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Safety mechanisms, wake up and shutdown methods in distributed power installations

Abstract

A distributed power system including multiple DC power sources and multiple power modules. The power modules include inputs coupled respectively to the DC power sources and outputs coupled in series to form a serial string. An inverter is coupled to the serial string. The inverter converts power input from the serial string to output power. A signaling mechanism between the inverter and the power module is adapted for controlling operation of the power modules. Also, for a protection method in the distributed power system, when the inverter stops production of the output power, each of the power modules is shut down and thereby the power input to the inverter is ceased.

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6515215	12/2002	Mimura	N/A	N/A
6515217	12/2002	Aylaian	N/A	N/A
6519165	12/2002	Koike	N/A	N/A
6528977	12/2002	Arakawa	N/A	N/A
6531848	12/2002	Chitsazan et al.	N/A	N/A
6545211	12/2002	Mimura	N/A	N/A
6548205	12/2002	Leung et al.	N/A	N/A
6560131	12/2002	vonBrethorst	N/A	N/A
6587051	12/2002	Takehara et al.	N/A	N/A
6590793	12/2002	Nagao et al.	N/A	N/A
6590794	12/2002	Carter	N/A	N/A
6593520	12/2002	Kondo et al.	N/A	N/A
6593521	12/2002	Kobayashi	N/A	N/A
6600100	12/2002	Ho et al.	N/A	N/A
6603672	12/2002	Deng et al.	N/A	N/A
6608468	12/2002	Nagase	N/A	N/A
6611130	12/2002	Chang	N/A	N/A
6611441	12/2002	Kurokami et al.	N/A	N/A
6628011	12/2002	Droppo et al.	N/A	N/A
6633824	12/2002	Dollar, II	N/A	N/A
6636431	12/2002	Seki et al.	N/A	N/A
6650031	12/2002	Goldack	N/A	N/A
6650560	12/2002	MacDonald et al.	N/A	N/A
6653549	12/2002	Matsushita et al.	N/A	N/A
6655987	12/2002	Higashikozono et al.	N/A	N/A
6657419	12/2002	Renyolds	N/A	N/A
6664762	12/2002	Kutkut	N/A	N/A
6672018	12/2003	Shingleton	N/A	N/A
6678174	12/2003	Suzui et al.	N/A	N/A
6690590	12/2003	Stamenic et al.	N/A	N/A
6693327	12/2003	Priefert et al.	N/A	N/A
6693781	12/2003	Kroker	N/A	N/A
6708507	12/2003	Sem et al.	N/A	N/A
6709291	12/2003	Wallace et al.	N/A	N/A
6724593	12/2003	Smith	N/A	N/A
6731136	12/2003	Knee	N/A	N/A
6738692	12/2003	Schienbein et al.	N/A	N/A
6744643	12/2003	Luo et al.	N/A	N/A
6750391	12/2003	Bower et al.	N/A	N/A
6765315	12/2003	Hammerstrom et al.	N/A	N/A
6768047	12/2003	Chang et al.	N/A	N/A
6768180	12/2003	Salama et al.	N/A	N/A
6788033	12/2003	Vinciarelli	N/A	N/A
6788146	12/2003	Forejt et al.	N/A	N/A

6795318	12/2003	Haas et al.	N/A	N/A
6800964	12/2003	Beck	N/A	N/A
6801442	12/2003	Suzui et al.	N/A	N/A
6807069	12/2003	Nieminen et al.	N/A	N/A
6809942	12/2003	Madenokouji et al.	N/A	N/A
6810339	12/2003	Wills	N/A	N/A
6812396	12/2003	Makita et al.	N/A	N/A
6828503	12/2003	Yoshikawa et al.	N/A	N/A
6828901	12/2003	Birchfield et al.	N/A	N/A
6835491	12/2003	Gartstein et al.	N/A	N/A
6837739	12/2004	Gorringe et al.	N/A	N/A
6838611	12/2004	Kondo et al.	N/A	N/A
6838856	12/2004	Raichle	N/A	N/A
6842354	12/2004	Tallam et al.	N/A	N/A
6844739	12/2004	Kasai et al.	N/A	N/A
6850074	12/2004	Adams et al.	N/A	N/A
6856102	12/2004	Lin et al.	N/A	N/A
6882131	12/2004	Takada et al.	N/A	N/A
6888728	12/2004	Takagi et al.	N/A	N/A
6894911	12/2004	Telefus et al.	N/A	N/A
6897370	12/2004	Kondo et al.	N/A	N/A
6914418	12/2004	Sung	N/A	N/A
6919714	12/2004	Delepaut	N/A	N/A
6927955	12/2004	Suzui et al.	N/A	N/A
6933627	12/2004	Wilhelm	N/A	N/A
6933714	12/2004	Fasshauer et al.	N/A	N/A
6936995	12/2004	Kapsokavathis et al.	N/A	N/A
6940735	12/2004	Deng et al.	N/A	N/A
6949843	12/2004	Dubovsky	N/A	N/A
6950323	12/2004	Achleitner et al.	N/A	N/A
6963147	12/2004	Kurokami et al.	N/A	N/A
6966184	12/2004	Toyomura et al.	N/A	N/A
6970365	12/2004	Turchi	N/A	N/A
6980783	12/2004	Liu et al.	N/A	N/A
6984967	12/2005	Notman	N/A	N/A
6984970	12/2005	Capel	N/A	N/A
6985967	12/2005	Hipp	N/A	N/A
6987444	12/2005	Bub et al.	N/A	N/A
6996741	12/2005	Pittelkow et al.	N/A	N/A
7030597	12/2005	Bruno et al.	N/A	N/A
7031176	12/2005	Kotsopoulos et al.	N/A	N/A
7038430	12/2005	Itabashi et al.	N/A	N/A
7039941	12/2005	Caporizzo et al.	N/A	N/A
7042195	12/2005	Tsunetsugu et al.	N/A	N/A
7045991	12/2005	Nakamura et al.	N/A	N/A
7046531	12/2005	Zocchi et al.	N/A	N/A
7053506	12/2005	Alonso et al.	N/A	N/A
7061211	12/2005	Satoh et al.	N/A	N/A
7061214	12/2005	Mayega et al.	N/A	N/A
7064967	12/2005	Ichinose et al.	N/A	N/A

7068017	12/2005	Willner et al.	N/A	N/A
7072194	12/2005	Nayar et al.	N/A	N/A
7078883	12/2005	Chapman et al.	N/A	N/A
7079406	12/2005	Kurokami et al.	N/A	N/A
7087332	12/2005	Harris	N/A	N/A
7088595	12/2005	Nino	N/A	N/A
7089780	12/2005	Sunshine et al.	N/A	N/A
7090509	12/2005	Gilliland et al.	N/A	N/A
7091707	12/2005	Cutler	N/A	N/A
7097516	12/2005	Werner et al.	N/A	N/A
7099169	12/2005	West et al.	N/A	N/A
7126053	12/2005	Kurokami et al.	N/A	N/A
7126294	12/2005	Minami et al.	N/A	N/A
7138786	12/2005	Ishigaki et al.	N/A	N/A
7142997	12/2005	Widner	N/A	N/A
7148669	12/2005	Maksimovic et al.	N/A	N/A
7150938	12/2005	Munshi et al.	N/A	N/A
7157888	12/2006	Chen et al.	N/A	N/A
7158359	12/2006	Bertele et al.	N/A	N/A
7158395	12/2006	Deng et al.	N/A	N/A
7161082	12/2006	Matsushita et al.	N/A	N/A
7174973	12/2006	Lysaght	N/A	N/A
7176667	12/2006	Chen et al.	N/A	N/A
7183667	12/2006	Colby et al.	N/A	N/A
7193872	12/2006	Siri	N/A	N/A
7202653	12/2006	Pai	N/A	N/A
7208674	12/2006	Aylaian	N/A	N/A
7218541	12/2006	Price et al.	N/A	N/A
7248946	12/2006	Bashaw et al.	N/A	N/A
7256566	12/2006	Bhavaraju et al.	N/A	N/A
7259474	12/2006	Blanc	N/A	N/A
7262979	12/2006	Wai et al.	N/A	N/A
7276886	12/2006	Kinder et al.	N/A	N/A
7277304	12/2006	Stancu et al.	N/A	N/A
7281141	12/2006	Elkayam et al.	N/A	N/A
7282814	12/2006	Jacobs	N/A	N/A
7282924	12/2006	Wittner	N/A	N/A
7291036	12/2006	Daily et al.	N/A	N/A
7298113	12/2006	Orikasa	N/A	N/A
RE39976	12/2007	Schiff et al.	N/A	N/A
7315052	12/2007	Alter	N/A	N/A
7319313	12/2007	Dickerson et al.	N/A	N/A
7324361	12/2007	Siri	N/A	N/A
7336004	12/2007	Lai	N/A	N/A
7336056	12/2007	Dening	N/A	N/A
7339287	12/2007	Jepsen et al.	N/A	N/A
7348802	12/2007	Kasanyal et al.	N/A	N/A
7352154	12/2007	Cook	N/A	N/A
7361952	12/2007	Miura et al.	N/A	N/A
7371963	12/2007	Suenaga et al.	N/A	N/A

7372712	12/2007	Stancu et al.	N/A	N/A
7385380	12/2007	Ishigaki et al.	N/A	N/A
7385833	12/2007	Keung	N/A	N/A
7388348	12/2007	Mattichak	N/A	N/A
7391190	12/2007	Rajagopalan	N/A	N/A
7394237	12/2007	Chou et al.	N/A	N/A
7405117	12/2007	Zuniga et al.	N/A	N/A
7414870	12/2007	Rottger et al.	N/A	N/A
7420354	12/2007	Cutler	N/A	N/A
7420815	12/2007	Love	N/A	N/A
7432691	12/2007	Cutler	N/A	N/A
7435134	12/2007	Lenox	N/A	N/A
7435897	12/2007	Russell	N/A	N/A
7443052	12/2007	Wendt et al.	N/A	N/A
7443152	12/2007	Utsunomiya	N/A	N/A
7450401	12/2007	Iida	N/A	N/A
7456510	12/2007	Ito et al.	N/A	N/A
7456523	12/2007	Kobayashi	N/A	N/A
7463500	12/2007	West	N/A	N/A
7466566	12/2007	Fukumoto	N/A	N/A
7471014	12/2007	Lum et al.	N/A	N/A
7471524	12/2007	Batarseh et al.	N/A	N/A
7479774	12/2008	Wai et al.	N/A	N/A
7482238	12/2008	Sung	N/A	N/A
7485987	12/2008	Mori et al.	N/A	N/A
7495419	12/2008	Ju	N/A	N/A
7504811	12/2008	Watanabe et al.	N/A	N/A
7518346	12/2008	Prexl et al.	N/A	N/A
7538451	12/2008	Nomoto	N/A	N/A
7560915	12/2008	Ito et al.	N/A	N/A
7589437	12/2008	Henne et al.	N/A	N/A
7595616	12/2008	Prexl et al.	N/A	N/A
7596008	12/2008	Iwata et al.	N/A	N/A
7599200	12/2008	Tomonaga	N/A	N/A
7600349	12/2008	Liebendorfer	N/A	N/A
7602080	12/2008	Hadar et al.	N/A	N/A
7602626	12/2008	Iwata et al.	N/A	N/A
7605498	12/2008	Ledenev et al.	N/A	N/A
7612283	12/2008	Toyomura et al.	N/A	N/A
7615981	12/2008	Wong et al.	N/A	N/A
7626834	12/2008	Chisenga et al.	N/A	N/A
7634667	12/2008	Weaver et al.	N/A	N/A
7646116	12/2009	Batarseh et al.	N/A	N/A
7649434	12/2009	Xu et al.	N/A	N/A
7659701	12/2009	Metsker et al.	N/A	N/A
7701083	12/2009	Savage	N/A	N/A
7709727	12/2009	Roehrig et al.	N/A	N/A
7719140	12/2009	Ledenev et al.	N/A	N/A
7723865	12/2009	Kitanaka	N/A	N/A
7733069	12/2009	Toyomura et al.	N/A	N/A

7748175	12/2009	Liebendorfer	N/A	N/A
7759575	12/2009	Jones et al.	N/A	N/A
7763807	12/2009	Richter	N/A	N/A
7772716	12/2009	Shaver, II et al.	N/A	N/A
7777570	12/2009	Lai	N/A	N/A
7780472	12/2009	Lenox	N/A	N/A
7782031	12/2009	Qiu et al.	N/A	N/A
7783389	12/2009	Yamada et al.	N/A	N/A
7787273	12/2009	Lu et al.	N/A	N/A
7804282	12/2009	Bertele	N/A	N/A
7807919	12/2009	Powell et al.	N/A	N/A
7808125	12/2009	Sachdeva et al.	N/A	N/A
7812592	12/2009	Prior et al.	N/A	N/A
7812701	12/2009	Lee et al.	N/A	N/A
7821225	12/2009	Chou et al.	N/A	N/A
7824189	12/2009	Lauermann et al.	N/A	N/A
7839022	12/2009	Wolfs	N/A	N/A
7843085	12/2009	Ledenev et al.	N/A	N/A
7864497	12/2010	Quardt et al.	N/A	N/A
7868599	12/2010	Rahman et al.	N/A	N/A
7880334	12/2010	Evans et al.	N/A	N/A
7883808	12/2010	Norimatsu et al.	N/A	N/A
7884278	12/2010	Powell et al.	N/A	N/A
7893346	12/2010	Nachamkin et al.	N/A	N/A
7898112	12/2010	Powell et al.	N/A	N/A
7900361	12/2010	Adest et al.	N/A	N/A
7906007	12/2010	Gibson et al.	N/A	N/A
7906870	12/2010	Ohm	N/A	N/A
7919952	12/2010	Fahrenbruch	N/A	N/A
7919953	12/2010	Porter et al.	N/A	N/A
7925552	12/2010	Tarbell et al.	N/A	N/A
7944191	12/2010	Xu	N/A	N/A
7945413	12/2010	Krein	N/A	N/A
7948221	12/2010	Watanabe et al.	N/A	N/A
7952897	12/2010	Nocentini et al.	N/A	N/A
7960650	12/2010	Richter et al.	N/A	N/A
7960950	12/2010	Glovinsky	N/A	N/A
7962249	12/2010	Zhang	700/297	H02J 3/381
7969043	12/2010	Caraghiorghiopol et al.	N/A	N/A
7969133	12/2010	Zhang et al.	N/A	N/A
7977810	12/2010	Choi et al.	N/A	N/A
8003885	12/2010	Richter et al.	N/A	N/A
8004113	12/2010	Sander et al.	N/A	N/A
8004116	12/2010	Ledenev et al.	N/A	N/A
8004117	12/2010	Adest et al.	N/A	N/A
8004237	12/2010	Manor et al.	N/A	N/A
8004866	12/2010	Bucella et al.	N/A	N/A
8013472	12/2010	Adest et al.	N/A	N/A

8018748	12/2010	Leonard	N/A	N/A
8035249	12/2010	Shaver, II et al.	N/A	N/A
8039730	12/2010	Hadar et al.	N/A	N/A
8049363	12/2010	McLean et al.	N/A	N/A
8050804	12/2010	Kernahan	N/A	N/A
8058747	12/2010	Avrutsky et al.	N/A	N/A
8058752	12/2010	Erickson, Jr. et al.	N/A	N/A
8067855	12/2010	Mumtaz et al.	N/A	N/A
8077437	12/2010	Mumtaz et al.	N/A	N/A
8080986	12/2010	Lai et al.	N/A	N/A
8089780	12/2011	Mochikawa et al.	N/A	N/A
8089785	12/2011	Rodriguez	N/A	N/A
8090548	12/2011	Abdennadher et al.	N/A	N/A
8093756	12/2011	Porter et al.	N/A	N/A
8093757	12/2011	Wolfs	N/A	N/A
8097818	12/2011	Gerull et al.	N/A	N/A
8098055	12/2011	Avrutsky et al.	N/A	N/A
8102074	12/2011	Hadar et al.	N/A	N/A
8102144	12/2011	Capp et al.	N/A	N/A
8111052	12/2011	Glovinsky	N/A	N/A
8116103	12/2011	Zacharias et al.	N/A	N/A
8138631	12/2011	Allen et al.	N/A	N/A
8138914	12/2011	Wong et al.	N/A	N/A
8139335	12/2011	Quardt et al.	N/A	N/A
8139382	12/2011	Zhang et al.	N/A	N/A
8148849	12/2011	Zanarini et al.	N/A	N/A
8158877	12/2011	Klein et al.	N/A	N/A
8169252	12/2011	Fahrenbruch et al.	N/A	N/A
8179147	12/2011	Dargatz et al.	N/A	N/A
8184460	12/2011	O'Brien et al.	N/A	N/A
8188610	12/2011	Scholte-Wassink	N/A	N/A
8204709	12/2011	Presher, Jr. et al.	N/A	N/A
8212408	12/2011	Fishman	N/A	N/A
8212409	12/2011	Bettenwort et al.	N/A	N/A
8232790	12/2011	Leong et al.	N/A	N/A
8233301	12/2011	Guo	N/A	N/A
8248804	12/2011	Han et al.	N/A	N/A
8271599	12/2011	Eizips et al.	N/A	N/A
8274172	12/2011	Hadar et al.	N/A	N/A
8279644	12/2011	Zhang et al.	N/A	N/A
8284574	12/2011	Chapman et al.	N/A	N/A
8289183	12/2011	Foss	N/A	N/A
8289742	12/2011	Adest et al.	N/A	N/A
8294451	12/2011	Hasenfus	N/A	N/A
8299757	12/2011	Yamauchi et al.	N/A	N/A
8299773	12/2011	Jang et al.	N/A	N/A
8304932	12/2011	Ledenev et al.	N/A	N/A
8310101	12/2011	Amaratunga et al.	N/A	N/A
8310102	12/2011	Raju	N/A	N/A
8314375	12/2011	Arditi et al.	N/A	N/A

8319471	12/2011	Adest et al.	N/A	N/A
8324921	12/2011	Adest et al.	N/A	N/A
8325059	12/2011	Rozenboim	N/A	N/A
8344548	12/2012	Stern	N/A	N/A
8355563	12/2012	Kasahara et al.	N/A	N/A
8369113	12/2012	Rodriguez	N/A	N/A
8378656	12/2012	de Rooij et al.	N/A	N/A
8379418	12/2012	Falk	N/A	N/A
8391031	12/2012	Garrity	N/A	N/A
8391032	12/2012	Garrity et al.	N/A	N/A
8395366	12/2012	Uno	N/A	N/A
8405248	12/2012	Mumtaz et al.	N/A	N/A
8405349	12/2012	Kikinis et al.	N/A	N/A
8405367	12/2012	Chisenga et al.	N/A	N/A
8410359	12/2012	Richter	N/A	N/A
8410889	12/2012	Garrity et al.	N/A	N/A
8410950	12/2012	Takehara et al.	N/A	N/A
8415552	12/2012	Hadar et al.	N/A	N/A
8415937	12/2012	Hester	N/A	N/A
8427009	12/2012	Shaver, II et al.	N/A	N/A
8436592	12/2012	Saitoh	N/A	N/A
8461809	12/2012	Rodriguez	N/A	N/A
8466789	12/2012	Muhlberger et al.	N/A	N/A
8472220	12/2012	Garrity et al.	N/A	N/A
8473250	12/2012	Adest et al.	N/A	N/A
8509032	12/2012	Rakib	N/A	N/A
8526205	12/2012	Garrity	N/A	N/A
8531055	12/2012	Adest et al.	N/A	N/A
8542512	12/2012	Garrity	N/A	N/A
8570017	12/2012	Perichon et al.	N/A	N/A
8581441	12/2012	Rotzoll et al.	N/A	N/A
8587151	12/2012	Adest et al.	N/A	N/A
8618692	12/2012	Adest et al.	N/A	N/A
8624443	12/2013	Mumtaz	N/A	N/A
8653689	12/2013	Rozenboim	N/A	N/A
8669675	12/2013	Capp et al.	N/A	N/A
8670255	12/2013	Gong et al.	N/A	N/A
8674548	12/2013	Mumtaz	N/A	N/A
8674668	12/2013	Chisenga et al.	N/A	N/A
8686333	12/2013	Arditi et al.	N/A	N/A
8710351	12/2013	Robbins	N/A	N/A
8751053	12/2013	Hadar et al.	N/A	N/A
8773236	12/2013	Makhota et al.	N/A	N/A
8791598	12/2013	Jain	N/A	N/A
8796884	12/2013	Naiknaware et al.	N/A	N/A
8809699	12/2013	Funk	N/A	N/A
8811047	12/2013	Rodriguez	N/A	N/A
8816535	12/2013	Adest et al.	N/A	N/A
8823212	12/2013	Garrity et al.	N/A	N/A
8823218	12/2013	Hadar et al.	N/A	N/A

8823342	12/2013	Williams	N/A	N/A
8835748	12/2013	Frolov et al.	N/A	N/A
8841916	12/2013	Avrutsky	N/A	N/A
8842397	12/2013	Fahrenbruch et al.	N/A	N/A
8853886	12/2013	Avrutsky et al.	N/A	N/A
8854193	12/2013	Makhota et al.	N/A	N/A
8859884	12/2013	Dunton et al.	N/A	N/A
8860241	12/2013	Hadar et al.	N/A	N/A
8860246	12/2013	Hadar et al.	N/A	N/A
8872439	12/2013	Cohen	N/A	N/A
8878563	12/2013	Robbins	N/A	N/A
8917156	12/2013	Garrity et al.	N/A	N/A
8922061	12/2013	Arditi	N/A	N/A
8933321	12/2014	Hadar et al.	N/A	N/A
8934269	12/2014	Garrity	N/A	N/A
8947194	12/2014	Sella et al.	N/A	N/A
8963375	12/2014	DeGraaff	N/A	N/A
8963378	12/2014	Fornage et al.	N/A	N/A
8963501	12/2014	Shigemizu et al.	N/A	N/A
8963518	12/2014	Wolfs	N/A	N/A
8972765	12/2014	Krolak et al.	N/A	N/A
9010645	12/2014	Arnouse	N/A	N/A
9041339	12/2014	Adest et al.	N/A	N/A
9088178	12/2014	Adest et al.	N/A	N/A
9130401	12/2014	Adest et al.	N/A	N/A
9142965	12/2014	Grana	N/A	N/A
9257848	12/2015	Coccia et al.	N/A	N/A
9291696	12/2015	Adest et al.	N/A	N/A
9362743	12/2015	Gazit et al.	N/A	N/A
9397497	12/2015	Ledenev	N/A	N/A
9401664	12/2015	Perreault et al.	N/A	N/A
9407161	12/2015	Adest et al.	N/A	N/A
9466737	12/2015	Ledenev	N/A	N/A
9577454	12/2016	Seymour et al.	N/A	N/A
9647442	12/2016	Yoscovich et al.	N/A	N/A
9660527	12/2016	Glovinski	N/A	N/A
9673630	12/2016	Ledenev et al.	N/A	N/A
9819178	12/2016	Gazit et al.	N/A	N/A
9831916	12/2016	Behrends	N/A	N/A
9843193	12/2016	Getsla	N/A	N/A
9853490	12/2016	Adest et al.	N/A	N/A
9865411	12/2017	Friebe et al.	N/A	N/A
9869701	12/2017	Sella et al.	N/A	N/A
9923516	12/2017	Har-Shai et al.	N/A	N/A
9991717	12/2017	Rowe et al.	N/A	N/A
9995796	12/2017	Johnson	N/A	N/A
10032939	12/2017	Ledenev et al.	N/A	N/A
10256770	12/2018	Hadar et al.	N/A	N/A
10432139	12/2018	Chaintreuil et al.	N/A	N/A
10457159	12/2018	Castelaz et al.	N/A	N/A

10666045	12/2019	Gemin et al.	N/A	N/A
10673253	12/2019	Adest et al.	N/A	N/A
10931119	12/2020	Har-Shai et al.	N/A	N/A
10969412	12/2020	Sella et al.	N/A	N/A
11018623	12/2020	Loewenstern et al.	N/A	N/A
11205946	12/2020	Yoscovich et al.	N/A	N/A
11276786	12/2021	Hopf et al.	N/A	N/A
11476799	12/2021	Sella et al.	N/A	N/A
11682918	12/2022	Adest et al.	N/A	N/A
11728724	12/2022	Braginsky et al.	N/A	N/A
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2005/0057215	12/2004	Matan	N/A	N/A
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2008/0149167	12/2007	Liu	N/A	N/A
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2008/0150484	12/2007	Kimball et al.	N/A	N/A
2008/0156551	12/2007	Kawahara et al.	N/A	N/A
2008/0164766	12/2007	Adest et al.	N/A	N/A
2008/0179949	12/2007	Besser et al.	N/A	N/A
2008/0186004	12/2007	Williams	N/A	N/A
2008/0191560	12/2007	Besser et al.	N/A	N/A
2008/0191675	12/2007	Besser et al.	N/A	N/A
2008/0192510	12/2007	Falk	N/A	N/A
2008/0192519	12/2007	Iwata et al.	N/A	N/A
2008/0198523	12/2007	Schmidt et al.	N/A	N/A
2008/0205096	12/2007	Lai et al.	N/A	N/A
2008/0218152	12/2007	Bo	N/A	N/A
2008/0224652	12/2007	Zhu et al.	N/A	N/A
2008/0236647	12/2007	Gibson et al.	N/A	N/A
2008/0236648	12/2007	Klein et al.	N/A	N/A
2008/0238195	12/2007	Shaver et al.	N/A	N/A
2008/0238372	12/2007	Cintra et al.	N/A	N/A
2008/0246460	12/2007	Smith	N/A	N/A
2008/0246463	12/2007	Sinton et al.	N/A	N/A
2008/0252273	12/2007	Woo et al.	N/A	N/A
2008/0264470	12/2007	Masuda et al.	N/A	N/A
2008/0266913	12/2007	Brotto et al.	N/A	N/A
2008/0266919	12/2007	Mallwitz	N/A	N/A
2008/0283118	12/2007	Rotzoll et al.	N/A	N/A
2008/0291707	12/2007	Fang	N/A	N/A
2008/0294472	12/2007	Yamada	N/A	N/A
2008/0297963	12/2007	Lee et al.	N/A	N/A
2008/0298608	12/2007	Wilcox	N/A	N/A
2008/0303503	12/2007	Wolfs	N/A	N/A
2008/0304296	12/2007	NadimpalliRaju et al.	N/A	N/A
2008/0304298	12/2007	Toba et al.	N/A	N/A
2009/0010035	12/2008	Williams	N/A	N/A
2009/0012917	12/2008	Thompson et al.	N/A	N/A
2009/0014050	12/2008	Haaf	N/A	N/A
2009/0014057	12/2008	Croft et al.	N/A	N/A
2009/0014058	12/2008	Croft et al.	N/A	N/A
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2009/0020151	12/2008	Fornage	N/A	N/A
2009/0021877	12/2008	Fornage et al.	N/A	N/A
2009/0039833	12/2008	Kitagawa	N/A	N/A
2009/0039852	12/2008	Fishelov et al.	N/A	N/A
2009/0064252	12/2008	Howarter et al.	N/A	N/A
2009/0066357	12/2008	Fornage	N/A	N/A
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2009/0146671	12/2008	Gazit	N/A	N/A
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2009/0182532	12/2008	Stoeber et al.	N/A	N/A
2009/0183763	12/2008	Meyer	N/A	N/A
2009/0184746	12/2008	Fahrenbruch	N/A	N/A
2009/0189456	12/2008	Skutt	N/A	N/A
2009/0190275	12/2008	Gilmore et al.	N/A	N/A
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2011/0050002	12/2010	De Luca	N/A	N/A
2011/0050190	12/2010	Avrutsky	N/A	N/A
2011/0056533	12/2010	Kuan	N/A	N/A
2011/0061705	12/2010	Croft et al.	N/A	N/A
2011/0061713	12/2010	Powell et al.	N/A	N/A
2011/0062784	12/2010	Wolfs	N/A	N/A
2011/0068633	12/2010	Quardt et al.	N/A	N/A
2011/0079263	12/2010	Avrutsky	N/A	N/A
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2011/0115393	12/2010	He	N/A	N/A
2011/0116294	12/2010	Wolf	N/A	N/A
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2011/0139213	12/2010	Lee	N/A	N/A
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2011/0181340	12/2010	Gazit	N/A	N/A
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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) The present application is a continuation of U.S. application Ser. No. 15/369,881, filed Dec. 5, 2016, which is a continuation-in-part of U.S. application Ser. No. 13/372,009, filed Feb. 13, 2012 (now U.S. Pat. No. 9,590,526), which is a continuation of U.S. application Ser. No. 12/329,525, filed Dec. 5, 2008 (now U.S. Pat. No. 8,531,055), which claims the benefit of U.S. Provisional Application Ser. No. 60/992,589, filed Dec. 5, 2007. U.S. application Ser. No. 12/329,525, filed Dec. 5, 2008 is a continuation-in-part of U.S. application Ser. No. 11/950,271, filed Dec. 4, 2007 (now U.S. Pat. No. 9,088,178), which claims the benefit of each of U.S. Provisional Application Ser. No. 60/916,815, filed May 9, 2007, U.S. Provisional Application Ser. No. 60/908,095, filed Mar. 26, 2007, U.S. Provisional Application No. 60/868,962, filed Dec. 7, 2006, U.S. Provisional Application No. 60/868,851, filed

Dec. 6, 2006, and U.S. Provisional Application No. 60/868,893, filed Dec. 6, 2006. U.S. application Ser. No. 15/369,881 also is a continuation-in-part of U.S. application Ser. No. 14/323,531, filed Jul. 3, 2014 (now U.S. Pat. No. 9,960,667), which is a continuation of U.S. application Ser. No. 12/328,742, filed Dec. 4, 2008 (now U.S. Pat. No. 8,816,535), which is a continuation-in-part of U.S. application Ser. No. 11/950,271, filed Dec. 4, 2007. Each of the above-mentioned disclosures are incorporated herein by reference in their entireties and for all purposes.

FIELD AND BACKGROUND

(1) The present invention relates to distributed power systems and, more particularly, wake-up and shutdown algorithms for the photovoltaic distributed power systems. The present invention also relates to anti-islanding in a distributed power system and, more particularly, system and method for protection of photovoltaic distributed power equipment and personnel during anti-islanding.

(2) Utility networks provide an electrical power system to utility customers. The distribution of electric power from utility companies to customers utilizes a network of utility lines connected in a grid-like fashion, referred to as an electrical grid. The electrical grid may consist of many independent energy sources energizing the grid in addition to utility companies energizing the grid, with each independent energy source being referred to as a distributed power (DP) generation system. The modern utility network includes the utility power source, consumer loads, and the distributed power generation systems which also supply electrical power to the network. The number and types of distributed power generation systems is growing rapidly and can include photovoltaics, wind, hydro, fuel cells, storage systems such as battery, super-conducting flywheel, and capacitor types, and mechanical devices including conventional and variable speed diesel engines, Stirling engines, gas turbines, and micro-turbines. These distributed power generation systems are connected to the utility network such that they operate in parallel with the utility power sources.

(3) One common problem faced by modern utility networks is the occurrence of islanding. Islanding is the condition where a distributed power generation system is severed from the utility network, but continues to supply power to portions of the utility network after the utility power supply is disconnected from those portions of the network. All photovoltaic systems must have anti islanding detection in order to comply with safety regulations. Otherwise the photovoltaic installation may shock or electrocute repairmen after the grid is shut down from the photovoltaic installation generating power as an island downstream. The island condition complicates the orderly reconnection of the utility network and poses a hazard also to equipment. Thus, it is important for an island condition to be detected and eliminated.

(4) Several techniques have been proposed to guard against islanding. For example, one method involves the monitoring of auxiliary contacts on all circuit breakers of the utility system between its main source of generation and DP systems. The auxiliary contacts are monitored for a change of state which represents an open circuit breaker on the utility source. The utility circuit breaker is typically monitored and tripped by external protective relays. When a loss of utility is detected by the change in state of the auxiliary contact of a circuit breaker, a transferred trip scheme is employed to open the interconnection between the utility and the distributed power system. A transferred trip scheme uses the auxiliary contacts of the utility source being monitored. The auxiliary contacts are connected in parallel with other devices which can trigger the trip of the local interconnection breaker. When the auxiliary contacts change state, a trip is induced on the local interconnection breaker. This prevents an island condition from occurring. The drawback of such a method is that often the point of utility isolation (the point at which the utility circuit breaker opens) is of such a distance from the local distributed power system that running a contact status signal back to the local distributed power system control system is not practical.

(5) Anti-islanding schemes presently used or proposed include passive schemes and active schemes. Passive schemes are based on local monitoring of the grid signals, such as under or over

voltage, under or over frequency, rate of change of frequency, phase jump, or system harmonics, for example. Active schemes are based on active signal injection with monitoring of the resulting grid signals, such as impedance measurement for example, or active signal injection with active controls, such as active frequency shifting or active voltage shifting for example. With active schemes, some distortion may occur in the output current waveform, thereby resulting in a tradeoff between islanding detection time and waveform distortion, with faster detection typically resulting in higher total harmonic distortion.
(6) A conventional installation of a solar distributed power system **10**, including multiple solar panels **101**, is illustrated in FIG. **1**. Since the voltage provided by each individual solar panel **101** is low, several panels **101** are connected in series to form a string **103** of panels **101**. For a large installation, when higher current is required, several strings **103** may be connected in parallel to form overall system **10**. The interconnected solar panels **101** are mounted outdoors, and connected to a maximum power point tracking (MPPT) module **107** and then to an inverter **104**. MPPT **107** is typically implemented as part of inverter **104** as shown in FIG. **1**. The harvested power from DC sources **101** is delivered to inverter **104**, which converts the direct-current (DC) into alternating-current (AC) having a desired voltage and frequency, which is usually 110V or 220V at 60 Hz, or 220V at 50 Hz. The AC current from inverter **104** may then be used for operating electric appliances or fed to the power grid.
(7) As noted above, each solar panel **101** supplies relatively very low voltage and current. A problem facing the solar array designer is to produce a standard AC current at 120V or 220V root-mean-square (RMS) from a combination of the low voltages of the solar panels. The delivery of high power from a low voltage requires very high currents, which cause large conduction losses on the order of the second power of the current i.sup.2. Furthermore, a power inverter, such as inverter **104**, which is used to convert DC current to AC current, is most efficient when its input voltage is slightly higher than its output RMS voltage multiplied by the square root of 2 (which is the peak voltage). Hence, in many applications, the power sources, such as solar panels **101**, are combined in order to reach the correct voltage or current. A large number of panels **101** are connected into a string **103** and strings **103** are connected in parallel to power inverter **104**. Panels **101** are connected in series in order to reach the minimal voltage required for inverter **104**. Multiple strings **103** are connected in parallel into an array to supply higher current, so as to enable higher power output.
(8) FIG. **1**B illustrates one serial string **103** of DC sources, e.g., solar panels **101***a*-**101***d*, connected to MPPT circuit **107** and inverter **104**. The current versus voltage (IV) characteristics is plotted (**110***a*-**110***d*) to the left of each DC source **101**. For each DC power source **101**, the current decreases as the output voltage increases. At some voltage value, the current goes to zero, and in some applications the voltage value may assume a negative value, meaning that the source becomes a sink. Bypass diodes (not shown) are used to prevent the source from becoming a sink. The power output of each source **101**, which is equal to the product of current and voltage (P=i*V), varies depending on the voltage drawn from the source. At a certain current and voltage, close to the falling off point of the current, the power reaches its maximum. It is desirable to operate a power generating cell at this maximum power point (MPP). The purpose of the MPPT is to find this point and operate the system at this point so as to draw the maximum power from the sources.
(9) In a typical, conventional solar panel array, different algorithms and techniques are used to optimize the integrated power output of system **10** using MPPT module **107**. MPPT module **107** receives the current extracted from all of solar panels **101** together and tracks the maximum power point for this current to provide the maximum average power such that if more current is extracted, the average voltage from the panels starts to drop, thus lowering the harvested power. MPPT module **107** maintains a current that yields the maximum average power from system **10**.
(10) However, since power sources **101***a*-**101***d* are connected in series to single MPPT **107**, MPPT **107** selects a maximum power point which is some average of the maximum power points of the

individual serially connected sources **101**. In practice, it is very likely that MPPT **107** would operate at an I-V point that is optimum for only a few or none of sources **101**. In the example of FIG. **1**B, the selected point is the maximum power point for source **101***b*, but is off the maximum power point for sources **101***a*, **101***c* and **101***d*. Consequently, the arrangement is not operated at best achievable efficiency.

(11) The present applicant has disclosed in co-pending U.S. application Ser. No. 11/950,271 entitled "Distributed Power Harvesting System Using DC Power Sources", the use of an electrical power converter, e.g., DC-to-DC converter, attached to the output of each power source, e.g., photovoltaic panel. The electrical power converter converts input power to output power by monitoring and controlling the input power at a maximum power level. This system may be used also to address the anti-islanding issue.

(12) The term "signaling" or "signaling mechanism" as used herein refers to either a signal modulated on an electromagnetic carrier signal or a simple unmodulated signal such as an on/off signal "keep alive" signal or "dry contact" signal. For a modulated signal, the modulation method may be by any such method known in the art by way of example, frequency modulation (FM) transmission, amplitude modulation (AM), FSK (frequency shift keying) modulation, PSK (phase shift keying) modulation, various QAM (Quadrature amplitude modulation) constellations, or any other method of modulation.

(13) The term "leakage" as used herein refers to electrical power which is radiated or conducted into an electrical signal line typically at low levels and typically because of insufficient isolation.

(14) The term "power module" as used herein includes power converters such as a DC-DC power converter but also includes modules adapted to control the power passing through the module or a portion of the power, whether by switching or other means.

SUMMARY

(15) The following summary of the invention is included in order to provide a basic understanding of some aspects and features of the invention. This summary is not an extensive overview of the invention and as such it is not intended to particularly identify key or critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented below.

(16) According to an aspect of the present invention, there is provided a distributed power system including a DC power source and a power module. The power module includes an input coupled respectively to the DC power source and an output. An inverter is coupled to the output. The inverter converts power input from the output of the power module to output power. A signaling mechanism between the inverter and the power module is adapted for controlling operation of the power module. During operation of the distributed power system, in some embodiments, the signaling mechanism may superimpose a signal on the output of the power module. The signaling mechanism may include a switch integrated with the inverter, the switch modulating the signal onto the output of the power module. A receiver integrated with the power modules receives the signal from the inverter. Alternatively a detection mechanism in the power module detects a signal at the frequency of the electrical grid. Alternatively, a signal from the electrical grid is detected in the output of the power module at a higher frequency up-converted from the frequency of the electrical grid. Alternatively, a detection mechanism in the power module detects a switching frequency of the inverter. The power modules are may be configured for operation in a safety mode, and during the safety mode, the power at the output of the power module, the voltage across the output of the power module, and/or the current flowing through it, are limited so as not to endanger personnel. The power module may include a detection mechanism wherein during operation of the distributed power system, the detection mechanism detects a signal from the inverter. Based on the signal, the operation of the power module is varied from the safety mode of operation to a normal mode of operation for converting power of the DC power source from the input to the output of the power

module.

(17) According to another aspect of the present invention there is provided a method for operating a distributed power system. The system includes a DC power source and a power module. The power module includes an input coupled to the DC power source. The power module includes an output. An inverter is coupled to the output of the power module. The inverter converts a power output from the power module to an output power. The method includes operating the power modules in a safety mode by limiting the power output from the power module. The safety mode is characterized by having less than a predetermined amount (e.g. ten milliamperes) of current flow and/or less than a predetermined amount (e.g. 2 Volts) through the output of the power module. A signal from the inverter is preferably monitored and upon detecting the signal from the inverter, the power input to the inverter is increased by operating the power module in a normal mode of operation for converting power of the DC power source from the input to the output of the power module. Upon detecting the signal and prior to the operation of the power module in the normal mode of operation, the voltage of the output of the power module is preferably ramped up slowly. The normal mode of operation of the power module may include controlling a maximum peak power at the input coupled to the DC power sources.

(18) According to an aspect of the present invention, there is provided in a distributed power system multiple DC power sources and multiple power modules which include inputs coupled respectively to the DC power sources. The power modules each include outputs coupled in series to form a serial string. An inverter is coupled to the serial string. The inverter converts power input from the string and produces output power. A protection mechanism in the power modules shuts down the power modules and ceases the power input to the inverter when the inverter stops producing the output power. Typically, the inverter is connected to the electrical grid. A monitoring mechanism is attached to the electrical grid which monitors one or more electrical parameters of the electrical grid. A shutdown mechanism is attached to the monitoring mechanism which when one or more of the electrical parameters is out of predetermined specification, the inverter stops the production of the output power or disconnects from the grid. A switch is preferably disposed between the serial string and the inverter. The switch is activated by the shutdown mechanism and the protection mechanism senses a change in current flowing through the serial string when the switch is activated. When the switch is connected serially with the serial string, the protection mechanism senses that current less than a previously specified minimal threshold current in the serial string; or when the switch is connected in parallel with the serial string the protection mechanism senses a current greater than a previously specified maximal threshold current in the string. Alternatively a signal-providing mechanism is attached to the inverter which provides a signal based on the shutdown mechanism. Multiple receivers are attached respectively to the power modules. The receivers receive the signal and multiple enabling mechanisms, which are attached respectively to the receivers, enable the respective power modules to supply the input power to the inverter based on the presence of the signal or absence thereof When the signal is a keep-alive signal, the enabling mechanisms enable the respective power modules to supply the input power to the inverter based on the presence of the keep-alive signal. When the signal is a shut-down signal, the enabling mechanism disables the respective power modules and stops supply of the input power to the inverter based on the presence of the shut-down signal. The signal in the serial string is optionally from the electrical grid and detected at the frequency of the electrical grid or detected at a higher frequency up converted from the frequency of the electrical grid. The signal in the serial string is optionally from the inverter or the output power therefrom, and detected at a switching frequency of the inverter. The signal is optionally superimposed on the power input to the inverter from the serial string. The signal may be wirelessly transmitted by the signal-providing mechanism, and the receiver in each of the power modules, receives the wirelessly transmitted signal.

(19) According to another aspect of the present invention, there is provided a protection method in a distributed power system including DC power sources and multiple power modules each of

which include inputs coupled to the DC power sources. The power modules each include outputs coupled in series to form a serial string. An inverter is coupled to the serial string. The inverter converts power input from the string and produces output power. When the inverter stops production of the output power, each of the power modules is shut down and thereby the power input to the inverter is ceased. When the inverter is connected to and supplies the output power to the electrical grid, one or more electrical parameters of the grid are monitored. When the one or more electrical parameters of the grid are out of a predetermined specification, the inverter is shut down and thereby production of the output power is stopped or the inverter is disconnected from the grid. When the inverter is shut down, a switch disposed between the serial string and the inverter is activated. When the switch is activated a change in current flowing through the serial string is sensed. Alternatively a signal is provided based on the shutdown mechanism. Multiple receivers are attached respectively to the power modules. The receivers receive the signals which enable the respective power modules to supply the input power to the inverter based on the presence of the signal or absence thereof. When the signal is a keep-alive signal, the respective power modules supply the input power to the inverter based on the presence of the keep-alive signal. When the signal is a shut-down signal, the respective power modules stop supply of the input power to the inverter based on the presence of the shut-down signal. The signal may be based on current in the serial string from the electrical grid and detected at the frequency of the electrical grid or detected at a higher frequency up converted from the frequency of the electrical grid. The signal in the serial string is optionally from the inverter or the output power therefrom, and detected at a switching frequency of the inverter. The signal is optionally actively superimposed on the power input to the inverter from the serial string. The signal may be wirelessly transmitted, and the receiver in each of the power modules, receives the wirelessly transmitted signal.
(20) The foregoing and/or other aspects will become apparent from the following detailed description when considered in conjunction with the accompanying drawing figures.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The accompanying drawings, which are incorporated in and constitute a part of this specification, exemplify embodiments of the present invention and, together with the description, serve to explain and illustrate principles of the invention. The drawings are intended to illustrate various features of the illustrated embodiments in a diagrammatic manner. The drawings are not intended to depict every feature of actual embodiments nor relative dimensions of the depicted elements, and are not necessarily drawn to scale.
(2) The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:
(3) FIG. **1** is a block diagram of a conventional power harvesting system using photovoltaic panels as DC power sources;
(4) FIG. **1**B illustrates current versus voltage characteristic curves for one serial string the DC power sources of FIG. **1**;
(5) FIG. **2** is a simplified block diagram illustrating a distributed power harvesting circuit, based on the disclosure in U.S. application Ser. No. 11/950,271, according to an aspect of the present invention;
(6) FIG. **2**A is a simplified block diagram of a DC-to-DC converter, including a feature of the present invention;
(7) FIG. **3** illustrates an exemplary DC-to-DC converter, is a simplified block diagram illustrating in more detail;
(8) FIG. **4** is a simplified block diagram of another exemplary system, according to an embodiment

of the present invention;
(9) FIG. **4**A is a simplified block diagram illustrating in more detail, a power module according to the embodiment of FIG. **4**;
(10) FIG. **4**B is a simplified block diagram illustrating in more detail, a signaling mechanism attached to a conventional inverter, according to embodiments of the present invention;
(11) FIG. **5** is a simplified flow diagram illustrating a method for wake-up and shutdown of a power harvesting system with a safety mode, according to a feature of the present invention;
(12) FIG. **5**A is a flow diagram illustrating methods for wake-up and shutdown of a power harvesting system, according to embodiments of the present invention, the flow diagram including method steps performed by the power converters/modules;
(13) FIG. **6** is another flow diagram illustrating methods for wake-up and shutdown of a power harvesting system, according to embodiments of the present invention, the flow diagram including method steps performed by the inverter of FIG. **2** or signaling block of FIG. **4**B;
(14) FIGS. **7** and **7**A illustrate a system for protection during an islanding condition, in accordance with aspects of the present invention;
(15) FIGS. **7**B and **7**C illustrate in more detail the system of FIGS. **7** and **7**A;
(16) FIG. **7**D illustrates a method, according to an aspect of the present invention using the system of FIGS. **7** and **7**A;
(17) FIGS. **8** and **8**A, illustrate a system for protection during an islanding condition in accordance with other aspects of the present invention;
(18) FIG. **8**B illustrates an example wherein a system according to an embodiment of the invention is applied as a retrofit to a prior art system, such as the system of FIG. **1**;
(19) FIGS. **9**, **9**A and **9**B illustrate a system for protection during an islanding condition, according to still other aspects of the present invention; and
(20) FIGS. **10** and **10**A, illustrate a system for protection during an islanding condition, according to yet other aspects of the present invention.

DETAILED DESCRIPTION

(21) Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.
(22) It should be noted, that although the discussion herein relates primarily to wake-up and shutdown methods in photovoltaic systems and more particularly to those systems previously disclosed in U.S. application Ser. No. 11/950,271, the present invention may, by non-limiting example, alternatively be configured as well using conventional photovoltaic distributed power systems and other distributed power systems including (but not limited to) wind turbines, hydroturbines, fuel cells, storage systems such as battery, super-conducting flywheel, and capacitors, and mechanical devices including conventional and variable speed diesel engines, Stirling engines, gas turbines, and micro-turbines.
(23) By way of introduction, it is important to note that aspects of the present invention have important safety benefits. While installing or performing maintenance on photovoltaic systems according to certain aspects of the present invention, installers are protected from danger of shock or electrocution since systems according to embodiments of the present invention do not output potentially dangerous high voltage and/or currents such as when solar panels are exposed to sunlight when an operational inverter is not connected during installation and maintenance procedures. Similarly, firefighters, even after they shut down the main electrical switch to a burning building can safely break into the burning building or hose the roof of the building with water without fear of high voltage DC conduction through the water, since high voltage direct current feeding the inverter is safely turned off.
(24) Before explaining embodiments of the invention in detail, it is to be understood that the

invention is not limited in its application to the details of design and the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting.

(25) Reference is now made to FIG. **2** which illustrates a distributed power harvesting circuit **20**, based on the disclosure in U.S. application Ser. No. 11/950,271. Circuit **20** enables connection of multiple distributed power sources, for example solar panels **101***a*-**101***d*, to a single power supply. Series string **203** of solar panels **101** may be coupled to an inverter **204** or multiple connected strings **203** of solar panels **101** may be connected to a single inverter **204**. In configuration **20**, each solar panel **101***a*-**101***d* is connected individually to a separate power converter circuit or a module **205***a*-**205***d*. Each solar panel **101** together with its associated power converter circuit **205** forms a power generating element **222**. (Only one such power generating element **222** is marked in FIG. **2**.) Each converter **205***a*-**205***d* adapts optimally to the power characteristics of the connected solar panel **101***a*-**101***d* and transfers the power efficiently from input to output of converter **205**. Converters **205***a*-**205***d* are typically microprocessor controlled switching converters, e.g. buck converters, boost converters, buck/boost converters, flyback or forward converters, etc. The converters **205***a*-**205***d* may also contain a number of component converters, for example a serial connection of a buck and a boost converter. Each converter **205***a*-**205***d* includes a control loop **221**, e.g. MPPT loop that receives a feedback signal, not from the converter's output current or voltage, but rather from the converter's input coming from solar panel **101**. The MPPT loop of converter **205** locks the input voltage and current from each solar panel **101***a*-**101***d* at its optimal power point, by varying one or more duty cycles of the switching conversion typically by pulse width modulation (PWM) in such a way that maximum power is extracted from each attached panel **101***a*-**101***d*. The controller of converter **205** dynamically tracks the maximum power point at the converter input. Feedback loop **221** is closed on the input power in order to track maximum input power rather than closing a feedback loop on the output voltage as performed by conventional DC-to-DC voltage converters.

(26) As a result of having a separate MPPT circuit in each converter **205***a*-**205***d*, and consequently for each solar panel **101***a*-**101***d*, each string **203** may have a different number or different specification, size and/or model of panels **101***a*-**101***d* connected in series. System **20** of FIG. **2** continuously performs MPPT on the output of each solar panel **101***a*-**101***d* to react to changes in temperature, solar radiance, shading or other performance factors that effect one or more of solar panels **101***a*-**101***d*. As a result, the MPPT circuit within the converters **205***a*-**205***d* harvests the maximum possible power from each panel **101***a*-**101***d* and transfers this power as output regardless of the parameters effecting other solar panels **101***a*-**101***d*.

(27) The outputs of converters **205***a*-**205***d* are series connected into a single DC output that forms the input to inverter **204**. Inverter **204** converts the series connected DC output of converters **205***a*-**205***d* into an AC power supply. Inverter **204**, regulates the voltage at the input of inverter **204**. In this example, an independent control loop **220** holds the voltage input to inverter **204** at a set value, say 400 volts. The current at the input of inverter **204** is typically fixed by the power available and generated by photovoltaic panels **101**.

(28) In order to legally be allowed to connect to the grid in each country, inverter **104**,**204** is preferably designed to comply with local electrical regulations. Electrical regulations typically dictate, among other things, the minimal and maximal voltages of the grid e.g. **220-260** root mean squares voltage V, and a range of permitted frequency, e.g. 45-55 Hz. Whenever the grid deviates from allowed values inverter **104**,**204** is required to disconnect from the grid. Disconnection from the grid is typically performed using software controlling inverter **104**, **204** and control circuitry which constantly monitors grid parameters, e.g. voltage, frequency.

(29) In system **10**, solar panels **101** are directly connected (e.g. in series-parallel) to inverter **104**.

When an islanding condition is detected, inverter **104** is disconnected from the grid. Hence, inverter **104** stops drawing current and therefore panels **101** output a relatively high open circuit voltage typically 25% higher than the normal operating voltage. An open circuit voltage 25% higher than nominal working voltage is typically safe, (less than the allowed 600 VDC in the USA and 1000 VDC in Europe) which are typical ratings for inverters **104** designed to be able to handle the higher open circuit voltage.

(30) In system **20**, there are power converters **205** which "push" power to the output of converters **205**. Under an islanding condition which has been detected by inverter **204**, inverter **204** is shut down and current is not flowing between converters **205** and inverter **204**. Consequently, in system **20**, the open circuit voltage at the input to inverter **204**, reaches dangerous voltages, higher than the open circuit maximum voltage ratings of inverters **104**, **204**.

(31) According to a feature of the present invention, information regarding wakeup or shut-down may be conveyed from inverter **204** to converters **205**. The information may be transmitted using any of the methods well known to those experienced in the art. According to certain embodiments, a modulation method may be used, by way of example, frequency modulation (FM) transmission, amplitude modulation (AM), FSK (frequency shift keying) modulation, PSK (phase shift keying) modulation, various QAM (Quadrature amplitude modulation) constellations, or any other method of modulation. Alternatively, inverter **204**, while converting power from its input to its output, actively creates a frequency ripple in serial string **203**. During normal operation, the 100 Hz (or 120 Hz in USA) ripple is detectable in serial string **203** since the capacitors of inverter **204** do not entirely block the alternating current (AC), and an additional signaling mechanism is not required to produce the 100/120 Hz signal in serial string **203**. Alternatively or in addition, one or more switching frequencies of inverter **204**, typically 16 Khz or 32 KHz may be detectable as leakage or provided intentionally to serial string **203**.

(32) Reference is now made to FIG. **2**A which illustrates a feature of the present invention. In FIG. **2**A, converter **205** is shown in more detail. Integrated with power converter **205** is a detector/receiver **207**, according to a feature of the present invention which is configured to receive, optionally amplify and detect the signal, e.g. at 100/120 Hz originating in inverter **204**.

(33) Controller **306** preferably cither polls a signal input **209** from receiver/detector **207** or uses signal input **209** as an interrupt so that only when detector/receiver **207** detects the 100/120 Hz signal, is module **205** in a normal operating mode converting power from its input to its output. Receiver **207** is alternatively configured to detect the 16/32 KHz inverter switching frequency and provides an enabling signal to controller on signal input **209** while inverter **204** is operating.

(34) Reference is now made to FIG. **3** which illustrates an exemplary DC-to-DC converter **205**, according to a feature of the present invention. DC-to-DC converters are used to either step down or step up a DC voltage input to a higher or a lower DC voltage output, depending on the requirements of the output circuit. However, in the embodiment of FIG. **3** the DC-DC converter **205** is used as a power converter, i.e., transferring the input power to output power, the input voltage varying according to the MPPT at the input, while the output current is dictated by the constant input voltage to inverter **104**, **204**. That is, the input voltage and current may vary at any time and the output voltage and current may vary at any time, depending on the operating condition of DC power sources **101**.

(35) Converter **205** is connected to a corresponding DC power source **101** at input terminals **314** and **316**. The converted power of the DC power source **101** is output to the circuit through output terminals **310**, **312**. Between the input terminals **314**, **316** and the output terminals **310**, **312**, the converter circuit includes input and output capacitors **320**, **340**, backflow prevention diodes **322**, **342** and a power conversion circuit including a controller **306** and an inductor **308**.

(36) Diode **342** is in series with output **312** with a polarity such that current does not backflow into the converter **205**. Diode **322** is coupled between the positive output lead **312** through inductor **308** which acts a short for DC current and the negative input lead **314** with such polarity to prevent a

current from the output **312** to backflow into solar panel **101**.
(37) A potential difference exists between wires **314** and **316** due to the electron-hole pairs produced in the solar cells of panel **101**. Converter **205** maintains maximum power output by extracting current from the solar panel **101** at its peak power point by continuously monitoring the current and voltage provided by panel **101** and using a maximum power point tracking algorithm. Controller **306** includes an MPPT circuit or algorithm for performing the peak power tracking. Peak power tracking and pulse width modulation (PWM) are performed together to achieve the desired input voltage and current. The MPPT in controller **306** may be any conventional MPPT, such as, e.g., perturb and observe (P&O), incremental conductance, etc. However, notably the MPPT is performed on panel **101** directly, i.e., at the input to converter **205**, rather than at the output of converter **205**. The generated power is then transferred to the output terminals **310** and **312**. The outputs of multiple converters **205** may be connected in series, such that the positive lead **312** of one converter **205** is connected to the negative lead **310** of the next converter **205**.
(38) In FIG. **3**, converter **205** is shown as a buck plus boost converter. The term "buck plus boost" as used herein is a buck converter directly followed by a boost converter as shown in FIG. **3**, which may also appear in the literature as "cascaded buck-boost converter". If the voltage is to be lowered, the boost portion is substantially shorted. If the voltage is to be raised, the buck portion is substantially shorted. The term "buck plus boost" differs from buck/boost topology which is a classic topology that may be used when voltage is to be raised or lowered, and sometimes appears in the literature as "cascaded buck-boost". The efficiency of "buck/boost" topology is inherently lower than a buck or a boost. Additionally, for given requirements, a buck-boost converter will need bigger passive components then a buck plus boost converter in order to function. Therefore, the buck plus boost topology of FIG. **3** has a higher efficiency than the buck/boost topology. However, the circuit of FIG. **3** continuously decides whether it is bucking or boosting. In some situations when the desired output voltage is similar to the input voltage, then both the buck and boost portions may be operational.
(39) The controller **306** may include a pulse width modulator, PWM, or a digital pulse width modulator, DPWM, to be used with the buck and boost converter circuits. Controller **306** controls both the buck converter and the boost converter and determines whether a buck or a boost operation is to be performed. In some circumstances both the buck and boost portions may operate together. That is, the input voltage and current are selected independently of the selection of output current and voltage. Moreover, the selection of either input or output values may change at any given moment depending on the operation of the DC power sources. Therefore, in the embodiment of FIG. **3**, converter **205** is constructed so that at any given time a selected value of input voltage and current may be up converted or down converted depending on the output requirement.
(40) In one implementation, an integrated circuit (IC) **304** may be used that incorporates some of the functionality of converter **205**. IC **304** is optionally a single ASIC able to withstand harsh temperature extremes present in outdoor solar installations. ASIC **304** may be designed for a high mean time between failures (MTBF) of more than 25 years. However, a discrete solution using multiple integrated circuits may also be used in a similar manner. In the exemplary embodiment shown in FIG. **3**, the buck plus boost portion of the converter **305** is implemented as the IC **304**. Practical considerations may lead to other segmentations of the system. For example, in one aspect of the invention, the IC **304** may include two ICs, one analog IC which handles the high currents and voltages in the system, and one simple low-voltage digital IC which includes the control logic. The analog IC may be implemented using power FETs which may alternatively be implemented in discrete components, FET drivers, A/Ds, and the like. The digital IC may form controller **306**.
(41) In the exemplary circuit **205** shown, the buck converter includes input capacitor **320**, transistors **328** and **330**, diode **322** positioned in parallel to transistor **328**, and inductor **308**. Transistors **328**, **330** each have a parasitic body diode **324**, **326**. The boost converter includes inductor **308**, which is shared with the buck converter, transistors **348** and **350** a diode **342**

positioned in parallel to transistor **350**, and output capacitor **340**. Transistors **348**, **350** each have a parasitic body diode **344**, **346**.

(42) System **20** includes converters **205** which are connected in series and carry the current from string **203**. If a failure in one of the serially connected converters **205** causes an open circuit in failed converter **205**, current ceases to flow through the entire string **203** of converters **205**, thereby causing system **20** to stop functioning. Aspects of the present invention provide a converter circuit **205** in which electrical components have one or more bypass routes associated with them that carry the current in case of an electrical component failing within one of converters **205**. For example, each switching transistor of either the buck or the boost portion of the converter has its own diode bypass. Also, upon failure of inductor **308**, the current bypasses the failed inductor **308** through parasitic diodes **344**,**346**.

(43) In FIG. **3**, detector/receiver block **207** is shown which is configured to provide an enable signal **209** to microcontroller **306** when the communications signal originating in inverter **104**,**204** is detected.

(44) Reference in now made to FIGS. **4**, which illustrate system **40**, according to an embodiment of the present invention. For simplicity, a single string **423** is shown of distributed power sources, e.g. solar panels **101***a*-**101***d* connected to respective power modules **405***a-d*. Serial string **423** is input to conventional inverter **104** through wires **412** and **410**. The output of inverter **104** is connected to and supplies electrical power to the electrical grid. At the input of inverter **104**, is connected a signaling mechanism **420** which superimposes a signal on serial string **423** through wires **412** and **410** when inverter **104** is converting power to the grid.

(45) Reference is now also made to FIG. **4**B which illustrates in more detail signaling mechanism **420**. Signaling mechanism **420** includes a relay **428** which is normally open and controlled by a microcontroller **422**. Relay **428** is switched at a given rate, e.g. 100 Hz, and the signal is superimposed by action of relay **428** onto serial string **423** over wires **410** and **412**. Microcontroller **422** typically provides the control of the signal, e.g. 100 Hz, during normal operation of distributed power system **40**. Microcontroller **422** is typically connected to one or more sensors in order to monitor the operation of inverter **104**. In the example of FIG. **4**B, microcontroller **422** monitors over-voltage of the input DC voltage to inverter **104**. The example shown in FIG. **4**B includes an input DC voltage tap **432** connected to an analog to digital converter (A/D) **430**, the output of which is provided to microcontroller **422**. The tap **432** may be, e.g., a Hall-effect sensors, series connected resistor across which the voltage drop is measured, etc. In one embodiment, an over-voltage condition as measured by microcontroller **422**, results in microcontroller **422** stopping the signaling through relay **428** and/or opening one or more protective relays **424**, **426** in series with the input DC voltage to inverter **104**. Note that one switch **424** or **426** may be enough for performing the required action, and two switches in series are shown solely for the purpose of illustration that double protection might be required by some regulatory bodies. A power management block **434** taps voltage for powering microcontroller **422** and any other active electronics components (not shown) in block **420**.

(46) Reference is now made to FIG. **4**A which illustrates in more detail certain aspects of power module **405**. Integrated with power module **405** is detector/receiver **207** which is configured to receive, optionally amplify and detect the signal, e.g. at 100 Hz, produced by signal mechanism **420**. Controller **306** preferably either polls signal input **209** or uses signal input **209** as an interrupt so that only when detector/receiver **207** detects the 100 Hz signal, is module **405** operating in a normal operating mode. Power module **405** is shown to include a bypass diode **414**. Optionally, power module **405** may include a conventional DC/DC switching converter with a control loop based on output power. Power module **405** includes at least one switch **416** controlled by controller **306** which functions to stop normal operation of power from the input of module **405** to the output of **405** when signal input **209** is absent indicating that inverter **104** is not transferring power to the electrical grid.

(47) Reference is now made to FIG. **5** which illustrates a simplified method for safe operation of system **40**, according to an aspect of the present invention. In step **501**, active control circuits, e.g. microcontroller **306**, are turned on. Module **205**, **405** begins operation (step **53**) in a safety mode. In safety mode, output current and/or voltage from module **405** is limited, for instance output voltage is limited to 2 volts and output current is limited to 10 mA so that a person can touch the wires of serial string **203**, **423** without any danger of electrocution.
(48) Controller **306** maintains safety mode operation (step **53**) until a communications signal, e.g. 100 Hz, is received (decision box **505**) by receiver/detector **207** from inverter **204** or signaling block **420**. When the communications signal is received (decision block **505**) indicating inverter **104** or **204** is connected and converting power, safety mode (step **53**) of operation ends. When the communications signal is received (decision block **505**), module **405** preferably enters a normal operation mode (step **57**), typically with maximum power point tracking. The normal operation of transferring power is maintained as long as the communications signal, e.g. 100 Hz is received from inverter **204** or signal mechanism **420**, and no other warning condition is present. If the communications signal is not detected, or another warning condition is present, the normal mode (step **57**) is typically ended and power conversion of modules **405** is typically turned off. If in decision box **509**, the communications signal is not detected, or another warning condition is present, the normal mode (step **57**) is typically ended and power conversion of modules **405** is typically turned off.
(49) Reference is now made to FIG. **5**A, which illustrates a method **50** for wake-up and shutdown of module **405**, according to embodiments of the present invention. Method **50** is applicable to both systems **20** and **40**. In step **501**, active control circuits, e.g. microcontroller **306**, are turned on. Active control circuits are typically turned on (step **501**) in the early morning when there is sufficient light to power the active control circuits typically with voltage of DC voltage source **101** reaching three volts. In decision block **503**, when voltage output—or power output—from DC voltage source **101** is sufficiently high and stable (e.g. voltage input to module **405** is ten volts for a period of 30 seconds), then module **205**,**405** begins operation (step **53**) in a safety mode. In safety mode, output current and/or voltage from module **405** is limited, for instance output voltage is limited to 2 volts and output current is limited to 10 mA so that a person can touch the wires of serial string **203**,**423** without any danger of electrocution. Note also, that in this case even if 25 modules are connected in series, the maximum output voltage of the string doesn't exceed 50V—which means the string voltage is still safe. Referring back to FIG. **3**, safety mode may be achieved by controller **306** in module **405** by turning on FET **330** and turning off FETS **328**, **348**, and **350**. Output wire **412** is held close to zero volts. Alternatively, the controller **306** may alternate the switches (e.g. switches **324** & **326** of buck converter) at a low duty-cycle in order to maintain a low output voltage.
(50) Referring back to FIG. **5**A, controller **306** maintains safety mode operation (step **53**) until a communications signal, e.g. 100 Hz, is received by receiver/detector **207** from inverter **204** or signaling block **420**. When the communications signal is received (decision block **505**) indicating inverter **104** or **204** is connected and converting power, safety mode (step **53**) of operation ends. When the communications signal is received (decision block **505**), module **405** preferably enters a voltage control mode (step **55**) and voltage output between wires **412**,**410** is slowly ramped up. Voltage continues to ramp up, typically as high as +60V until module **205**,**405** detects that current is being drawn by the inverter **104**, **204** (step **507**). When sufficient current is drawn (step **507**), module **205**, **405** begins normal operation, (step **57**) e.g. for module **205**, the normal mode is the maximum power point (MPP) tracking mode of converting DC power from its input to its output by maintaining maximum power at its input. The normal operation of transferring power is maintained as long as the communications signal, e.g. 100 Hz is received from inverter **204** or signal mechanism **420**, and no other warning condition is present. If the communications signal is not detected, or another warning condition is present, the normal mode (step **57**) is typically ended

and power conversion of modules **405** is typically turned off. Exemplary warning conditions in decision box **509**, which cause module **205**,**405** to end normal mode (step **57**) and to stop transferring power to its output include: (i) input voltage less than predetermined value, e.g. about 10 volts for 5 seconds, (ii) rapid change in output voltage, for instance greater than 20% in 100 milliseconds, (iii) reception of signal requesting to stop producing power, (iv) not receiving a signal to produce power (in the case where recurring “allow production” signals are required for the converter to function), or (v) output exceeds over voltage threshold caused for instance when multiple modules **205** in string **203** are converting power (step **57**) and one of modules **205** of string **203** shuts down, then the other modules **205** of string **203** have a raise of output voltage.
(51) Reference is now made to FIG. **6**, which illustrates a method **60** performed by inverter **204** or signaling block **420** attached at the input of inverter **104**. In step **601**, inverter **104** is off or inverter **204** is on standby, and not converting power to its output. In decision box **603**, start conditions for turning on inverter **104**,**204** are determined. Typically, as a safety requirement, inverter **104** delays operation (converting power to its output) until after at least 5 minutes of connection to a functioning AC-grid at its output. This safety requirement may be achieved using microcontroller **422** and at least one of relays **424** and **426** in signaling block **420**. In inverter **204**, a minimum voltage is required at the input to inverter **204** (e.g. if the safety output voltage of each module is 2V, and the minimal-length string allowed contains 5 modules, the inverter will wait until at least 10V are present at its DC input) and only thereafter does inverter **204** begin to charge its input, typically to a specified standard input of 400V.
(52) In step **605**, communications signal, e.g. 100 Hz, is superimposed on serial string **203**,**423** either from signaling mechanism **420** or from inverter **204** for instance when at least a 50 Watt load is attached to the output of inverter **204**. In decision box **607**, when the specified input voltage is reached, e.g. 400V for inverter **204**, inverter **204** is turned on or inverter **104** is attached to serial string **423** by mechanism **420**. In decision box **609**, if a time out occurs before the minimum specified input voltage is reached of inverter **204**,**404** then inverter is returned to the off or standby state (step **601**). Otherwise inverter **204**,**404** is connected or turned on in step **611**. Inverter **204**, **404** remains on and connected unless a warning condition (decision box **613**) occurs. Possible warning conditions include, (i) disconnection from the electrical grid, (ii) electrical grid stops producing power (islanding), (iii) less than 50 Watts transferred in the last minute, (iv) input voltage to inverter **204**,**404** is over the maximum limit, and (v) input power is over the maximum limit. If a warning condition occurs (decision box **613**) communications signal is turned off (step **615**) for inverter **404** or inverter **204** is turned off or put into standby.
(53) Reference is now made to FIG. **7** which illustrates a system **70** for protection during an islanding condition, in accordance with embodiments of the present invention. For simplicity, a single string **723** is shown of distributed power sources, e.g. solar panels **201** *a*-**201** *d* connected to respective power converters **705** *a*-*d*. Serial string **723** is input to inverter **704** through wires **412** and **410**. The output of inverter **704** is connected to and supplies electrical power to the electrical grid. Inverter **704**, typically includes a monitoring, and detection mechanism **701** which monitors one or more parameters of the electrical grid such as voltage and/or frequency. If one or more of the grid parameters is out of specification indicating an islanding condition, monitoring and detection mechanism **701** typically causes inverter **704** to be shut down or inverter **704** is disconnected from the grid so that output power is no longer supplied by inverter **704** to the grid. At the same time, a signal **714** is transmitted to a switch mechanism **703** which may be located at the input of inverter **704** before input capacitor **708**. Switch mechanism **703** is optionally packaged with inverter **704** or may be integrated with inverter **704** and packaged separately. In this example, signal **714** activates switch mechanism **703** so that when switch **703** is activated, the current flowing through serial string **723** and wires **410**, **412** varies abruptly.
(54) Reference is now also made to FIG. **7**A which illustrates in more detail converter **705**. Converter **705** is equipped with a current sensing mechanism **707** which upon sensing a variation in

current through serial string **723** signals controller **306** to shut down and stop converting power. Typically, current sensing mechanism **707** includes an analog/digital converter which continuously feeds data to controller **306**. Controller **306** detects a shutdown in current and decides to shut down the converters **705** accordingly.

(55) Reference is now also made to FIGS. B and C which illustrate schematically switch mechanism **703** in more detail. FIG. **7**B illustrates switch mechanism **703** in a serial configuration in which switch **703** is connected in series with the serial string **723** and FIG. **7**C illustrates a parallel configuration in which switch **703** is connected in parallel with serial string **723**. In the serial configuration (FIG. **7**B) switch **703** is closed during normal operation of inverter **704**. When an island condition is detected, serial switch **703** opens during shut down of inverter **704**. Current sensing mechanism **707** upon sensing zero current signals controller **306** that output current is less than a previously specified minimum value and controller **306** shuts down power conversion in converter **705**. In the parallel configuration (FIG. **7**C), switch **703** is open during normal operation of inverter **704**. When an island condition is detected, parallel switch **703** closes during shut down of inverter **704**. With all the current of serial string **723** flowing through the switch **703** at minimal load, the current increases to above a previously specified maximum current. Current sensing mechanism **707** upon sensing a current maximum signals controller **306** that output current is above maximal previously specified value and controller **306** shuts down power conversion. Switch mechanism **703** in different embodiments may be embodied by a mechanical switch or a solid state switch with current and voltage ratings appropriate to the present application. Switch mechanism **703** is preferably selected by one skilled in the art of power electronics so that arcing across its open terminals is avoided while practicing some embodiments of the present invention.

(56) Reference is now made FIG. **7**D which illustrates a method, according to an embodiment of the present invention. In decision block **750**, output power from inverter **104**, **204** is constantly monitored. If output power is stopped, power converters **705** are shut down.

(57) Reference is now made to FIG. **8**, illustrating a system **80** according to other embodiments of the present invention for protection during an islanding condition. For simplicity, a single string **823** is shown of distributed power sources, e.g. solar panels **201** *a*-**201** *d* connected to respective power converters **805** *a-d*. Serial string **823** is input to inverter **804** through wires **412** and **410**. The output of inverter **804** is connected to and supplies electrical power to the electrical grid. Inverter **804**, typically includes a monitoring and detection mechanism **701** which monitors one or more parameters of the electrical grid such as voltage and/or frequency. If one or more of the grid parameters is out of specification indicating an islanding condition, monitoring/detection mechanism **701** typically shuts down inverter **804** or disconnects from the grid, so that output power is no longer supplied by inverter **804** to the grid. During normal operation, a line communications transmitter **803** superimposes a keep-alive signal, for instance between 1 kilohertz to 100 Megahertz on direct current (DC) input lines **410** and **412** attached to serial string **823**.

(58) Reference is now also made to FIG. **8**A which illustrates converter **805** in more detail. The keep-alive signal is constantly monitored and detected by a line communications receiver **807**. Only while receiver **807** senses the keep-alive signal does receiver **807** provide an enable signal to controller **306**. When controller **306** doesn't receive an enabling signal from receiver **807**, controller **306** shuts down power conversion of converter **805**.

(59) Alternatively, instead of a “keep-alive” signal, a stop signal **814** which is first generated by monitoring and detection mechanism **701** when an islanding condition is detected, is transmitted to receiver **807**. The stop signal is transmitted over line communications by superimposing a varying (e.g. 10 Khz to 100 Mhz) signal over the power lines of serial string **823**. Receiver **807** receives the stop signal and relays the stop signal to controller **306** using, e.g., a single disable bit. Controller **306** on receiving a disable signal, stops converting power to the output of converter **805**. Typically, when converters **805** are disabled they go into a bypass mode which allows current from other converters **805** to pass through. Hence, the stop signal may be continued until all power stops being

supplied on string **823** by all of converters **805**.

(60) It should be noted that one skilled in the art would realize that although in system **80**, converters **805** are shown to have feedback loop **221**, as in controller **205** of system **20**, embodiments of the present invention as illustrated in system **70** using switch mechanism **703** and/or in system **80** using line communications, to the serial string may be applied to and find benefit in other distributed power systems using converters without feedback loops **221** as applied to prior art system **10**. Similarly, conventional inverters **104** may be used instead of inverter **804** with communications transmitter **803** added to inverter **104** either by the inverter manufacturer or as a retrofit. For example, FIG. **8**B illustrates a system according to an embodiment of the invention applied as a retrofit to a prior art system, such as the system of FIG. **1**. In this example, detection mechanism **701** and switch mechanism **703** are installed between the grid and the conventional inverter **104**. Of course, detection mechanism **701** and switch mechanism **703** may be incorporated into the inverter, e.g., for original installation, rather than a retrofit. Also, other implementations described herein may be used instead of detection mechanism **701** and switch mechanism **703**. Advantages of incorporation of monitoring and detection mechanism **701** and one of switch mechanism **703** or communications transmitter **803** into system **10** is beneficial during installation, maintenance, and firefighting.

(61) Reference in now made to FIG. **9** which illustrates system **90**, according to another embodiment of the present invention for protection during an islanding condition. For simplicity, a single string **923** is shown of distributed power sources, e.g. solar panels **201** *a*-**201** *d* connected to respective power converters **905***a-d*. Serial string **923** is input to conventional inverter **104** through wires **412** and **410**. The output of inverter **104** is connected to and supplies electrical power to the electrical grid. Inverter **104**, typically includes a monitoring and detection mechanism **701** which monitors one or more parameters of the electrical grid such as voltage and/or frequency. If one or more of the grid parameters is out of specification indicating an islanding condition, monitoring and detection mechanism **701** typically shuts down inverter **104** so that output power is no longer supplied by inverter **104** to the grid. During normal operation, a 100 Hz (or 120 Hz. in USA) ripple current is detectable between lines **410**, **412** and in serial string **923** since capacitors of inverter **104** do not block entirely the alternating current (AC), or the 100/120 Hz is intentionally leaked into serial string **923** through lines **410**, **412**.

(62) Reference is now also made to FIG. **9**A which illustrates converter **905** in more detail. The 100/120 Hz leakage is constantly monitored and detected by a receiver **907**. Only while receiver **907** senses the leakage from the grid does receiver **907** provide an enable signal to controller **306**. When controller **306** doesn't receive an enabling signal from receiver **907**, controller **306** shuts down power conversion of converters **905**.

(63) Alternatively or in addition, one or more switching frequencies of inverter **104**, typically 16 Khz or 32 KHz. may be detected as leakage or provided intentionally to serial string **923** along lines **412**,**410**. Receiver **907** is configured to detect the 16/32 KHz inverter switching frequency and provides an enabling signal to controller while inverter **104** is operating.

(64) Reference is now made to FIG. **9**B, showing a simplified block diagram according to an embodiment of the present invention for up conversion of 100/120 Hz. into a higher frequency in order to enable faster detection in receiver **907** of leakage from the grid. The 100 Hertz or 120 Hertz signal is AC coupled by capacitor **931** to remove the direct current component in serial string **923** and lines **410** and **412**. The 100/120 Hz. signal is optionally amplified and rectified by a full wave rectifier **935** so that a 100 Hz or 120 Hz unipolar DC ripple is achieved. The 100/120 Hz unipolar signal is split. One portion of the 100/120 Hz. unipolar ripple is converted to a square wave, such as in a comparator/digitize circuit **939**. A second portion of the 100/120 Hz unipolar ripple undergoes a known phase shift, e.g. of 400 Hz. in a phase shifter **933** and output to a second comparator/digitizing circuit **931**. The two outputs of two digitizing circuits **939**,**931** undergo an exclusive OR in a XOR circuit **933** which outputs a signal at a much higher frequency, e.g. 800 Hz.

(65) Reference is now made to FIG. **10**, illustrating a system **1000** according to other embodiments of the present invention for protection during an islanding condition. For simplicity, a single string **1023** is shown of distributed power sources, e.g. solar panels **201** *a*-**201** *d* connected to respective power converters **1005** *a-d*. Serial string **1023** is input to inverter **1004** through wires **412** and **410**. The output of inverter **1004** is connected to and supplies electrical power to the electrical grid. Inverter **1004**, typically includes a monitoring and detection mechanism **701** which monitors one or more parameters of the electrical grid such as voltage and/or frequency. If one or more of the grid parameters is out of specification indicating an islanding condition, monitoring, and detection mechanism **701** typically shuts down inverter **1004** or disconnects inverter **704** from the grid so that output power is no longer supplied by inverter **1004** to the grid. During normal operation, a wireless transmitter **1003** transmits wirelessly a signal, for instance between 100 Megahertz-10 Gigahertz.
(66) Reference is now also made to FIG. **10**A which illustrates converter **1005** in more detail. The wireless signal is received and constantly monitored by a wireless receiver **1007** Only while receiver **1007** senses the wireless signal does receiver **1007** provide an enable signal to controller **306**. When controller **306** doesn't receive an enabling signal from receiver **1007**, controller **306** shuts down power conversion of converter **1005**.
(67) The present invention has been described in relation to particular examples, which are intended in all respects to be illustrative rather than restrictive. Those skilled in the art will appreciate that many different combinations of hardware, software, and firmware will be suitable for practicing the present invention. Moreover, other implementations of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. Various aspects and/or components of the described embodiments may be used singly or in any combination in the server arts. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.
(68) While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

Claims

1. A method comprising: receiving power from a direct current (DC) power source at an input of a power converter; performing, with a controller, the following steps: operating one or more switches of the power converter in a safety mode by limiting output voltage at an output of the power converter below a predetermined voltage; detecting, while limiting the output voltage in the safety mode, receipt of a communication signal; responsive to the detecting receipt of the communication signal, transitioning from the safety mode to a voltage control process including: operating the one or more switches of the power converter to cause increases of the output voltage, and detecting, for each of the increases of the output voltage, an amount of current being drawn from the output of the power converter; after detecting that the amount of current being drawn exceeds a preexisting level, the controller transitioning the power converter from the voltage control process to a maximum power point tracking mode; maintaining, by the controller and after the transitioning from the voltage control process, the output voltage to be below a maximum output voltage of the power converter while simultaneously remaining in the maximum power point tracking mode; and responsive to an interruption in receipt of the communication signal, transitioning from the maximum power point tracking mode to the safety mode.
2. The method of claim 1, further comprising: responsive to a different interruption in receipt of the communication signal, transitioning from the voltage control process to the safety mode.
3. The method of claim 1, wherein the DC power source comprises one or more solar cells.

4. The method of claim 1, wherein the detecting receipt of the communication signal comprises detecting receipt of the communication signal from a signaling mechanism integrated in an inverter.
5. The method of claim 1, wherein the power converter comprises a direct current to direct current (DC/DC) converter.
6. The method of claim 1, wherein the detecting receipt of the communication signal comprises one of: detecting the communication signal at a frequency of an electrical grid; detecting the communication signal at a second frequency, wherein the second frequency is up-converted from the frequency of the electrical grid; and detecting the communication signal at a frequency of an inverter.
7. The method of claim 1, wherein the detecting receipt of the communication signal comprises one of: detecting the communication signal delivered over an electrical conductor; and detecting the communication signal delivered over a wireless medium.
8. The method of claim 1, wherein the detecting receipt of the communication signal is based on a change in voltage, current, or power corresponding to an inverter or a power grid.
9. An apparatus comprising: a power converter comprising: an input configured to receive power from a direct current (DC) power source, an output terminal, and a controller, wherein the controller is further configured to: operate one or more switches of the power converter in a safety mode by limiting output voltage at the output terminal of the power converter below a predetermined voltage; detect, while limiting the output voltage in the safety mode, receipt of a communication signal; responsive to the detecting receipt of the communication signal, transition from the safety mode to a voltage control process including: operating the one or more switches of the power converter to cause increases of the output voltage, and detecting, for each of the increases of the output voltage, an amount of current being drawn from the output terminal of the power converter; after detecting the amount of current being drawn exceeds a preexisting level, the controller transitioning the power converter from the voltage control process to a maximum power point tracking mode; maintain, by the controller and after the transitioning from the voltage control process, the output voltage to be below a maximum output voltage of the power converter while simultaneously remaining in the maximum power point tracking mode; and responsive to an interruption in receipt of the communication signal, transition from the maximum power point tracking mode to the safety mode.
10. The apparatus of claim 9, wherein the voltage control process further includes: responsive to a different interruption in receipt of the communication signal, transitioning from the voltage control process to the safety mode.
11. The apparatus of claim 9, wherein the DC power source comprises one or more solar cells.
12. The apparatus of claim 9, wherein the controller is further configured to detect receipt of the communication signal by detecting receipt of the communication signal from a signaling mechanism integrated in an inverter.
13. The apparatus of claim 9, wherein the power converter comprises a direct current to direct current (DC/DC) converter.
14. The apparatus of claim 9, wherein the controller is further configured to detect receipt of the communication signal by one of: detecting the communication signal at a frequency of an electrical grid; detecting the communication signal at a second frequency, wherein the second frequency is up-converted from the frequency of the electrical grid; and detecting the communication signal at a frequency of an inverter.
15. The apparatus of claim 9, the controller is further configured to detect receipt of the communication signal by one of: detecting the communication signal delivered over an electrical conductor; and detecting the communication signal delivered over a wireless medium.
16. The apparatus of claim 9, wherein the controller is further configured to detect receipt of the communication signal based on a change in voltage, current, or power corresponding to an inverter or a power grid.

17. A method comprising: receiving power from a direct current (DC) power source at an input of a power converter; performing, with a controller, the following steps: operating one or more switches of the power converter in a safety mode by limiting output voltage at an output of the power converter below a predetermined voltage; detecting, while limiting the output voltage in the safety mode, receipt of a communication signal; responsive to the detecting receipt of the communication signal, transitioning from the safety mode to a voltage control process including: operating the one or more switches of the power converter to cause increases of the output voltage, and detecting, for each of the increases of the output voltage, an amount of current being drawn, from the output of the power converter; after detecting the amount of current being drawn exceeds a preexisting level, and responsive to continuously detecting receipt of the communication signal, the controller transitioning the power converter from the voltage control process to a maximum power point tracking mode; and responsive to an interruption in receipt of the communication signal, transitioning from the voltage control process to the safety mode.
18. The method of claim 17, further comprising: after transitioning to the maximum power point tracking mode and responsive to a different interruption in receipt of the communication signal, transitioning from the maximum power point tracking mode to the safety mode.
19. The method of claim 17, wherein the DC power source comprises one or more solar cells.
20. The method of claim 17, wherein the detecting receipt of the communication signal comprises detecting receipt of the communication signal from a signaling mechanism integrated in an inverter.
21. The method of claim 17, wherein the power converter comprises a direct current to direct current (DC/DC) converter.
22. The method of claim 17, wherein the detecting receipt of the communication signal comprises one of: detecting the communication signal at a frequency of an electrical grid; detecting the communication signal at a second frequency, wherein the second frequency is up-converted from the frequency of the electrical grid; and detecting the communication signal at a frequency of an inverter.
23. The method of claim 17, wherein the detecting receipt of the communication signal comprises one of: detecting the communication signal delivered over an electrical conductor; and detecting the communication signal delivered over a wireless medium.
24. The method of claim 17, wherein the detecting receipt of the communication signal is based on a change in voltage, current, or power corresponding to an inverter or a power grid.