC SOLAR DYE CELLS**  
(71) Applicant: **3GSOLAR PHOTOVOLTAICS LTD.**,  
Jerusalem (IL)  
(72) Inventors: **Barry Breen**, Givat-Zeev (IL); **Nir Stein**,  
Tel-Aviv (IL); **Ron Paz**, Rehovot (IL); **Jonathan Goldstein**,  
Jerusalem (IL)  
(73) Assignee: **3GSolar Photovoltaics Ltd**, Jerusalem  
(IL)  
(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

**H01G 9/00** (2006.01)  
**H01L 51/00** (2006.01)  
(52) **U.S. Cl.**  
CPC ..... **H01G 9/2077** (2013.01); **H01G 9/0036**  
(2013.01); **H01G 9/2031** (2013.01); **H01G**  
**9/2095** (2013.01); **H01G 9/2059** (2013.01);  
**H01L 51/003** (2013.01); **Y02E 10/542**  
(2013.01)  
(58) **Field of Classification Search**  
CPC ..... H01L 51/003  
See application file for complete search history.

(21) Appl. No.: **14/904,953**  
(22) PCT Filed: **Jul. 15, 2014**  
(86) PCT No.: **PCT/IB2014/063131**  
§ 371 (c)(1),  
(2) Date: **Jan. 14, 2016**  
(87) PCT Pub. No.: **WO2015/008227**  
PCT Pub. Date: **Jan. 22, 2015**

(56) **References Cited**  
**U.S. PATENT DOCUMENTS**  
2006/0219294 A1\* 10/2006 Yabuuchi ..... H01G 9/2031  
136/263  
2007/0209696 A1\* 9/2007 Duerr ..... H01G 9/2031  
136/252

(65) **Prior Publication Data**  
US 2016/0141113 A1 May 19, 2016

(Continued)  
**FOREIGN PATENT DOCUMENTS**  
EP 1589548 A1 10/2005  
WO 2011009631 A1 1/2011

**Related U.S. Application Data**  
(60) Provisional application No. 61/846,093, filed on Jul.  
15, 2013.

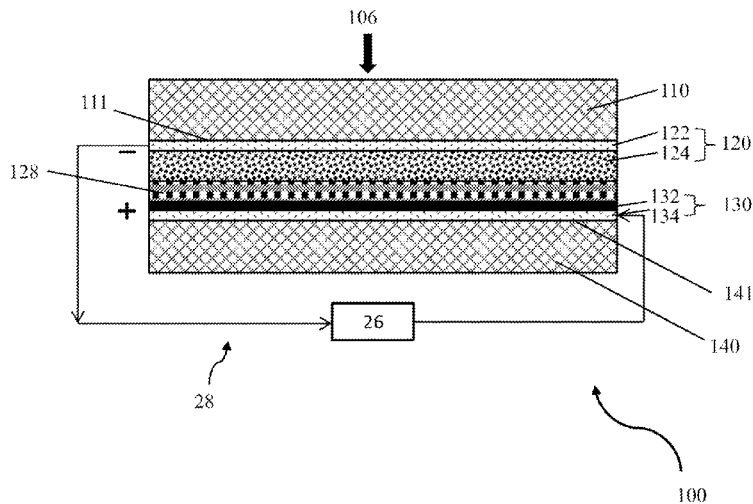
**OTHER PUBLICATIONS**  
Durr et al., "Low-temperature fabrication of dye-sensitized solar  
cells by transfer of composite porous layers," Nature Materials 4,  
607-611 (2005) (Year: 2005).\*  
(Continued)

(51) **Int. Cl.**  
**H02N 6/00** (2006.01)  
**H01L 31/042** (2014.01)  
**H01L 21/00** (2006.01)  
**H01G 9/20** (2006.01)

*Primary Examiner* — Angelo Trivisonno  
(74) *Attorney, Agent, or Firm* — Marc Van Dyke

(57) **ABSTRACT**  
Solar dye cells having a plastic housing, and methods of  
construction such solar dye cells.

**20 Claims, 12 Drawing Sheets**





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

(10) **Patent No.:** **US 9,704,653 B2**  
(45) **Date of Patent:** **Jul. 11, 2017**

- (54) **PHOTOVOLTAIC CELL**
- (71) Applicant: **3GSOLAR PHOTOVOLTAICS LTD.**,  
Jerusalem, IL (US)
- (72) Inventors: **Jonathan R. Goldstein**, Jerusalem (IL);  
**Barry Breen**, Jerusalem (IL); **Ilya Yakupov**,  
Rehovot (IL); **Eli Rosh Hodesh**, Rishon Lezion (IL); **Ron Paz**,  
Rehovot (IL)
- (73) Assignee: **3GSOLAR PHOTOVOLTAICS LTD.**,  
Jerusalem (IL)

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

(21) Appl. No.: **14/562,728**  
(22) Filed: **Dec. 7, 2014**

(65) **Prior Publication Data**  
US 2015/0243446 A1 Aug. 27, 2015

**Related U.S. Application Data**  
(63) Continuation of application No. 12/618,741, filed on Nov. 15, 2009, now abandoned, which is a (Continued)

(51) **Int. Cl.**  
**H01G 9/20** (2006.01)  
**H01L 51/44** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01G 9/2068** (2013.01); **H01G 9/2022** (2013.01); **H01G 9/2077** (2013.01); (Continued)

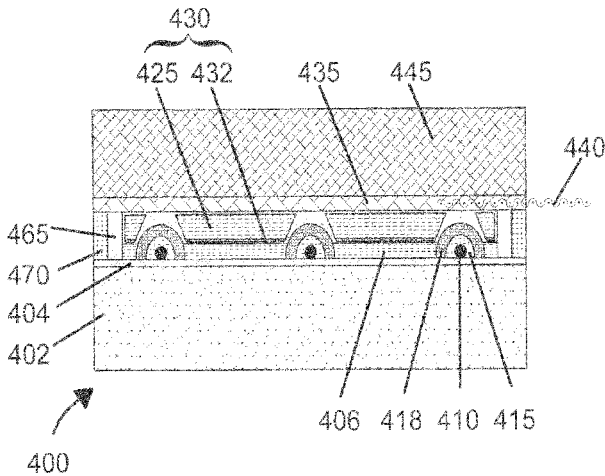
(58) **Field of Classification Search**  
CPC .. H01G 9/2013; H01G 9/2018; H01G 9/2022; H01G 9/2027; H01G 9/2031; H01G 9/2059; H01G 9/2068; H01G 9/2077  
See application file for complete search history.

- (56) **References Cited**
- U.S. PATENT DOCUMENTS
- 2003/0230337 A1\* 12/2003 Gaudiana ..... H01G 9/2031 136/256
- 2004/0163700 A1\* 8/2004 Mizuta ..... H01G 9/2013 136/263
- (Continued)

**FOREIGN PATENT DOCUMENTS**  
JP 2006107892 A \* 4/2006  
*Primary Examiner* — Bethany L Martin  
(74) *Attorney, Agent, or Firm* — Marc Van Dyke

(57) **ABSTRACT**  
A photovoltaic cell including: (a) a housing adapted to enclose the photovoltaic cell, and including an at least partially transparent cell wall; (b) an electrolyte, disposed within the cell wall, and containing a corrosive redox species; (c) an at least partially transparent conductive coating disposed on an interior surface of the cell wall, within the photovoltaic cell; (d) an anode disposed on the conductive coating, the anode including a porous film adapted to make intimate contact with the redox species, and a dye, absorbed on a surface of the porous film, the dye and the film adapted to convert photons to electrons; (e) a cathode, disposed within an interior surface of the housing and disposed substantially opposite the anode, including a conductive carbon layer, and a catalytic component, associated with the carbon layer and adapted to catalyze a redox reaction, the carbon layer adapted to transfer electrons from the catalytic component to a current collection component of the cathode, and (f) at least one metal strip or wire, electrically associated with the anode and with the conductive coating, the strip or wire having sufficient thickness to form a protrusion protruding above a plane of the porous film by at least 50 micrometers, wherein a distance between a surface of the catalytic component and a surface of the porous film is less than 20 micrometers.

**20 Claims, 20 Drawing Sheets**





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

(10) **Patent No.:** **US 9,574,092 B2**  
(45) **Date of Patent:** **Feb. 21, 2017**

(54) **SOLAR-RADIATION-ABSORBING FORMULATIONS AND RELATED APPARATUS AND METHODS**  
(75) Inventors: **Shlomo Magdassi**, Jerusalem (IL);  
**Daniel Mandler**, Jerusalem (IL);  
**Mubeen Baidossi**, Kefar Qara (IL);  
**Rachel Assa**, Moshav Ginaton (IL);  
**Ophir Chernin**, Beit Shemesh (IL);  
**Yaniv Binyamin**, Tzur Hadassah (IL)

4,278,829 A 7/1981 Powell  
4,300,532 A 11/1981 Olsen  
4,530,722 A 7/1985 Moore et al.  
4,849,298 A 7/1989 Raevsky  
5,154,769 A 10/1992 Kuske et al.  
5,196,228 A \* 3/1993 Kirby ..... C09D 183/04  
427/226  
5,250,112 A 10/1993 Wussow et al.  
5,409,777 A 4/1995 Kennedy et al.  
5,814,434 A 9/1998 Nakamura et al.  
6,632,529 B1 10/2003 Clough  
2002/0047058 A1 4/2002 Verhoff et al.  
2003/0035917 A1 2/2003 Hyman  
2004/0011252 A1 1/2004 Sturgill et al.  
2005/0107870 A1 5/2005 Wang et al.  
2006/0011490 A1\* 1/2006 Nguyen ..... C25C 3/08  
205/372  
2006/0052233 A1 3/2006 Beeckman et al.  
2006/0249705 A1 11/2006 Wang et al.  
2007/0027241 A1 2/2007 Akamatsu  
2007/0149673 A1 6/2007 Sturgill et al.  
2008/0038561 A1 2/2008 Yoshizawa et al.  
2009/0162651 A1 6/2009 Rios et al.  
2010/0139749 A1 6/2010 Mapel  
2010/0139818 A1 6/2010 Ishii et al.  
2010/0167033 A1 7/2010 Poppe et al.  
2010/0218822 A1 9/2010 Yamasaki et al.  
2010/0239871 A1 9/2010 Scheffer et al.  
2011/0017097 A1 1/2011 Ruckebusch et al.

(73) Assignee: **BrightSource Industries (Israel), Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 786 days.

(21) Appl. No.: **14/112,052**

(22) PCT Filed: **Apr. 17, 2012**

(86) PCT No.: **PCT/US2012/033878**  
§ 371 (c)(1),  
(2), (4) Date: **Jan. 24, 2014**

(87) PCT Pub. No.: **WO2012/145283**  
PCT Pub. Date: **Oct. 26, 2012**

(65) **Prior Publication Data**  
US 2014/0141236 A1 May 22, 2014

**Related U.S. Application Data**

(60) Provisional application No. 61/476,301, filed on Apr. 17, 2011.

(51) **Int. Cl.**  
**C09D 5/32** (2006.01)  
**C09D 183/16** (2006.01)  
**F24J 2/48** (2006.01)  
**C09D 7/12** (2006.01)  
**B05D 3/00** (2006.01)  
**F24J 2/07** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **C09D 5/32** (2013.01); **B05D 3/002** (2013.01); **C09D 7/1216** (2013.01); **F24J 2/485** (2013.01); **F24J 2/07** (2013.01); **Y02E 10/40** (2013.01); **Y10T 428/26** (2015.01); **Y10T 428/31612** (2015.04)

(58) **Field of Classification Search**  
CPC ..... C09D 5/32; F24J 2/485; B05D 3/002  
See application file for complete search history.

(56) **References Cited**  
**U.S. PATENT DOCUMENTS**

3,755,223 A \* 8/1973 Engel ..... C08L 63/00  
244/1 R  
4,224,355 A 9/1980 Lampkin et al.

**OTHER PUBLICATIONS**

International Search Report and Written Opinion for International Application No. PCT/US12/33878.  
Office Action issued Apr. 28, 2015, in Chinese Application No. 201280001921.9.

\* cited by examiner

*Primary Examiner* — Charles Boyer  
(74) *Attorney, Agent, or Firm* — Potomac Law Group, PLLC; Mark Catan

(57) **ABSTRACT**

Paint formulations having a high absorptivity with respect to solar radiation are disclosed herein. The disclosed paint formulations are also thermally and mechanically durable, thereby enabling the paint formulations to be used on components in solar thermal applications where exposure to high temperatures and environmental conditions may be an issue. The paint formulation can include an oxide-based pigment, an organic binder, one or more additives, an inorganic filler, and/or an organic solvent. The pigment can have a relatively high absorptivity with respect to light having a wavelength in the range from 250 nm to 3000 nm. Curing of the paint formulation can irreversibly convert the organic binder into an inorganic binder.

**18 Claims, 3 Drawing Sheets**



(12) **United States Patent**  
**Kroizer**

(10) **Patent No.:** **US 9,541,071 B2**  
(45) **Date of Patent:** **\*Jan. 10, 2017**

(54) **CONCENTRATED SOLAR POWER PLANT WITH INDEPENDENT SUPERHEATER**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventor: **Israel Kroizer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 233 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/092,130**

(22) Filed: **Nov. 27, 2013**

(65) **Prior Publication Data**

US 2014/0152024 A1 Jun. 5, 2014

**Related U.S. Application Data**

(60) Provisional application No. 61/733,019, filed on Dec. 4, 2012.

(51) **Int. Cl.**  
**F03G 6/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **F03G 6/065** (2013.01); **F03G 6/06** (2013.01); **Y02E 10/46** (2013.01); **Y02E 20/14** (2013.01)

(58) **Field of Classification Search**  
CPC ..... **F03G 6/065**; **F03G 6/06**; **Y02E 20/14**; **Y02E 10/46**

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,933,885 A 4/1960 Vago et al.  
3,977,197 A 8/1976 Brantley et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

DE 2510168 A1 9/1976  
DE 10329623 B3 1/2005  
(Continued)

OTHER PUBLICATIONS

Abengoa Solar, Inc., "Advanced Thermal Storage for Central Receivers with Supercritical Coolants," Grant DE-FG36-08G018149, Jun. 2010.

(Continued)

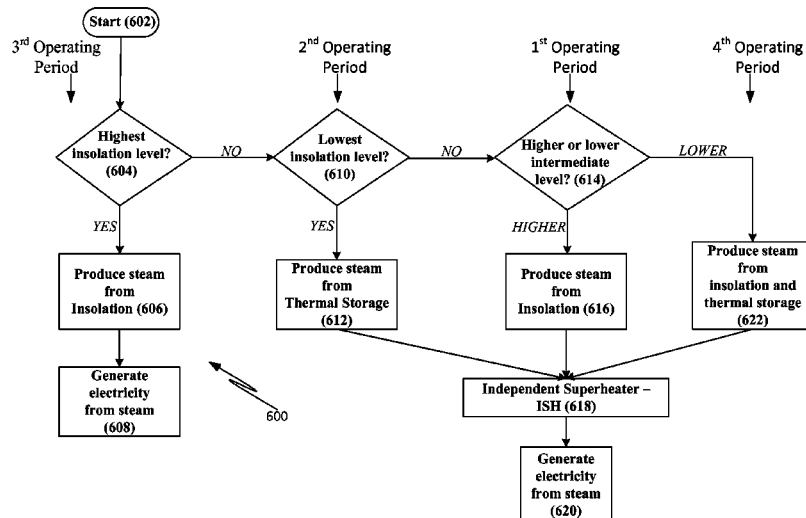
*Primary Examiner* — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Potomac Law Group, PLLC; Mark Catan

(57) **ABSTRACT**

Steam can be generated using insolation by a solar collection system. A thermal storage system can store enthalpy in insolation-generated steam at times and can generate steam from stored enthalpy at other times. During some operating periods, a gas-fired superheater can further heat the generated steam to provide superheated steam to generate electricity. Steam at a substantially uniform electricity generating temperature may be produced selectively and at different operating periods from insolation only, from insolation and gas firing, from transfer of enthalpy from a thermal storage system and gas firing, or from a combination of insolation, stored enthalpy transfer, and gas firing. Operating periods can be characterized by at least one of an insolation level, a time of day, or a stage in the operation process. The generated steam can be used in the production of electricity.

**20 Claims, 8 Drawing Sheets**



(12) **United States Patent**  
**Goldstein**

(10) **Patent No.:** **US 9,530,572 B2**  
(45) **Date of Patent:** **Dec. 27, 2016**

- (54) **SOLAR CELL DEVICE**
- (71) Applicant: **3GSOLAR PHOTOVOLTAICS LTD.,**  
Jerusalem (IL)
- (72) Inventor: **Jonathan Goldstein,** Jerusalem (IL)
- (73) Assignee: **3GSOLAR PHOTOVOLTAICS LTD.,**  
Jerusalem (IL)
- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
- (21) Appl. No.: **15/089,597**
- (22) Filed: **Apr. 4, 2016**
- (65) **Prior Publication Data**  
US 2016/0293344 A1 Oct. 6, 2016

**Related U.S. Application Data**

- (63) Continuation of application No. 14/658,661, filed on Mar. 16, 2015, now Pat. No. 9,305,714, which is a continuation of application No. 14/082,460, filed on Nov. 18, 2013, now Pat. No. 8,981,206, which is a continuation of application No. 12/814,523, filed on (Continued)

**Foreign Application Priority Data**

- (30) Jan. 12, 2003 (IL) ..... 153895
- (51) **Int. Cl.**  
**H01G 9/20** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **H01G 9/2077** (2013.01); **H01G 9/2018** (2013.01); **H01G 9/2031** (2013.01)

(58) **Field of Classification Search**  
CPC . H01L 31/048; H01L 31/0485; H01L 31/0488  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

- 4,115,917 A \* 9/1978 Charon ..... H05B 3/145  
156/291
- 4,117,210 A \* 9/1978 Deb ..... H01M 14/005  
429/111

(Continued)

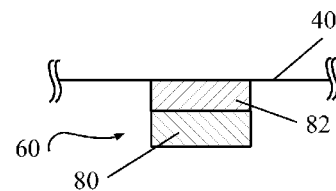
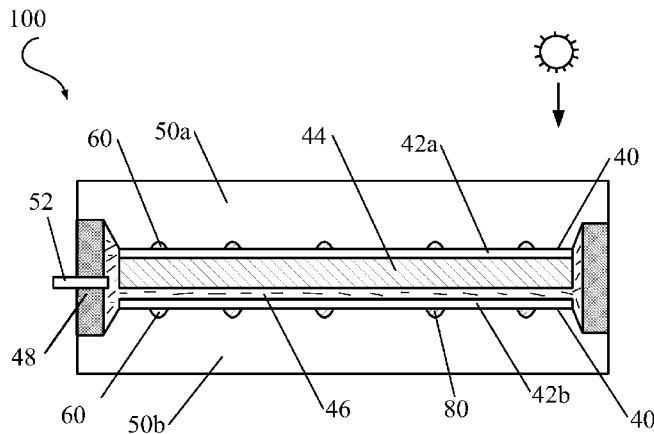
*Primary Examiner* — Golam Mowla

(74) *Attorney, Agent, or Firm* — Marc Van Dyke

(57) **ABSTRACT**

A photovoltaic cell including: (a) a housing including an at least partially transparent cell wall having an interior surface; (b) an electrolyte, disposed within the cell wall, and containing an iodide based species; (c) a transparent electrically conductive coating disposed on the interior surface; (d) an anode disposed on the conductive coating, the anode including: (i) a porous film containing titania, the porous film adapted to make intimate contact with the iodide based species, and (ii) a dye, absorbed on a surface of the porous film, the dye and the porous film adapted to convert photons to electrons; (e) a cathode disposed on an interior surface of the housing, and disposed substantially opposite the anode; (f) electrically-conductive metallic wires, disposed at least partially within the cell, the wires electrically contacting the anode and the electrically conductive coating, and (g) a second electrically conductive coating including an inorganic binder and an inorganic electrically conductive filler, the second coating bridging between and electrically communicating between each of the wires and the transparent coating, the wires adapted to boost collection of a current generated by the cell.

**20 Claims, 8 Drawing Sheets**





(12) **United States Patent**  
**Goldstein**

(10) **Patent No.:** **US 9,305,714 B2**  
(45) **Date of Patent:** **Apr. 5, 2016**

- (54) **SOLAR CELL DEVICE**
- (71) Applicant: **3GSOLAR PHOTOVOLTAICS LTD.**,  
Jerusalem (IL)
- (72) Inventor: **Jonathan Goldstein, II (IL)**
- (73) Assignee: **3GSOLAR PHOTOVOLTAICS LTD.**,  
Har Hotzvim Industrial Park, Jerusalem
- (\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.
- (21) Appl. No.: **14/658,661**
- (22) Filed: **Mar. 16, 2015**
- (65) **Prior Publication Data**  
US 2015/0287542 A1 Oct. 8, 2015

**Related U.S. Application Data**

- (63) Continuation of application No. 14/082,460, filed on  
Nov. 18, 2013, now Pat. No. 8,981,206, which is a  
continuation of application No. 12/814,523, filed on  
Jun. 14, 2010, now Pat. No. 8,586,861, which is a  
  
(Continued)

**Foreign Application Priority Data**

- (30) Jan. 12, 2003 (IL) ..... 153895
- (51) **Int. Cl.**  
**H01G 9/20** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **H01G 9/2031** (2013.01); **H01G 9/2068**  
(2013.01); **Y02E 10/542** (2013.01)
- (58) **Field of Classification Search**  
CPC ..... H01L 31/048; H01L 31/0485; H01L  
31/0488  
USPC ..... 136/251, 252, 256, 263  
See application file for complete search history.

- (56) **References Cited**  
  
U.S. PATENT DOCUMENTS  
  
4,115,917 A \* 9/1978 Charon ..... H05B 3/145  
156/291  
4,117,210 A \* 9/1978 Deb ..... H01M 14/005  
429/111  
4,199,637 A \* 4/1980 Sado ..... B29C 47/0004  
200/511  
4,369,730 A \* 1/1983 Izu ..... C23C 16/545  
118/50.1  
4,426,339 A \* 1/1984 Kamath ..... H01C 7/027  
219/549  
4,541,905 A \* 9/1985 Kuwana ..... C25B 11/0489  
204/290.11

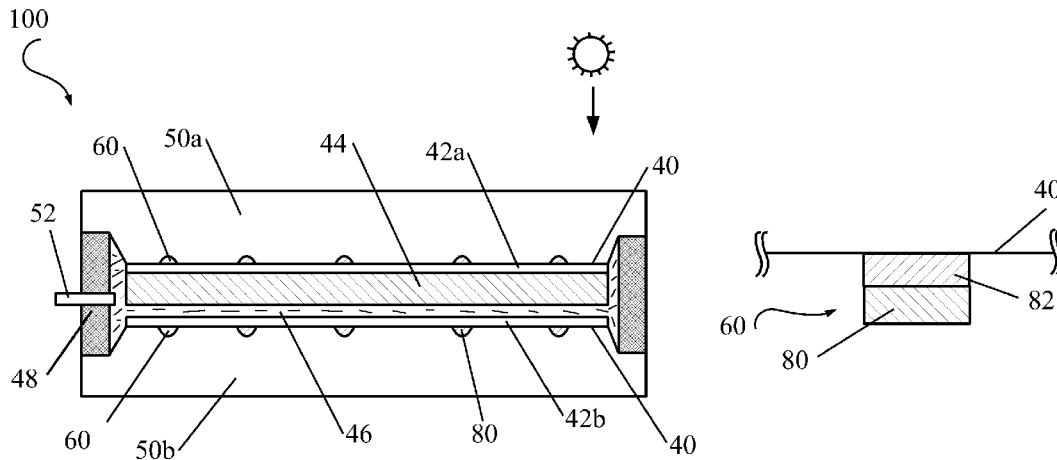
(Continued)

*Primary Examiner* — Golam Mowla  
(74) *Attorney, Agent, or Firm* — Marc Van Dyke

**ABSTRACT**

(57) A photovoltaic cell including: (a) a housing including an at least partially transparent cell wall having an interior surface; (b) an electrolyte, disposed within the cell wall, and containing an iodide based species; (c) a transparent electrically conductive coating disposed on the interior surface; (d) an anode disposed on the conductive coating, the anode including: (i) a porous film containing titania, the porous film adapted to make intimate contact with the iodide based species, and (ii) a dye, absorbed on a surface of the porous film, the dye and the porous film adapted to convert photons to electrons; (e) a cathode disposed on an interior surface of the housing, and disposed substantially opposite the anode; (f) electrically-conductive metallic wires, disposed at least partially within the cell, the wires electrically contacting the anode and the electrically conductive coating, and (g) a second electrically conductive coating including an inorganic binder and an inorganic electrically conductive filler, the second coating bridging between and electrically communicating between each of the wires and the transparent coating, the wires adapted to boost collection of a current generated by the cell.

**18 Claims, 8 Drawing Sheets**







US009249785B2

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

(10) **Patent No.:** **US 9,249,785 B2**  
(45) **Date of Patent:** **Feb. 2, 2016**

(54) **METHOD AND SYSTEM FOR OPERATING A SOLAR STEAM SYSTEM DURING REDUCED-INSOLATION EVENTS**

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventors: **Elon Silberstein**, Arad (IL); **Rotem Hayut**, Jerusalem (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISREAL) LTD.**, Jerusalem (IL)

OTHER PUBLICATIONS

“Mean and Peak Wind Load Reduction on Heliostats,” Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 229 days.

(21) Appl. No.: **13/728,328**

(22) Filed: **Dec. 27, 2012**

(65) **Prior Publication Data**

US 2013/0192589 A1 Aug. 1, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/593,123, filed on Jan. 31, 2012.

(51) **Int. Cl.**

**F03G 6/06** (2006.01)  
**F01K 13/02** (2006.01)  
**F22G 5/12** (2006.01)

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

CPC . **F03G 6/06** (2013.01); **F01K 13/02** (2013.01);  
**F03G 6/065** (2013.01); **F22G 5/12** (2013.01);  
**Y02E 10/46** (2013.01)

(58) **Field of Classification Search**

CPC ..... **Y02E 10/40–10/46**; **F24J 2/40–2/407**;  
**F22B 35/104**; **F22B 1/006**; **F03G 6/003**;  
**F03G 6/065**

USPC ..... **60/600**, **641.8–641.15**; **126/569–620**  
See application file for complete search history.

Primary Examiner — Thomas Denion

Assistant Examiner — Laert Dounis

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.;  
Mark A. Catan

(57)

**ABSTRACT**

A solar energy system can be controlled during periods of reduced insolation. For example, one or more environmental condition sensors can detect environmental properties indicating current or expected insolation levels and can generate at least one signal indicating a current or impending transient reduced-insolation event. The at least one signal can be received (for example, by a controller) from the sensors that indicates changes in insolation. Responsively to the at least one signal, characteristics of a current reduced insolation event or of an impending transient reduced-insolation event can be calculated. In response to the calculated characteristics, a quantity of available insolation can be calculated. An attemperation flow rate in the solar steam system can be controlled responsively to the calculated quantity of available insolation such that the temperature of steam entering the steam turbines is maintained within a predefined range.

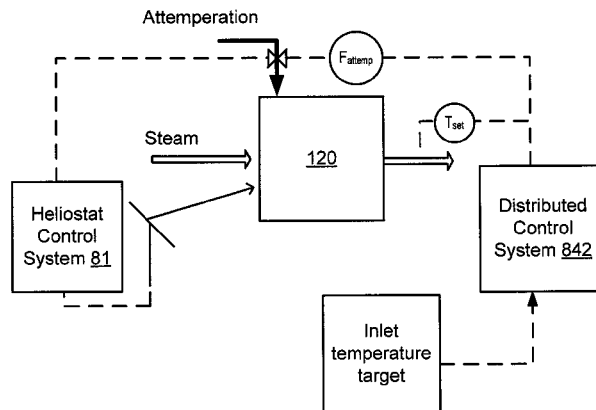
(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

(Continued)

**18 Claims, 12 Drawing Sheets**



(12) **United States Patent**  
**Goldberg**

(10) **Patent No.:** **US 9,222,702 B2**  
(45) **Date of Patent:** **Dec. 29, 2015**

(54) **SYSTEMS AND METHODS FOR CONTROL AND CALIBRATION OF A SOLAR POWER TOWER SYSTEM**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventor: **Nitzan Goldberg**, Jerusalem (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 431 days.

(21) Appl. No.: **13/686,630**

(22) Filed: **Nov. 27, 2012**

(65) **Prior Publication Data**  
US 2013/0139804 A1 Jun. 6, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/565,883, filed on Dec. 1, 2011.

(51) **Int. Cl.**  
**F24J 2/38** (2014.01)

(52) **U.S. Cl.**  
CPC ..... **F24J 2/38** (2013.01); **F24J 2002/385** (2013.01); **F24J 2200/04** (2013.01); **Y02E 10/47** (2013.01)

(58) **Field of Classification Search**  
CPC ..... F24J 2/38; F24J 2/40; F24J 2/542; F24J 2/5424; F24J 2200/04; F24J 2002/385; Y02E 10/41; Y02E 10/47; G01S 3/7861  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004  
EP 0106688 3/1985  
(Continued)

OTHER PUBLICATIONS

“Mean and Peak Wind Load Reduction on Heliostats,” Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

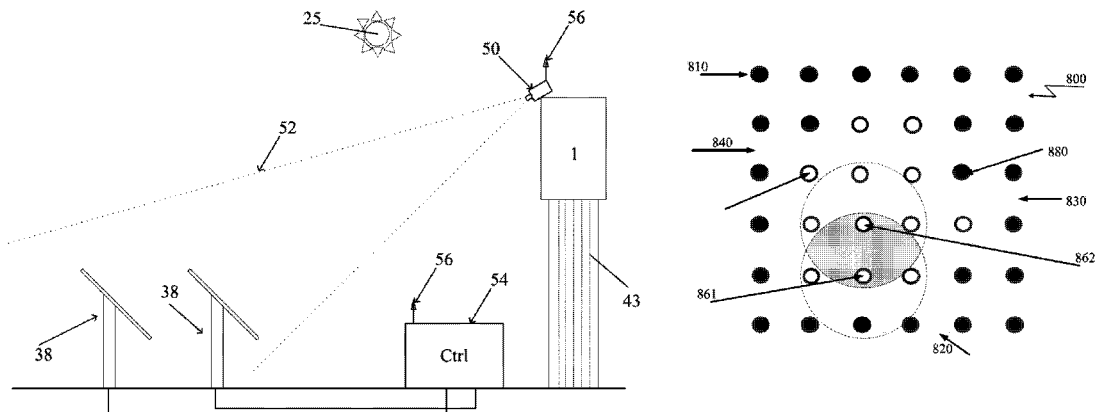
(Continued)

*Primary Examiner* — Alfred Basicas  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system can include a plurality of heliostats configured to reflect sunlight to a target mounted on a tower. Each of the heliostats can have a heliostat controller configured to control a respective heliostat so that the sunlight reflected therefrom is directed to at least one of a plurality of cameras. The cameras can be oriented to image the heliostat. A second controller can be configured to compute geometry data that defines a geometry of the surface of the heliostat from captured images thereof. The geometry data can designate a plurality of subsections of the surface. The computing by the second controller can include storing data indicating sections of the captured images corresponding to the plurality of subsections of the heliostat. The second controller can also calculate data indicating respective surface normals of each of said subsections of each of said heliostat.

**20 Claims, 8 Drawing Sheets**





US009161385B2

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

(10) **Patent No.:** **US 9,161,385 B2**  
(45) **Date of Patent:** **Oct. 13, 2015**

(54) **SYSTEMS AND METHODS FOR WIRELESS COMMUNICATIONS IN A SOLAR FIELD**

Y02B 90/2638; Y02B 90/2653; F24J 2/40; F24J 2002/0084; F24J 2200/04; C10J 2300/123; C10J 2300/1292; G02B 19/0042; G01R 22/063; H04W 16/18; H04W 84/12; H02G 1/00; H02J 3/383; H02J 3/385; H02J 7/0052; H02J 7/35; H02J 13/0024; H02J 13/0062; H02J 13/0075

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

USPC ..... 370/310-350  
See application file for complete search history.

(72) Inventors: **Yossi Azancot**, Jerusalem (IL); **Lev Razamat**, Rishon Letziyon (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(56) **References Cited**

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 135 days.

U.S. PATENT DOCUMENTS

(21) Appl. No.: **14/088,529**

2004/0054774 A1 3/2004 Barber et al.  
2008/0084858 A1 4/2008 Hart et al.  
2009/0137221 A1 5/2009 Nanda et al.

(Continued)

(22) Filed: **Nov. 25, 2013**

OTHER PUBLICATIONS

(65) **Prior Publication Data**

US 2014/0146741 A1 May 29, 2014

International Search Report and Written Opinion for International Application No. PCT/IB13/60389, mailed May 12, 2014.

**Related U.S. Application Data**

*Primary Examiner* — Tri H Phan

(60) Provisional application No. 61/729,701, filed on Nov. 26, 2012.

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(51) **Int. Cl.**

**H04B 7/00** (2006.01)  
**H04B 7/185** (2006.01)  
**H04W 4/00** (2009.01)  
**H04W 84/12** (2009.01)  
**H04W 16/18** (2009.01)

(57) **ABSTRACT**

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

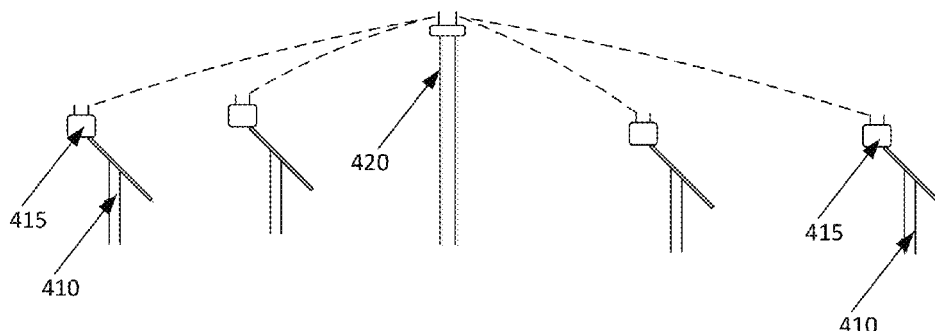
CPC ..... **H04W 84/12** (2013.01); **H04W 16/18** (2013.01)

Embodiments relate to methods and systems of controlling and operating a wirelessly controlled solar field. By placing a higher density of access points in regions close to the solar field border, communication interference may be mitigated. A method of mitigating interference between an access point and a heliostat in a wireless communication system located in a solar field, may include in a first section of the solar field, deploying a first plurality of access points such that each of the access points is a first distance from its neighbor; and in a second section of the solar field, deploying a second plurality of access points such that each of the access points is a second distance from its neighbor. The first distance is greater than the second distance and the second section of the solar field may be closer to a perimeter of the solar field.

(58) **Field of Classification Search**

CPC ..... Y02E 10/40; Y02E 40/00; Y02E 40/72; Y04S 10/30; Y04S 10/40123; Y04S 20/34; Y04S 20/40; Y04S 20/52; Y04S 20/322; Y04S 20/525; Y04S 40/122; Y04S 1/24; Y04S 1/126; Y02B 70/343; Y02B 70/3208; Y02B 90/242; Y02B 90/248; Y02B 90/2623;

**27 Claims, 10 Drawing Sheets**





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

(10) **Patent No.:** **US 9,046,307 B2**  
(45) **Date of Patent:** **Jun. 2, 2015**

(54) **INTEGRATED SOLAR ENERGY THERMAL STORAGE SYSTEM AND METHODS**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventors: **Moshe Luz**, Petach Tikva (IL); **Alon Ganany**, Tel Aviv (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 226 days.

(21) Appl. No.: **13/873,319**

(22) Filed: **Apr. 30, 2013**

(65) **Prior Publication Data**

US 2013/0292084 A1 Nov. 7, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/641,739, filed on May 2, 2012.

(51) **Int. Cl.**

**F03G 6/00** (2006.01)  
**F01K 1/00** (2006.01)  
**F28D 20/00** (2006.01)  
**F03G 6/06** (2006.01)  
**F24J 2/07** (2006.01)  
**F24J 2/40** (2006.01)  
**F24J 2/16** (2006.01)  
**F24J 2/10** (2006.01)

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

CPC **F28D 20/00** (2013.01); **F03G 6/06** (2013.01); **F28D 2020/0047** (2013.01); **F24J 2/07** (2013.01); **F24J 2/16** (2013.01); **F24J 2/40** (2013.01); **F24J 2002/1076** (2013.01); **Y02E 10/41** (2013.01)

(58) **Field of Classification Search**

CPC ... **F28D 20/00**; **F28D 2020/0047**; **F03G 6/06**; **F24J 2/40**; **F24J 2/07**; **F24J 2/16**; **F24J 2002/1076**; **Y02E 10/41**  
USPC ..... **60/641.8–641.15, 659**  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,455,826 A \* 6/1984 Knoos ..... 60/526  
7,191,597 B2 \* 3/2007 Goldman ..... 60/641.8  
7,654,073 B2 \* 2/2010 Primlani ..... 60/39.183  
2011/0153095 A1 \* 6/2011 Rock et al. .... 700/286  
2012/0319410 A1 \* 12/2012 Ambrosek et al. .... 290/1 R

\* cited by examiner

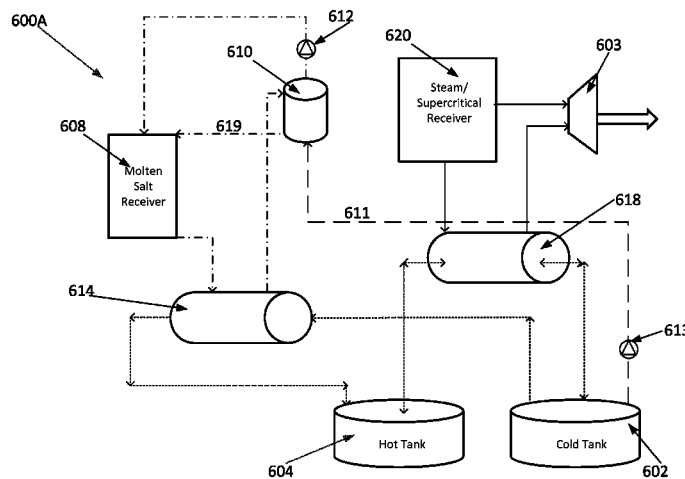
*Primary Examiner* — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy thermal storage system can include a receiver in which a first storage medium is heated by insolation. First and second thermal storage reservoirs for a second storage medium can be provided. A first heat exchanger can be configured to transfer heat in the first storage medium to the second storage medium. A buffer tank can be located at a height above the receiver and can be fluidically connected to the first heat exchanger at its inlet and the receiver at its outlet. A second heat exchanger can be configured to transfer heat between the second storage medium and pressurized water and/or steam. The use of a buffer tank in conjunction with the first storage medium increases the overall efficiency of the system and results in a higher temperature for the thermal storage system, which can be used to generate superheated steam.

**22 Claims, 7 Drawing Sheets**





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

(10) **Patent No.:** **US 9,003,795 B2**  
(45) **Date of Patent:** **Apr. 14, 2015**

(54) **METHOD AND APPARATUS FOR OPERATING A SOLAR STEAM SYSTEM**

USPC ..... 60/641.1-641.15, 641.8, 664, 645;  
126/600, 617, 601, 605, 610  
See application file for complete search history.

(75) Inventors: **Sami Katz**, Kiryat Bialik (IL); **Israel Kroizer**, Jerusalem (IL)

(56) **References Cited**

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

U.S. PATENT DOCUMENTS

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 31 days.

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **13/511,158**

DE 10248068 5/2004  
EP 0106688 3/1985

(22) PCT Filed: **Nov. 23, 2010**

(Continued)

(86) PCT No.: **PCT/IB2010/055368**

OTHER PUBLICATIONS

§ 371 (c)(1),  
(2), (4) Date: **May 22, 2012**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://beb.es/documentos/descargar.php?id=29>.

(87) PCT Pub. No.: **WO2011/064718**

PCT Pub. Date: **Jun. 3, 2011**

(Continued)

(65) **Prior Publication Data**

US 2012/0227401 A1 Sep. 13, 2012

*Primary Examiner* — Thomas Denion

*Assistant Examiner* — Kelsey Stanek

**Related U.S. Application Data**

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(60) Provisional application No. 61/264,055, filed on Nov. 24, 2009.

(57) **ABSTRACT**

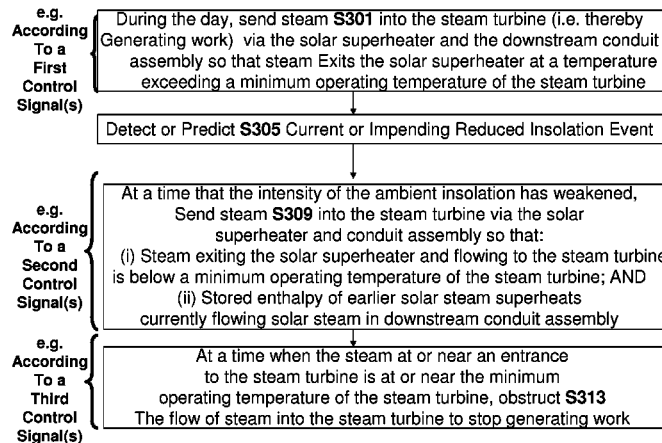
(51) **Int. Cl.**  
**B60K 16/00** (2006.01)  
**F24J 2/07** (2006.01)  
**F24J 2/16** (2006.01)

The disclosed subject matter relates to methods and systems for operating a solar steam system in response to a detected or predicted reduced insolation condition (for example, sunset or a cloud condition). In some embodiments, for a period of time, enthalpy stored within a solid material of a conduit via which steam travels en route to a steam turbine is used to heat the steam to drive the turbine. In some embodiments, a net migration of heliostats away from the steam superheater is carried out in response to the detected or predicted reduced insolation condition.

(52) **U.S. Cl.**  
CPC .. **F24J 2/07** (2013.01); **Y02E 10/41** (2013.01);  
**F24J 2/16** (2013.01); **Y02E 10/46** (2013.01)

(58) **Field of Classification Search**  
CPC ..... F03G 6/003; F03G 6/065; F22B 1/006;  
F24J 2/07; F24J 2/16; Y02E 10/41; Y02E  
10/46

**20 Claims, 27 Drawing Sheets**



(12) **United States Patent**  
**Goldstein**

(10) **Patent No.:** **US 8,981,206 B2**  
(45) **Date of Patent:** **\*Mar. 17, 2015**

(54) **SOLAR CELL DEVICE**  
(71) Applicant: **3GSolar Photovoltaics Ltd.**, Jerusalem (IL)  
(72) Inventor: **Jonathan Goldstein**, Jerusalem (IL)  
(73) Assignee: **3GSolar Photovoltaics Ltd.**, Jerusalem (IL)  
(\*) 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.

(58) **Field of Classification Search**  
USPC ..... 136/251, 252, 256, 259; 257/433; 438/64, 66, 98  
See application file for complete search history.

(56) **References Cited**  
U.S. PATENT DOCUMENTS  
4,199,637 A \* 4/1980 Sado ..... 428/119  
5,350,644 A \* 9/1994 Graetzel et al. .... 429/111  
5,441,827 A \* 8/1995 Graetzel et al. .... 429/111  
6,069,313 A \* 5/2000 Kay ..... 136/249  
6,291,763 B1 \* 9/2001 Nakamura ..... 136/256  
6,358,438 B1 \* 3/2002 Isozaki et al. .... 252/511  
6,376,765 B1 \* 4/2002 Wariishi et al. .... 136/263  
6,384,321 B1 \* 5/2002 Mikoshiba et al. .... 136/263

(21) Appl. No.: **14/082,460**  
(22) Filed: **Nov. 18, 2013**  
(65) **Prior Publication Data**  
US 2014/0124026 A1 May 8, 2014

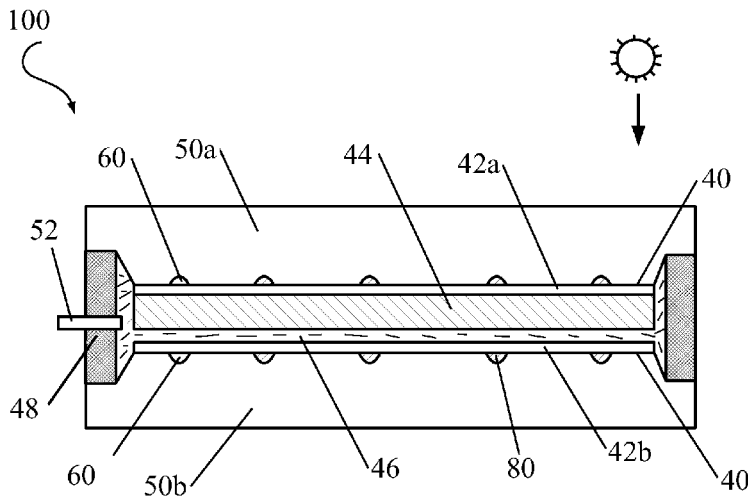
(Continued)  
*Primary Examiner* — Golam Mowla  
(74) *Attorney, Agent, or Firm* — Marc Van Dyke

**Related U.S. Application Data**  
(63) Continuation of application No. 12/814,523, filed as application No. PCT/IL2008/001550 on Nov. 26, 2008, now Pat. No. 8,586,861, and a continuation-in-part of application No. 12/744,914,  
(Continued)

(57) **ABSTRACT**  
A photovoltaic cell including: (a) a housing including an at least partially transparent cell wall having an interior surface; (b) an electrolyte, containing an iodide based species; (c) a transparent electrically conductive coating disposed on the interior surface; (d) an anode disposed on the conductive coating, the anode including: (i) a porous film containing titania, the porous film adapted to make intimate contact with the iodide based species, and (ii) a dye, absorbed on a surface of the porous film, the dye and the porous film adapted to convert photons to electrons; (e) a cathode disposed on an interior surface of the housing; (f) electrically-conductive metallic wires, disposed within the cell, and electrically contacting the anode and the coating, and (g) a second electrically conductive coating including an inorganic binder and an inorganic electrically conductive filler, the second coating bridging between each of the wires and the transparent coating.

(30) **Foreign Application Priority Data**  
Jan. 12, 2003 (IL) ..... 153895  
(51) **Int. Cl.**  
**H01G 9/20** (2006.01)  
(52) **U.S. Cl.**  
CPC ..... **H01G 9/2031** (2013.01); **H01G 9/2068** (2013.01); **Y02E 10/542** (2013.01)  
USPC ..... **136/251**; 136/252; 136/256; 136/259; 438/64; 438/66; 438/98; 257/433

**20 Claims, 8 Drawing Sheets**





US008931475B2

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

(10) **Patent No.:** **US 8,931,475 B2**  
(45) **Date of Patent:** **Jan. 13, 2015**

(54) **SYSTEMS AND METHODS FOR CONTROL OF A SOLAR POWER TOWER USING INFRARED THERMOGRAPHY**

USPC ..... 431/600, 603, 680, 681, 696, 701, 714;  
126/572, 601, 584, 604, 605, 600, 603,  
126/680, 681, 696, 701, 714

See application file for complete search history.

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Ophir Chernin**, Ramat Beit Shemesh (IL); **Gideon Goldwine**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL); **Rotem Hayut**, Jerusalem (IL); **Dan Franck**, Modi'in (IL); **Israel Kroizer**, Jerusalem (IL); **Ziv Aumann**, Jerusalem (IL)

(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

OTHER PUBLICATIONS

Cohen et al., "Final Report on the Operation and Maintenance Improvement Project for Concentrating Solar Power Plants," SAND99-1290 [online], Jun. 1999 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://infohouse.p2ric.org/ref/17/16933/1693301.pdf>>.

(Continued)

*Primary Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

Systems and methods for directly monitoring energy flux of a solar receiver in a solar energy-based power generation system include measuring infrared radiation emanating from the solar receiver. Such measurement can be achieved using one or more infrared thermography detectors, such as an IR camera. Resulting thermal data obtained by the imaging can be used to determine energy flux distribution on the receiver. A user or a system controller can use the determined flux distribution to adjust heliostat aiming to achieve a desired operation condition. For example, heliostats can be adjusted to achieve a uniform energy flux distribution across the external surface of the receiver and/or to maximize heat transfer to a fluid flowing through the receiver within system operating limits.

**27 Claims, 6 Drawing Sheets**

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1228 days.

(21) Appl. No.: **12/500,101**

(22) Filed: **Jul. 9, 2009**

(65) **Prior Publication Data**

US 2010/0006087 A1 Jan. 14, 2010

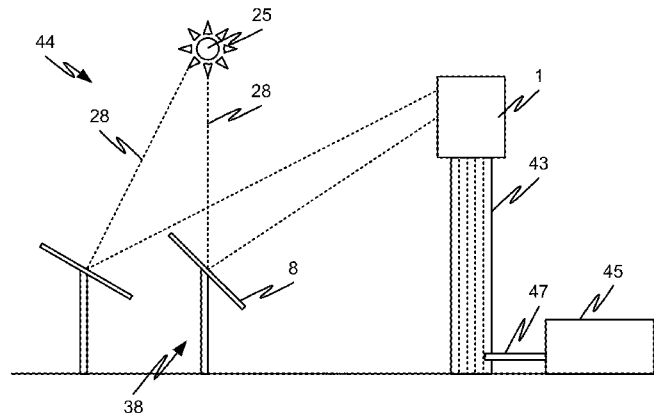
**Related U.S. Application Data**

(60) Provisional application No. 61/079,441, filed on Jul. 10, 2008.

(51) **Int. Cl.**  
**F24J 2/07** (2006.01)  
**F24J 2/10** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC .... **F24J 2/07** (2013.01); **F24J 2/10** (2013.01);  
**F24J 2/402** (2013.01); **F24J 2/38** (2013.01);  
**Y02E 10/41** (2013.01); **Y02E 10/47** (2013.01)  
USPC ..... **126/572**; 126/600; 126/603; 126/680;  
126/601; 126/701

(58) **Field of Classification Search**  
CPC ..... F24J 2/402; F24J 2/07; F24J 2/10;  
F24J 2/38; Y02E 10/41





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

(10) **Patent No.:** **US 8,739,775 B2**  
(45) **Date of Patent:** **Jun. 3, 2014**

(54) **DEVICES, METHODS, AND SYSTEMS FOR CONTROL OF HELIOSTATS**

(75) Inventors: **Gil Kroyzer**, Jerusalem (IL); **Rotem Hayut**, Yavne (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 856 days.

(21) Appl. No.: **12/867,552**

(22) PCT Filed: **Feb. 17, 2009**

(86) PCT No.: **PCT/US2009/034323**

§ 371 (c)(1),  
(2), (4) Date: **Oct. 12, 2010**

(87) PCT Pub. No.: **WO2009/103077**

PCT Pub. Date: **Aug. 20, 2009**

(65) **Prior Publication Data**

US 2011/0036343 A1 Feb. 17, 2011

**Related U.S. Application Data**

(60) Provisional application No. 61/028,525, filed on Feb. 14, 2008.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **126/601**; 126/574; 126/593; 126/599

(58) **Field of Classification Search**  
USPC ..... 126/571–577, 593, 599, 600–603, 126/605–607

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://ccb.es/documentos/descargar.php?id=29>.

(Continued)

*Primary Examiner* — Scott J Sugarman

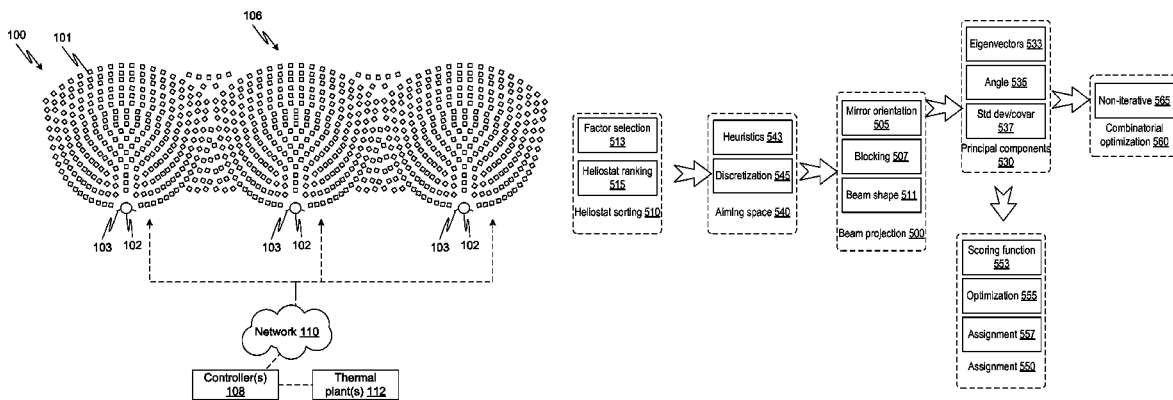
*Assistant Examiner* — Robert E Tallman

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge, P.C.; Mark A. Catan

(57) **ABSTRACT**

Adherence to flux or resultant measurable parameter limits, ranges, or patterns can be achieved by directing heliostat mounted mirrors to focus on aiming points designated on the surface of a solar receiver. Different heliostats can be directed to different aiming points, and a heliostat can be directed to different aiming points at different times. The cumulative flux distribution resulting from directing a plurality of heliostats to any aiming point on a receiver surface can be predicted by using statistical methods to calculate the expected beam projection for each individual heliostat or alternatively for a group of heliostats. Control of the heliostats in a solar power system can include designating aiming points on a receiver from time to time and assigning heliostats to aiming points from time to time in accordance with an optimization goal.

**26 Claims, 5 Drawing Sheets**







US008627664B2

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

(10) **Patent No.:** **US 8,627,664 B2**  
(45) **Date of Patent:** **Jan. 14, 2014**

(54) **METHOD AND SYSTEM FOR OPERATING A SOLAR STEAM SYSTEM**

(75) Inventors: **Sami Katz**, Kiriati-Bialik (IL); **Israel Kroizer**, Jerusalem (IL)

(73) Assignee: **BrightSource Industries (Israel), Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 448 days.

(21) Appl. No.: **12/905,789**

(22) Filed: **Oct. 15, 2010**

(65) **Prior Publication Data**  
US 2011/0088396 A1 Apr. 21, 2011

**Related U.S. Application Data**

(60) Provisional application No. 61/252,121, filed on Oct. 15, 2009.

(51) **Int. Cl.**  
**F03G 6/00** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **60/641.8**; 60/641.11; 60/641.13;  
60/641.14; 60/641.15

(58) **Field of Classification Search**  
USPC ..... 60/641.8, 641.11–641.15, 653,  
60/677–679, 663, 666; 126/585, 593, 595,  
126/601  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
3,892,433 A 7/1975 Blake  
3,924,604 A 12/1975 Anderson

4,034,735 A 7/1977 Waldrip  
4,044,753 A 8/1977 Fletcher et al.  
4,102,326 A 7/1978 Sommer  
4,117,682 A 10/1978 Smith  
4,146,785 A 3/1979 Neale  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith  
4,227,513 A 10/1980 Blake et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

Lopez-Martinez et al., "Vision-based system for the safe operation of a solar power tower plant," Iberamia, 2002, LNAI 2527: pp. 943-952.\*

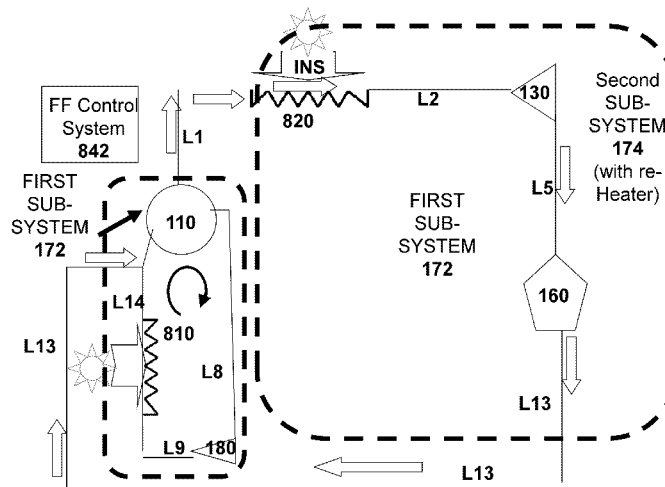
(Continued)

*Primary Examiner* — Thomas Denion  
*Assistant Examiner* — Philip Eklem  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.;  
Mark A. Catan

(57) **ABSTRACT**

Methods, apparatus and systems for operating a solar steam system in response to a detected or predicted reduced or impending reduced insolation event are disclosed herein. Examples of transient reduced insolation events include but are not limited to cloud-induced reduction in insolation, dust-induced reduction in insolation, and insolation events caused by solar eclipses. In some embodiments, in response to the detecting or predicting, steam flow is regulated within the solar steam system to reduce a flow rate into a steam turbine. Alternatively or additionally, one or more heliostats may be responsively redirected onto a steam superheater or steam re-heater.

**3 Claims, 33 Drawing Sheets**





US008544272B2

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

(10) **Patent No.:** **US 8,544,272 B2**  
(45) **Date of Patent:** **Oct. 1, 2013**

(54) **SOLAR RECEIVER**

(56) **References Cited**

(75) Inventors: **Israel Kroizer**, Jerusalem (IL); **Gabriel Kaufmann**, Beit Hananya (IL); **Leon Afremov**, Yehud (IL); **Yoel Gilon**, Jerusalem (IL)

U.S. PATENT DOCUMENTS  
811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

FOREIGN PATENT DOCUMENTS  
EP 0106688 3/1985  
JP 56-102646 8/1981  
(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 732 days.

OTHER PUBLICATIONS

(21) Appl. No.: **12/664,038**

“Mean and Peak Wind Load Reduction on Heliostats,” Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

(22) PCT Filed: **Jun. 11, 2008**

(86) PCT No.: **PCT/US2008/066597**

§ 371 (c)(1),  
(2), (4) Date: **Jun. 1, 2010**

(Continued)

(87) PCT Pub. No.: **WO2008/154599**

PCT Pub. Date: **Dec. 18, 2008**

*Primary Examiner* — Kenneth Bomberg  
*Assistant Examiner* — Shafiq Mian  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(65) **Prior Publication Data**

US 2010/0236239 A1 Sep. 23, 2010

(57) **ABSTRACT**

**Related U.S. Application Data**

(60) Provisional application No. 60/943,096, filed on Jun. 11, 2007.

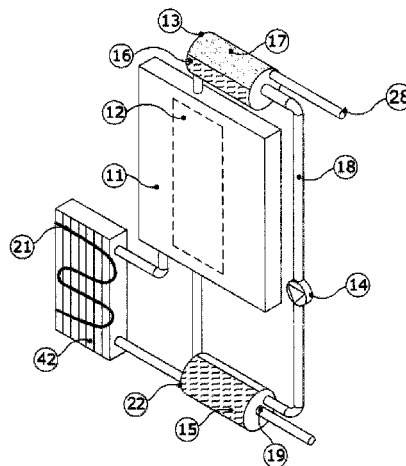
(51) **Int. Cl.**  
**F03G 6/06** (2006.01)  
**F01K 7/34** (2006.01)

A method for generating steam for a turbine electric power plant uses solar radiation. Solar radiation is directed onto a solar receiver. The solar receiver includes a first section, which receives feedwater input and is arranged to heat the feedwater input to generate steam using the directed solar radiation. Feedwater flows through a feedwater vessel to serve as feedwater input to an inlet of the first section of the receiver. Water is separated from the steam in steam separation vessel, which is in fluid communication with an outlet of the first section of the receiver. The feedwater input may be selectively preheated by a source of preheat other than solar energy in response to system operating conditions, predicted insolation schedule, or an electrical energy tariff schedule.

(52) **U.S. Cl.**  
USPC ..... **60/641.8**; 60/653

(58) **Field of Classification Search**  
USPC ..... 60/641.8, 653  
See application file for complete search history.

**9 Claims, 9 Drawing Sheets**





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

(10) **Patent No.:** **US 8,490,618 B2**  
(45) **Date of Patent:** **Jul. 23, 2013**

(54) **SOLAR RECEIVER**

(75) Inventors: **Israel Kroizer**, Jerusalem (IL); **Gabriel Kaufmann**, Beit Hananya (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 653 days.

(21) Appl. No.: **12/670,622**

(22) PCT Filed: **Jul. 28, 2008**

(86) PCT No.: **PCT/US2008/071366**

§ 371 (c)(1),

(2), (4) Date: **Jun. 2, 2010**

(87) PCT Pub. No.: **WO2009/015388**

PCT Pub. Date: **Jan. 29, 2009**

(65) **Prior Publication Data**

US 2010/0252025 A1 Oct. 7, 2010

**Related U.S. Application Data**

(60) Provisional application No. 60/951,970, filed on Jul. 26, 2007.

(51) **Int. Cl.**  
**F24J 2/24** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **126/600; 126/651; 126/571; 126/634; 126/684; 126/696**

(58) **Field of Classification Search**  
USPC ..... **126/600, 569, 571, 572, 573, 634, 126/684, 696; 60/641.8**

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,921,711 A	11/1975	Westbrock
4,015,584 A	4/1977	Haberman
4,055,948 A	11/1977	Kraus et al.
4,117,682 A	10/1978	Smith
4,119,083 A	10/1978	Heyen et al.
4,129,117 A	12/1978	Harvey

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE	2828118	1/1980
DE	10248068	5/2004

(Continued)

**OTHER PUBLICATIONS**

Paul et al., "Optimization of bed parameters for packed bed solar energy collection system," *Renewable Energy*, 2004, 29:pp. 1863-1876.

(Continued)

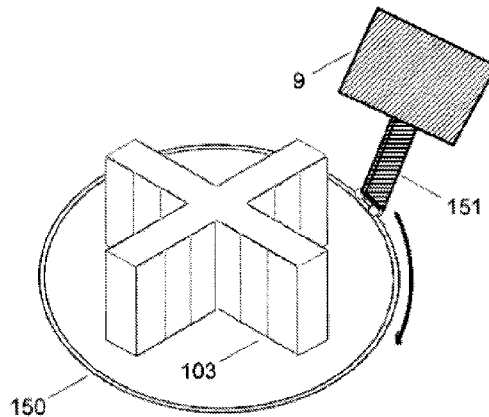
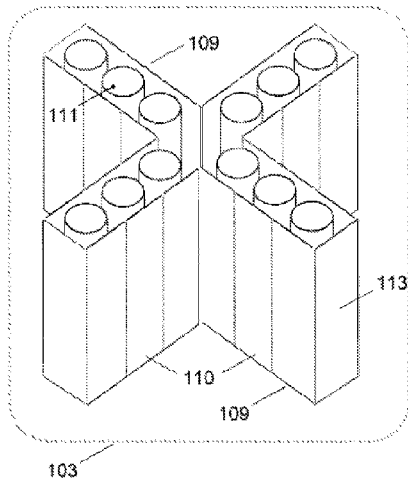
*Primary Examiner* — Alfred Bashichas

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy conversion system may include a receiver with a first heat transfer fluid channel having at least two opposite sides. Each side may present an external surface facing in a direction opposite to that of the external surface of the other opposite side. Each side may be configured to contact a heat transfer fluid carried in the first heat transfer fluid channel. A heliostat field may be configured to direct solar energy to each of the at least two opposite sides during the course of a day such that a thermal stress tending to bend the channel remains below a specified level.

**19 Claims, 8 Drawing Sheets**





US008365718B2

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

(10) **Patent No.:** **US 8,365,718 B2**  
(45) **Date of Patent:** **Feb. 5, 2013**

(54) **METHOD AND CONTROL SYSTEM FOR OPERATING A SOLAR POWER TOWER SYSTEM**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

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

(21) Appl. No.: **13/192,858**

(22) Filed: **Jul. 28, 2011**

(65) **Prior Publication Data**

US 2012/0024282 A1 Feb. 2, 2012

**Related U.S. Application Data**

(63) Continuation of application No. 12/269,785, filed on Nov. 12, 2008, now Pat. No. 8,001,960.

(60) Provisional application No. 60/987,132, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/40** (2006.01)

(52) **U.S. Cl.** ..... **126/595**; 126/600; 126/572; 126/601; 126/602; 126/643; 353/3; 136/246; 136/248; 60/641.5

(58) **Field of Classification Search** ..... 126/600, 126/595, 572, 601, 643, 602; 353/3; 136/248, 136/246; 60/641.5

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

3,892,433 A 7/1975 Blake  
3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrup  
4,044,753 A 8/1977 Fletcher et al.  
4,102,326 A 7/1978 Sommer  
4,117,682 A 10/1978 Smith  
4,146,785 A 3/1979 Neale  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

“Central Receiver Systems” in: Stine, W.B., and Geyer, M., Power from the Sun [online], 2001 [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://www.powerfromthesun.net/Chapter10/Chapter10new.htm>>, Chapter 10.

(Continued)

*Primary Examiner* — Steven B McAllister

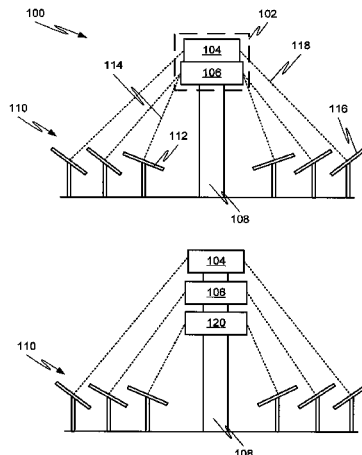
*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar receiver and a secondary solar receiver. The secondary solar receiver generates steam using energy from solar radiation incident thereon. The primary solar receiver receives the generated steam from the secondary solar receiver and superheats the steam using energy from solar radiation incident thereon. A plurality of heliostat-mounted mirrors reflects incident solar radiation onto one of the primary and secondary solar receivers. A controller aims a portion of the heliostat-mounted mirrors at the primary solar receiver such that a predetermined thermal profile is provided on a surface of the primary solar receiver.

**14 Claims, 3 Drawing Sheets**





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

(10) **Patent No.:** **US 8,360,051 B2**  
(45) **Date of Patent:** **Jan. 29, 2013**

(54) **SOLAR RECEIVER WITH ENERGY FLUX MEASUREMENT AND CONTROL**

(75) Inventors: **Yoel Gilon, Jerusalem (IL); Gil Kroyzer, Jerusalem (IL); Rotem Hayut, Jerusalem (IL)**

(73) Assignee: **Brightsource Industries (Israel) Ltd., Jerusalem (IL)**

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1077 days.

(21) Appl. No.: **12/269,793**

(22) Filed: **Nov. 12, 2008**

(65) **Prior Publication Data**

US 2009/0250052 A1 Oct. 8, 2009

**Related U.S. Application Data**

(60) Provisional application No. 60/987,133, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/578; 126/573; 126/572; 126/600; 126/680; 126/684; 126/688; 374/137; 250/203.4; 60/641.8; 60/641.11; 60/641.15; 359/853**

(58) **Field of Classification Search** ..... **126/578, 126/573, 600, 680, 684, 688; 374/137; 250/203.4; 359/853; 60/641.8, 641.11, 641.15**  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A	1/1906	Carter	
2,999,943 A	9/1961	Willard	
3,504,524 A *	4/1970	Maley	374/5
3,563,771 A *	2/1971	Tung	501/33
3,670,717 A *	6/1972	Abbot	126/687

3,892,433 A	7/1975	Blake	
3,924,604 A	12/1975	Anderson	
4,034,735 A	7/1977	Waldrup	
4,044,753 A	8/1977	Fletcher et al.	
4,102,326 A	7/1978	Sommer	
4,117,682 A	10/1978	Smith	
4,146,785 A	3/1979	Neale	
4,172,443 A	10/1979	Sommer	
4,219,729 A *	8/1980	Smith	250/203.4

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE	3325919 A1 *	1/1985
DE	10248068	5/2004

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://beb.es/documentos/descargar.php?id=29>.

(Continued)

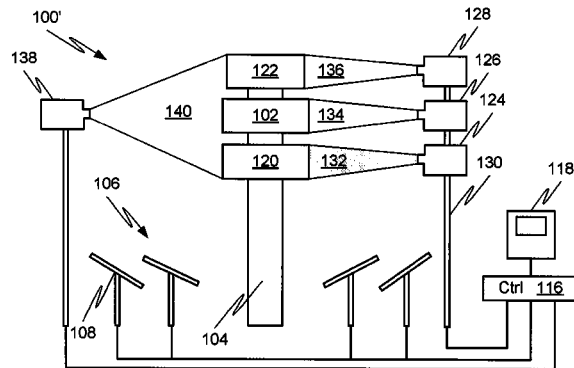
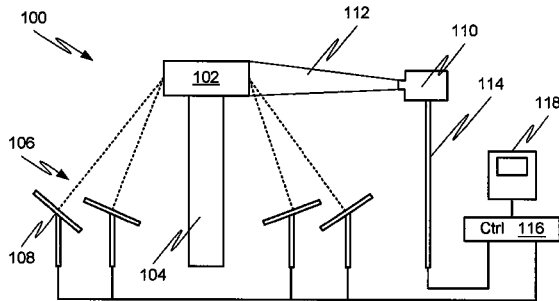
*Primary Examiner* — Carl Price

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge PC; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system has a solar receiver with an external surface configured for high absorption of light incident thereon. The solar receiver also has a plurality of light-reflecting elements arranged on the external surface. The light-reflecting elements produce at least partially diffuse reflection of light energy incident thereon. Heliostats concentrate solar radiation onto the external surface of the solar receiver. An imaging device provides a digital image of at least a portion of the external surface of the solar receiver. A controller can control the heliostats in response to apparent brightness of the light-reflecting elements as represented in the digital image.

**20 Claims, 3 Drawing Sheets**





US008327840B2

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

(10) **Patent No.:** **US 8,327,840 B2**  
(45) **Date of Patent:** **Dec. 11, 2012**

(54) **SOLAR POWER TOWER SYSTEM  
OPERATION AND CONTROL**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel  
Kroizer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**,  
Jerusalem (IL)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 140 days.

(21) Appl. No.: **12/841,335**

(22) Filed: **Jul. 22, 2010**

(65) **Prior Publication Data**

US 2010/0282242 A1 Nov. 11, 2010

**Related U.S. Application Data**

(62) Division of application No. 12/269,785, filed on Nov.  
12, 2008, now Pat. No. 8,001,960.

(60) Provisional application No. 60/987,132, filed on Nov.  
12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/600**; 126/643; 126/602; 126/572;  
126/601; 136/248; 136/246; 60/641.5; 353/3

(58) **Field of Classification Search** ..... 126/600,  
126/602, 572, 601, 643; 353/3; 136/248,  
136/246; 60/641.5

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
3,892,433 A 7/1975 Blake

3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrip  
4,044,753 A 8/1977 Fletcher et al.  
4,102,326 A 7/1978 Sommer  
4,117,682 A 10/1978 Smith  
4,146,785 A 3/1979 Neale  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith  
4,227,513 A 10/1980 Blake et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 A1 5/2004  
(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating  
Solar Power Plants Using Machine Vision [online]. [retrieved on  
Nov. 17, 2009]. Retrieved from the Internet: <URL: [http://beb.es/  
documentos/descargar.php?id=29](http://beb.es/documentos/descargar.php?id=29)>.

(Continued)

*Primary Examiner* — Steven B McAllister

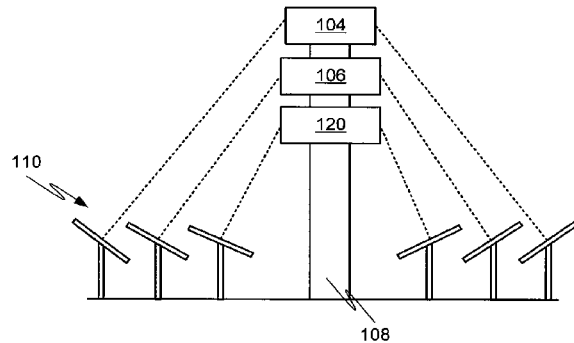
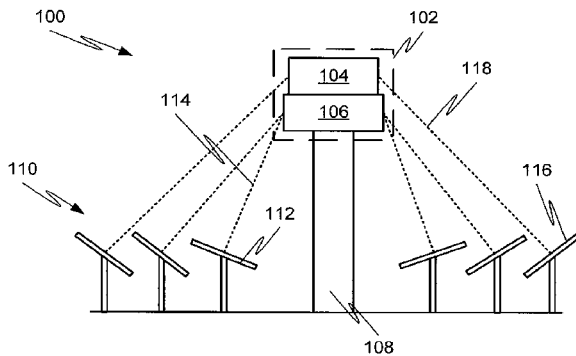
*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.;  
Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar  
receiver and a secondary solar receiver. The secondary solar  
receiver generates steam using energy from solar radiation  
incident thereon. The primary solar receiver receives the gen-  
erated steam from the secondary solar receiver and superheats  
the steam using energy from solar radiation incident thereon.  
A plurality of heliostat-mounted mirrors reflects incident  
solar radiation onto one of the primary and secondary solar  
receivers. A controller aims a portion of the heliostat-  
mounted mirrors at the primary solar receiver such that a  
predetermined thermal profile is provided on a surface of the  
primary solar receiver.

**20 Claims, 3 Drawing Sheets**





US008063349B2

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

(10) **Patent No.:** **US 8,063,349 B2**  
(45) **Date of Patent:** **Nov. 22, 2011**

(54) **HELIOSTATS AND SOLAR CONCENTRATION SYSTEMS EMPLOYING HELIOSTATS**

(58) **Field of Classification Search** ..... 353/3; 126/680, 126/683, 684, 685, 686, 689, 690, 691; 250/203.4, 250/203.7; 359/853  
See application file for complete search history.

(75) Inventors: **Shmuel Huss**, Jerusalem (IL); **Hagai Huss**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Yoel Gilon**, Jerusalem (IL); **Danny Franck**, Modi'in (IL); **Susan Walzer**, Givat Ze'ev (IL)

(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A	1/1906	Carter	
3,892,433 A	7/1975	Blake	
3,924,604 A	12/1975	Anderson	
4,034,735 A	7/1977	Waldrup	
4,122,827 A	10/1978	Rhodes	
4,162,825 A *	7/1979	Dowty	359/847
4,209,236 A	6/1980	Horton et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 2008/118980 10/2008

(Continued)

OTHER PUBLICATIONS

Pottler et al., "Photogrammetry: A Powerful Tool for Geometric Analysis of Solar Concentrators and Their Components," Journal of Solar Energy Engineering, Feb. 2005, 127(1):pp. 94-101.

(Continued)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

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

(21) Appl. No.: **12/595,241**

(22) PCT Filed: **Apr. 15, 2008**

(86) PCT No.: **PCT/US2008/060388**

§ 371 (c)(1),  
(2), (4) Date: **Mar. 29, 2010**

(87) PCT Pub. No.: **WO2008/128237**

PCT Pub. Date: **Oct. 23, 2008**

(65) **Prior Publication Data**

US 2010/0175738 A1 Jul. 15, 2010

**Related U.S. Application Data**

(60) Provisional application No. 60/911,893, filed on Apr. 15, 2007.

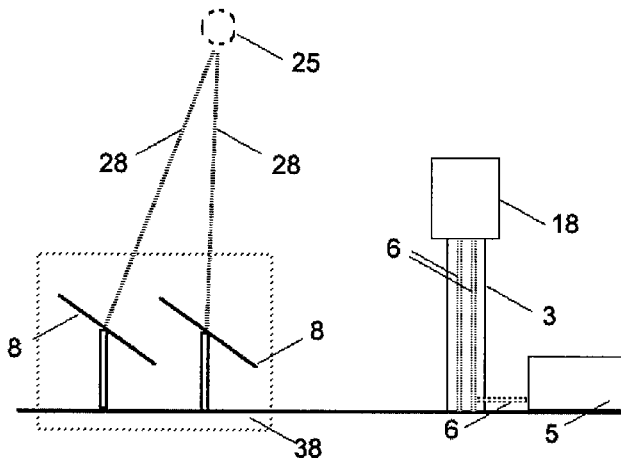
(51) **Int. Cl.**  
**G02B 7/04** (2006.01)  
**G02B 27/40** (2006.01)  
**G02B 27/64** (2006.01)

(52) **U.S. Cl.** ..... **250/203.4**; 353/3; 359/853; 126/680; 126/684

(57) **ABSTRACT**

A solar heliostat and system are described with various characteristics particularly suitable for concentrating systems with a relatively large number of small heliostats. Other features contribute to high performance, low cost, high durability, and high temperature operation, such as desired for high efficiency thermal power generation.

**20 Claims, 9 Drawing Sheets**





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

(10) **Patent No.:** **US 8,033,110 B2**  
(45) **Date of Patent:** **Oct. 11, 2011**

(54) **SOLAR POWER GENERATION WITH MULTIPLE ENERGY CONVERSION MODES**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Arnold J. Goldman**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gideon Goldwine**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

4,117,682 A 10/1978 Smith  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith  
4,227,513 A 10/1980 Blake et al.  
4,245,618 A 1/1981 Wiener  
4,265,223 A 5/1981 Miserlis et al.  
4,289,114 A 9/1981 Zadiraka

(Continued)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 252 days.

OTHER PUBLICATIONS

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://bcb.es/documentos/descargar.php?id=29>>.

(Continued)

(21) Appl. No.: **12/404,663**

(22) Filed: **Mar. 16, 2009**

(65) **Prior Publication Data**

US 2009/0229264 A1 Sep. 17, 2009

**Related U.S. Application Data**

(60) Provisional application No. 61/036,959, filed on Mar. 16, 2008, provisional application No. 61/053,341, filed on May 15, 2008, provisional application No. 61/140,966, filed on Dec. 28, 2008.

Primary Examiner — Hoang Nguyen

(74) Attorney, Agent, or Firm — Miles & Stockbridge P.C.; Mark A. Catan

(51) **Int. Cl.**  
**B60K 16/00** (2006.01)

(52) **U.S. Cl.** ..... **60/641.11**; 60/641.15

(58) **Field of Classification Search** ..... 60/641.8–641.15  
See application file for complete search history.

(57) **ABSTRACT**

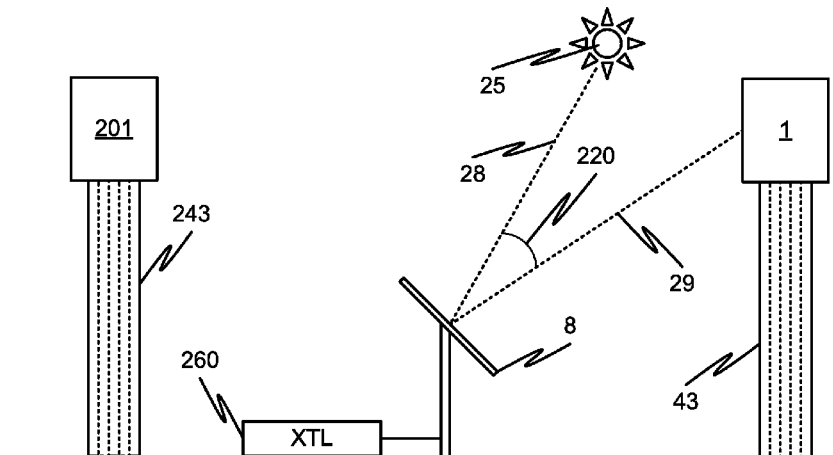
A multi-mode solar power generation system can include a first energy conversion system that generates electricity from a working fluid heated by a portion of solar radiation focused by a plurality of heliostats. The multi-mode solar power generation system can also include a second energy conversion system that generates electricity from an unused portion of the focused solar radiation using a different energy conversion mode than that of the first energy conversion system. The second energy conversion system can include one or more photovoltaic converters, which directly convert solar radiation to electricity. The unused radiation from the first energy conversion system can include radiation spillage or dumped radiation from a thermal receiver of the first energy conversion system.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,892,433 A 7/1975 Blake  
3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrip  
4,044,753 A 8/1977 Fletcher et al.

**38 Claims, 13 Drawing Sheets**





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

(10) **Patent No.:** **US 8,001,960 B2**  
(45) **Date of Patent:** **Aug. 23, 2011**

(54) **METHOD AND CONTROL SYSTEM FOR OPERATING A SOLAR POWER TOWER SYSTEM**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

(73) Assignee: **BrightSource Industries (Israel) Ltd.** (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 19 days.

(21) Appl. No.: **12/269,785**

(22) Filed: **Nov. 12, 2008**

(65) **Prior Publication Data**

US 2009/0217921 A1 Sep. 3, 2009

**Related U.S. Application Data**

(60) Provisional application No. 60/987,132, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/600**; 126/572; 126/601; 126/605; 126/610; 126/643; 60/641.8; 60/641.15; 136/246; 136/248; 700/275

(58) **Field of Classification Search** ..... 126/600, 126/572, 684, 601, 643, 610, 605, 578; 60/641.8, 60/641.15; 136/246, 248; 250/203.4; 700/275  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A	1/1906	Carter
3,892,433 A	7/1975	Blake
3,924,604 A	12/1975	Anderson

4,034,735 A	7/1977	Waldrup	
4,044,753 A	8/1977	Fletcher et al.	
4,102,326 A *	7/1978	Sommer	126/575
4,117,682 A	10/1978	Smith	
4,172,443 A *	10/1979	Sommer	126/680
4,219,729 A	8/1980	Smith	
4,227,513 A	10/1980	Blake et al.	
4,245,618 A	1/1981	Wiener	

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 A1 \* 5/2004

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://bcb.es/documentos/descargar.php?id=29>>.

(Continued)

*Primary Examiner* — Steven B McAllister

*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar receiver and a secondary solar receiver. The secondary solar receiver generates steam using energy from solar radiation incident thereon. The primary solar receiver receives the generated steam from the secondary solar receiver and superheats the steam using energy from solar radiation incident thereon. A plurality of heliostat-mounted mirrors reflects incident solar radiation onto one of the primary and secondary solar receivers. A controller aims a portion of the heliostat-mounted mirrors at the primary solar receiver such that a predetermined thermal profile is provided on a surface of the primary solar receiver.

**20 Claims, 3 Drawing Sheets**

