

APPARATUSES AND METHODS FOR DISMANTLING PHOTOVOLTAIC MODULES

Technical Field

[0001] This disclosure generally relates to apparatuses and methods for the dismantling of photovoltaic modules.

Background

[0002] This background description is provided for the purpose of generally presenting the context of the disclosure. Contents of this background section are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0003] Photovoltaic (PV) modules form part of solar energy harvesting systems or solar farms. Solar farms comprise a large collection of photovoltaic (PV) solar panels that absorb energy from the sun, convert it into electricity and transmit that electricity to the power grid for distribution and consumption. A PV module comprises several interconnected solar cells. The solar cells are sandwiched between a sun-facing cover glass layer and a back support which may either be a backsheet or another glass layer. The former is known as glass-backsheet PV module, while the latter is known as glass-glass PV module. The cover glass layer protects the solar cells and ensures the robustness of the entire PV module while maintaining a high degree of transparency. The backsheet is often made from a plastic material that electrically isolates, protects and shields the PV cells from weather and moisture. The backsheet, solar cell and cover glass layer are bound together using layers of encapsulating material. The entire PV module is secured at its periphery using a frame that is often fabricated using aluminium or an aluminium alloy. The frame ensures robustness and a practical and safe coupling to the PV module. A layer of sealant may be deposited around the parts of the PV module contacting the frame as a moisture barrier. A junction box is provided for housing the electrical connections of the PV module. The junction box is often provided on a side of the PV module opposite of the side intended to be directed towards the sun.

[0004] PV modules are provided outdoors and are continuously subjected to harsh weather conditions. Over time PV modules degrade and require replacement. Used PV modules may be transported to a dedicated facility for dismantling and component

recovery, but this can involve significant technical and logistical challenges due to the bulk of the modules, the large number that may need to be transported and processed, and the remote location of many solar farms. There is a need to provide more efficient apparatuses and methods for on-site dismantling of PV modules or at least provide a useful alternative to any existing apparatuses and methods.

Summary

[0005] Some embodiments relate to an apparatus for dismantling photovoltaic (PV) modules, wherein the PV module is a glass-backsheet PV module, a glass-glass PV module or a combination thereof, the apparatus comprising:

a frame removal station;

a PV module dismantling station;

a solar cell separation station; and

one or more conveyor elements configured to convey the PV modules through the stations;

wherein the apparatus is configured to:

receive a PV module on one end of one of the conveyor elements;

separate a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

separate a junction box and a back support from the frameless PV module by the PV module dismantling station to recover the junction box and the back support and obtain a partially disassembled PV module; and

separate encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a cover glass panel and obtain encapsulated solar cells;

wherein the apparatus is mountable on a vehicle for on-site dismantling operations.

[0006] In some embodiments, the frame removal station comprises a tool positioning system with a frame removal tool mounted on an end of the tool positioning system to separate the frame from the PV module.

[0007] In some embodiments, the frame removal tool comprises a retractable holding jig to secure at least a part of the frame and apply pressure outwards onto the part of the frame for removal.

[0008] In some embodiments, the PV module is rectangular with a frame element attached on each side of the rectangular PV module; and the frame removal tool comprises a plurality of holding jigs, each jig being positioned to secure and apply pressure outwards onto the frame element.

[0009] In some embodiments, the frame removal station comprises one or more holding elements to collect separated frames.

[0010] In some embodiments, the PV module dismantling station comprises a junction box scraper and one or more of a cutting tool, a picking tool, and a grinding tool; wherein the junction box scraper is configured to separate the junction box from the frameless PV module; the cutting tool is configured to cut the backsheet of the frameless PV module; the picking tool is configured to pick up and peel off the backsheet cut by the cutting tool; and the grinding tool is configured to grind down the back support of the frameless PV module.

[0011] In some embodiments, the grinding tool is a hammer mill configured to grind down the back support of a glass-glass PV module into glass shards.

[0012] In some embodiments, the PV module dismantling station comprises a tool positioning system configured to move one or more of the junction box scraper, cutting tool, picking tool or grinding tool.

[0013] In some embodiments, the junction box scraper is a heatable scraper.

[0014] In some embodiments, the heatable scraper is configured for heating to a temperature in the range of 100°C to 300°C.

[0015] In some embodiments, the PV module dismantling station is configured to heat the PV module to a temperature in the range of 100°C to 300°C to soften an adhesive material around the junction box before removal of the junction box from the PV module.

[0016] In some embodiments, the solar cell separation station comprises a tool positioning system with an encapsulated solar cell scraping tool mounted on one end of

the tool positioning system to scrape off the encapsulated solar cells from the partially disassembled PV module.

[0017] In some embodiments, the encapsulated solar cell scraping tool comprises one or more alignment tools to control the depth at which scraping is performed by the scraping tool.

[0018] In some embodiments, the solar cell separation station comprises a vacuum conveyor system configured to transport away separated encapsulated solar cells.

[0019] In some embodiments, the tool positioning system is a 3-axis motion system or a robotic arm system.

[0020] Some embodiments relate to a method of dismantling photovoltaic (PV) modules using the apparatus as disclosed herein, the method comprising:

providing a PV module on one end of the conveyor elements;

separating a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

separating a junction box and a back support from the frameless PV module by the PV module dismantling station to recover the junction box and the back support and obtain a partially disassembled PV module; and

separating encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a cover glass panel and obtain encapsulated solar cells.

[0021] In some embodiments, the PV module is a glass-backsheet PV module, glass-glass PV module or a combination thereof.

[0022] Some embodiments relate to a vehicle comprising the apparatus as disclosed herein, the apparatus being provided in the vehicle's hold; wherein the vehicle is configured to receive PV modules on one end of the one or more conveyor elements of the apparatus through an opening in its hold to dismantle the PV modules.

[0023] Some embodiments relate to a method for on-site dismantling of PV modules, the method comprising:

providing the vehicle as disclosed herein;

providing PV modules on one end of the one or more conveyor elements of the apparatus;

dismantling of the PV modules by operation of the apparatus; and

recovering of dismantled components of the PV modules.

Brief Description of the Drawings

[0024] Some embodiments of apparatuses and methods for dismantling PV modules, in accordance with the present disclosure, will now be described, by way of non-limiting example only, with reference to the accompanying drawings in which:

[0025] Figure 1 illustrates a flowchart of a method of dismantling a PV module;

[0026] Figure 2 illustrates a vehicle comprising a containerized apparatus for dismantling PV modules;

[0027] Figure 3 illustrates a cross-section view of various stations of an apparatus for dismantling PV modules during transportation;

[0028] Figure 4 illustrates a cross-section view of various stations of an apparatus for dismantling PV modules during operation;

[0029] Figures 5 to 8 illustrate parts of a frame removal station of an apparatus;

[0030] Figure 9 illustrates a perspective view of a series of stations of the apparatus;

[0031] Figure 10 illustrates a perspective view showing some internal parts of a series of stations of the apparatus;

[0032] Figure 11 illustrates a side view of a series of stations of the apparatus;

[0033] Figure 12 illustrates a top view of a series of stations of the apparatus;

[0034] Figure 13 illustrates an inside view of a frame removal station of the apparatus;

[0035] Figure 14 illustrates an inside view of a PV module dismantling station; and

[0036] Figure 15 illustrates an inside view of a solar cell separation station of the apparatus.

Detailed Description

[0037] Disclosed embodiments relate to an apparatus (900 of Figures 9, 10, 11 and 12) for dismantling photovoltaic (PV) modules and a method (Figure 1) for dismantling PV modules using the apparatus. The PV modules are preferably of the type with a frame housing encapsulated solar cells that are sandwiched between a cover glass panel and a back support. The back support may be another glass panel (i.e., a glass-glass PV module) or a backsheet (i.e., a glass-backsheet PV module). Some embodiments also relate to a vehicle (10 of Figure 2) comprising the apparatus for dismantling PV modules and method for the on-site dismantling of PV modules using the vehicle.

[0038] The apparatus for dismantling PV modules comprises a series of stations for performing specific dismantling actions. The stations include a frame removal station (21 of Figure 3 and 31 of Figure 4) to separate and recover the frame from the PV module; a PV module dismantling station (22 of Figure 3 and 32 of Figure 4) to separate and recover the junction box and back support (which may be a glass panel or a backsheet) from the frameless PV module; and a solar cell separation station (23 of Figure 3 and 33 of Figure 4) to separate and recover the cover glass panel and the encapsulated solar cells. A conveyor element (305, 315, 325 and 335 of Figure 4) is provided to convey PV modules through the stations.

[0039] Based on Figure 1, the apparatus is configured to receive a PV module on one end of the conveyor element (step 1, 110), separate a frame from the PV module by the frame removal station to recover a frame (122) and obtain a frameless PV module (step 2, 120), separate a junction box and a back support from the frameless PV module to recover the junction box and the back support (132) and obtain a partially disassembled PV module by the PV module dismantling station (step 3, 130), and separate encapsulated solar cells (EVA-Si solar cells) from the partially disassembled PV module to obtain EVA-Si solar cells and recover a cover glass panel (142) from the partially disassembled PV module by the solar cell separation station (step 4, 140). Advantageously, the apparatus is containerized and mountable on one or more vehicles, thus enabling it to be mobile and operable close to a solar farm allowing the dismantling of the PV modules on-site. The on-site dismantling of PV modules allows recovery of

useful materials from the PV modules. Transport of whole PV modules is more logistically challenging and expensive due to higher transportation volume and weight. Hence, further advantageously, the on-site dismantling of the PV modules using the embodiments makes the transport and recycling of PV modules less complex and less expensive with substantive volume and weight reduction. The embodiments also improve the degree to which materials are recovered from PV modules in comparison to conventional recycling techniques.

Frame Removal Station

[0040] Based on Figure 3, the frame removal station (21) comprises a container/housing (211) for housing the components of the station. The frame removal station (21) comprises two operation windows (212) for allowing the entry and exit of PV modules, a frame removal tool (2131) and a horizontal working bed with a conveyor element (214). The frame removal station (21) comprises a tool positioning system (213) with the frame removal tool (2131) mounted on an end of the tool positioning system to separate the frame from the PV module. Based on Figure 8, the frame removal tool may comprise a retractable holding jig (812) to secure at least a part of the frame (810) and apply pressure outwards onto the part of the frame for removal. The arrow (816) indicates the direction in which force is applied by the retractable holding jig with respect to the PV module (814). In some embodiments, the PV module (814) is rectangular with a frame element provided on each side of the rectangular PV module. The frame removal tool may comprise a plurality of holding jigs, each jig is positioned to secure and apply pressure directed towards each frame element. The frame removal station also comprises one or more holding elements to collect separated frames. The holding element may be in the form of a rack or a collection container provided to collect the frames as they are separated from the PV module.

[0041] The frame removal station of some embodiments comprise one or more hydraulic presses to hold down or secure the PV module while the frames are removed. The hydraulic presses may be provided in a roof region of the frame removal station. By securing the PV module during frame dismantling, the hydraulic presses reduce the likelihood of movement of the PV module which may result in incomplete removal of frames, thereby improving the efficiency of the apparatuses.

[0042] In some embodiments, holding arms and guards may be provided on a periphery of the frame removal station to enhance collection of dismantled frames. The collected frames may be deposited on a material recovery conveyer belt (1250 of Figure 12, for example) for subsequent recovery and transport.

PV Module Dismantling Station

[0043] The PV module dismantling station separates the junction box and back support from the frameless PV module after the separation of the frame. Separation of the frame allows the removal of the back support. The back support may be a backsheet or a glass panel. Figure 3 shows a PV module dismantling station (22) for dismantling a glass-backsheet PV module. The PV module dismantling station (22) comprises a container/housing (221) holding its various components. The container (221) comprises two operational windows (222) to allow entry and exit of the frameless PV modules from the frame removal station (21). A tool positioning system (223) is provided with a junction box scraper (2231), a cutting tool (2232) (for example a wheel cutter), a picking tool (2233). Also provided in the dismantling station (22) is a working bed (224) for receiving a PV module. The working bed (224) comprises an embedded heating element, a suction setup and a conveyor element. The working bed (224) may be heated using the embedded heating element to heat a PV module placed on the working bed. The working bed (224) may be configured to heat the PV module to a temperature in the range of about 100°C to about 300°C, such as about 150°C to about 300°C, about 200°C to about 300°C, about 250°C to about 300°C, about 100°C to about 150°C, about 100°C to about 200°C, about 100°C to about 250°C, about 150°C to about 200°C, about 150°C to about 250°C, or about 200°C to about 250°C, to soften the adhesive material around the junction box before removal of the junction box from the PV module. The heating temperature may be chosen based on the adhesive used to secure the junction box to the PV module.

[0044] The junction box scraper (2231) is configured to separate the junction box from the frameless PV module. Thereafter, the cutting tool (2232) is configured to cut the backsheet into strips that are more easily removed from the frameless PV module. After the backsheet is cut, the picking tool (2233) is configured to separate the backsheet from the rest of the frameless PV module and deposit it at a collection station or on a separate conveyor element intended for the collection of recovered materials.

[0045] In some embodiments, the junction box scraper (2231) is heatable via an embedded heating rod or filament. Alternatively, the junction box scraper (2231) may be heated by a separate heating bed provided within the PV module dismantling station (22). The scraper (2231) may be heatable to a temperature in the range of about 100°C to about 300°C, such as about 150°C to about 300°C, about 200°C to about 300°C, about 250°C to about 300°C, about 100°C to about 150°C, about 100°C to about 200°C, about 100°C to about 250°C, about 150°C to about 200°C, about 150°C to about 250°C, or about 200°C to about 250°C. The heated scraper may be used in place of the heated working bed to soften the adhesive around the junction box.

[0046] In some embodiments, the picking tool (2233) is replaced with or augmented with a grinding tool for grinding down the back support to allow access to the encapsulated solar cells for further dismantling. The grinding tool may be configured to grind down the backsheet of a glass-backsheet PV module or the back glass panel of a glass-glass PV module, or both types of back support. In some embodiments, the grinding tool is a hammer mill or a similar pulverizing tool configured to grind down the back support of a glass-glass PV module into glass shards. The glass shards may be collected using a collection conveyer for subsequent recycling.

[0047] In some embodiments, instead of having a single tool positioning system (223) control the tools in the PV module dismantling station (22), each of the tools (i.e., each of the junction box scraper (2231), cutting tool (2232), picking tool (2233) or grinding tool) is a separate device capable of independent operation, for instance, each tool may be attached to its own tool positioning system.

Solar Cell Separation Station

[0048] Based on Figure 3, the solar cell separation station (23) comprises a container/housing (231), two operation windows (232) to allow entry and exit of the partially dismantled PV modules from the PV module dismantling station (22), and a tool positioning system (233) having an encapsulated solar cell scraping tool. The encapsulated solar cell scraping tool may be equipped with one or more alignment tools (2331) (for example alignment wheel tools). The solar cell separation station (23) also comprises a working bed (234) having an embedded heating element, a suction setup and a conveyor element. The working bed (234) is able to accommodate a partially disassembled PV module. As with the working bed of the PV module dismantling station

(224), the working bed of the solar cell separation station (234) is also heatable such that a partially disassembled PV module placed on the working bed may be heated to facilitate removal of the cover glass panel. The encapsulated solar cell scraping tool is configured to scrape off the encapsulated solar cells from the cover glass panel of the partially dismantled PV modules. In some embodiments, the encapsulated solar cell scraping tool is a heatable scraper that may be used in place of the heated working bed to ease the scraping of encapsulated solar cells for removal of the cover glass panel. In some embodiments, the solar cell separation station comprises a vacuum conveyor system configured to transport away scraped off encapsulated solar cells. The vacuum conveyor system may include a vacuum pump and one or more suction lines coupled to the encapsulated solar cell scraping tool to directly remove encapsulated solar cells which have been scraped off by the scraping tool. The vacuum conveyor system may be configured to transport the encapsulated solar cell cells to a designated collection point.

[0049] The one or more alignment tools (2331) is configured to control the depth at which scraping is performed by the scraping tool, to advantageously allow the apparatuses to be flexibly used to scrape encapsulated solar cells of varying thickness. In embodiments wherein the tool positioning system is implemented using a multi-axial motion system (including, for example, a 3-axis motion system or a robotic arm system), motion of the scraping tool along a single axis (such as Z-axis) may be used to control the depth (i.e., depth in relation to the PV module) at which scraping is performed by the scraping tool. The ability to control the depth of scraping advantageously allows the apparatuses to be flexibly used for PV modules of varying glass thickness.

[0050] The disclosed apparatus is sufficiently well contained and modular to be loaded in a vehicle such as a truck, and can be deployed in solar farms for on-site dismantling operations. The various stations of the apparatus may be placed inside a truck to be powered by an energy generation device such as a fuel-powered generator provided within or in the proximity of the truck. Figure 2 illustrates a vehicle (10) to transport the apparatus. The vehicle (10) comprises a holder or a container (11) to house the apparatus, as well as supporting components required to drive or power the apparatus including a compressor and a vacuum generator (15). Other components of the vehicle (10) include an operational window or opening (12) provided to link up stations and transport PV modules between stations, a dismantling tool set (13), and a working bed with conveyor elements (14).

[0051] Figure 11 illustrates a side view of a series of stations of the apparatus. In the frame removal station (31), there is provided a frame removal tool (1110), an adjustable conveyer belt (1120) and a horizontal working bed (1130). As illustrated by the shaded lines, parts of the conveyer belt (1120) may be varied in height, or alternatively folded to be retained within the container of the frame removal station for convenient transportation. In the PV module dismantling station (32), there is provided a picking tool (1170), a wheel cutter (1172), a junction box scraper (1174) all of which are mounted on a tool positioning system (1175). The tool positioning system (1175) in this instance is a 3-axis motion system or a robotic arm system. The PV module dismantling occurs on a horizontal working bed (1178). In some embodiments, the horizontal working bed (1178) is equipped with an embedded heating element used to heat up the PV modules and loosen any adhesives in the PV module in preparation for dismantling. In the solar cell separation station (33), there is provided an encapsulated solar cell scraping tool (1180) equipped with an alignment tool. The encapsulated solar cell scraping tool (1180) is mounted in a tool positioning system (1182). The solar cell separation station (33) also comprises a horizontal working bed (1150) with embedded heating elements.

[0052] Figure 12 illustrates a top view of a series of stations of the apparatus. In the frame removal station (31), there is provided a hydraulic pump (1210). The hydraulic pump (1210) is used as a securing mechanism for the PV modules before frames are removed. After frames are removed, the hydraulic pump (1210) is released to allow subsequent movement of the frameless PV module. There are also illustrated materials recovery conveyer belts (1240 and 1250) for collecting recovered materials such as the frames. The PV module dismantling station (32) is equipped with a compressor (1220) to power the various elements of the station. Similarly, the solar cell separation station (33) is equipped with a vacuum (1230) to power the various components of the station that rely on vacuum pressure.

[0053] Figure 13 illustrates an inside view of a frame removal station of the apparatus. Illustrated in Figure 13 is an adjustable frame removal tool (1310) mounted on a tool positioning system (1312). The tool positioning system (1312) may be implemented using a 3-axis motion system or a robotic arm system. The PV modules may be received on the conveyer element (1330 for frame removal). Figure 14 illustrates an inside view of a PV module dismantling station (32). Illustrated in Figure 14 is a dismantling tool (1410) mounted on a 3-axis motion system (1420). Any recovered materials after the dismantling

process are conveyed using the conveyer element (1430). The components of the PV module dismantling station are powered by a compressor (1440). Figure 15 illustrates an inside view of a solar cell separation station (33) of the apparatus. Illustrated in Figure 15 is an encapsulated solar cell scraping tool (1510) with an adjustable slit mounted on a tool positioning system (1520). The tool positioning system (1520) may be implemented using a 3-axis motion system or a robotic arm system. Any recovered materials are collected using the materials recovery conveyer belt (1530). Some components of the solar cell separation station (33) may be powered using the vacuum (1540).

[0054] The encapsulated solar cell scraping tool (1510) of some embodiments comprises an alignment tool and a scraping end. The alignment tool may be an alignment roller. The alignment roller is used to determine a height of the encapsulated solar cells with respect to the glass panel. In operation, the alignment tool/roller may be lowered down towards the encapsulated solar cells to align and guide the operation of the scraping end. Operation of the scraping end is adjusted to perform scraping at a controlled depth lower than the alignment roller to scrape encapsulated solar cells off the cover glass panel. The ability to control the depth of the scraping advantageously allows the apparatus to be flexibly used for encapsulated solar cells of varying thickness without the need for any specific modification.

[0055] The apparatus of this disclosure may be suitably mounted in a variety of land vehicles, including both motored vehicles such as vans and trucks, and railed vehicles such as trains and trams. The apparatus may also be mounted on watercraft or amphibious vehicles such as ships, boats and car boats for servicing floating solar farms.

Method of Dismantling PV Module

[0056] Some embodiments of the disclosure are directed to the method of dismantling photovoltaic (PV) modules using the disclosed apparatus. Based on Figure 1, the method comprises providing a PV module on one end of the conveyor element (step 110). After the vehicle is deployed in a solar farm, the apparatus within the vehicle is operated to dismantle PV modules. The PV modules may be placed on a segment of the conveyor element of the apparatus for sequential dismantling by the various stations of the apparatus. When the PV module is received by the frame removal station, the method proceeds with separating a frame from the PV module by the frame removal station to recover a frame and obtain a frameless PV module (step 120). This is followed by

separating a junction box and a back support from the frameless PV module to recover the junction box and the back support and obtain a partially disassembled PV module by the PV module dismantling station (step 130). Subsequently, encapsulated solar cells are separated from the partially disassembled PV module to obtain encapsulated solar cells and recover a cover glass panel from the partially disassembled PV module by the solar cell separation station (step 140). The method may be used to dismantle both glass-backsheet PV modules, glass-glass PV modules, or combinations thereof.

[0057] Figure 4 illustrates an apparatus configured for dismantling glass-backsheet PV modules during operation. A PV module (41) is loaded into the frame removal station (31) via a conveyor element (305). The tool positioning system (313) is lowered towards the PV module (41) to dismantle and recover the frame using the frame removing tool (3131). The PV module without frame (42) is conveyed to the PV module dismantling station (32) via a conveyor element (315). The tool positioning system (323) is lowered towards the PV module without frame (42) to dismantle and recover the junction box by using the junction box scraper (3231). Subsequently, the tool positioning system (323) is lowered and the backsheet of the PV module without frame (42) is cut into strips using the wheel cutter (3232). The tool positioning system (323) is lowered to peel off and recover the backsheet by using the picking tool (3233).

[0058] The methods of some embodiments are configured to dismantle PV modules with a back support made of a glass panel (glass-glass PV modules). To separate the glass back support and access the encapsulated solar cells, the picking tool (3233) is replaced with or augmented with a grinding tool such as a hammer mill to fragment the glass panel into glass shards. The methods of these embodiments comprise lowering the tool positioning system (323) containing the grinding tool to fragment the glass back support into glass shards after the junction box has been removed. The glass shards may be recovered for recycling.

[0059] The partially disassembled PV module (43) that is without the frame, junction box and the back support is transferred to the solar cell separation station (33) via a conveyor element (325). The tool positioning system (333) is lowered towards the partially disassembled PV module (43) to scrape and recover a cover glass panel and encapsulated solar cells by using an encapsulated solar cell scraping tool equipped with alignment wheel tool (3331). The alignment wheel tool of the solar cell separation station (33) is used to control the scraping depth based on the thickness of the encapsulated

solar cells. The encapsulated solar cells are unloaded via a conveyor element (335) which allows the transfer of the encapsulated solar cells to a transportation truck. The encapsulated solar cells may be packed and transported to a centralized recycling plant for further processing.

[0060] The tool positioning systems of the various stations perform the function of positioning and moving relevant tools or tool components with respect to the PV module to perform the relevant steps of dismantling and/or recovery of materials. In some embodiments, the tool positioning system may be implemented using a multi-axial motion system integrated in each of the stations, such as a 3-axis motion system or a robotic arm. A 3-axis motion system may comprise multiple linear axes operating in unison to provide 3-axis movement of a tool element mounted on a part of the 3-axis system. In some embodiments, the tool positioning system may be implemented using a robotic arm system.

[0061] The position of the dismantling tool in each station and the conveyor elements may be swapped or alternated according to the needs of the dismantling process. The dismantling tool for the disclosed stations may be installed on horizontal beds, while an overhead crane may be installed on the ceiling of the containerized stations for transporting PV modules between stations. In some embodiments, the disclosed stations may be containerized in a single container with a series of conveyor systems.

[0062] Embodiments according to the disclosure advantageously enable the dismantling of PV modules on-site allowing the efficient transportation of the dismantled components to their respective recycling destinations. Alternatively, the various dismantled components may be retained on the solar farm for use with reconstituted solar cells.

[0063] The various stations of the apparatus may be separated from each other and deployed independently to perform a subset of the steps of dismantling as illustrated in Figure 1. The modularity of the various stations also allows the deployment of a subset of the stations in environments where only a subset of stations needs to be deployed. For example, in some embodiments, the apparatus may comprise only the frame removal station and/or the PV module dismantling station. The modularity of the stations also allows convenient transport of the containerized modules for deployment in remote and space constrained environments.

[0064] In some embodiments, each station may be containerised in standard containers of length of about 20 ft or 40 ft, or dimensions of about 2.4m×2.4m×5.9m or about 2.4m×2.4m×12m. Advantageously, the dimensions of the various stations may be adjusted to suit solar panels of different sizes or configurations. For example, the position of the holding jigs of the frame removal station may be varied to adapt the station to solar panels of different sizes. The frame removal station of some embodiments may allow a manual adjustment of the position of the holding jigs to adapt the frame removal station to solar panels of different dimensions.

[0065] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavor to which this specification relates.

[0066] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0067] The scope of this disclosure encompasses all changes, substitutions, variations, alterations, and modifications to the example embodiments described or illustrated herein that a person having ordinary skill in the art would comprehend. The scope of this disclosure is not limited to the example embodiments described or illustrated herein. Moreover, although this disclosure describes and illustrates respective embodiments herein as including particular components, elements, feature, functions, operations, or steps, any of these embodiments may include any combination or permutation of any of the components, elements, features, functions, operations, or steps described or illustrated anywhere herein that a person having ordinary skill in the art would comprehend. Although this disclosure describes or illustrates particular embodiments as providing particular advantages, particular embodiments may provide none, some, or all of these advantages.

Claims

1. An apparatus for dismantling photovoltaic (PV) modules, wherein the PV module is a glass-backsheet PV module, a glass-glass PV module or a combination thereof, the apparatus comprising:
 - a frame removal station;
 - a PV module dismantling station;
 - a solar cell separation station; and
 - one or more conveyor elements configured to convey the PV modules through the stations;wherein the apparatus is configured to:
 - receive a PV module on one end of one of the conveyor elements;
 - separate a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;
 - separate a junction box and a back support from the frameless PV module by the PV module dismantling station to recover the junction box and the back support and obtain a partially disassembled PV module; and
 - separate encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a cover glass panel and obtain encapsulated solar cells;wherein the apparatus is mountable on a vehicle for on-site dismantling operations.
2. The apparatus of claim 1, wherein the frame removal station comprises a tool positioning system with a frame removal tool mounted on an end of the tool positioning system to separate the frame from the PV module.
3. The apparatus of claim 2, wherein the frame removal tool comprises a retractable holding jig to secure at least a part of the frame and apply pressure outwards onto the part of the frame for removal.
4. The apparatus of any one of claims 1 to 3, wherein the PV module is rectangular with a frame element attached on each side of the rectangular PV module; and the frame removal tool comprises a plurality of holding jigs, each jig being positioned to secure and apply pressure outwards onto the frame element.

5. The apparatus of any one of claims 1 to 4, wherein the frame removal station comprises one or more holding elements to collect separated frames.
6. The apparatus of any one of claims 1 to 5, wherein the PV module dismantling station comprises a junction box scraper and one or more of a cutting tool, a picking tool, and a grinding tool;
wherein the junction box scraper is configured to separate the junction box from the frameless PV module;
the cutting tool is configured to cut the backsheet of the frameless PV module;
the picking tool is configured to pick up and peel off the backsheet cut by the cutting tool; and
the grinding tool is configured to grind down the back support of the frameless PV module.
7. The apparatus of claim 6, wherein the grinding tool is a hammer mill configured to grind down the back support of a glass-glass PV module into glass shards.
8. The apparatus of claim 6 or 7, wherein the PV module dismantling station comprises a tool positioning system configured to move one or more of the junction box scraper, cutting tool, picking tool or grinding tool.
9. The apparatus of any one of claims 6 to 8, wherein the junction box scraper is a heatable scraper.
10. The apparatus of claim 9, wherein the heatable scraper is configured for heating to a temperature in the range of 100°C to 300°C.
11. The apparatus of any one of claims 6 to 8, wherein the PV module dismantling station is configured to heat the PV module to a temperature in the range of 100°C to 300°C to soften an adhesive material around the junction box before removal of the junction box from the PV module.

12. The apparatus of any one of claims 1 to 11, wherein the solar cell separation station comprises a tool positioning system with an encapsulated solar cell scraping tool mounted on one end of the tool positioning system to scrape off the encapsulated solar cells from the partially disassembled PV module.
13. The apparatus of claim 12, wherein the encapsulated solar cell scraping tool comprises one or more alignment tools to control the depth at which scraping is performed by the scraping tool.
14. The apparatus of any one of claims 1 to 13, wherein the solar cell separation station comprises a vacuum conveyor system configured to transport away separated encapsulated solar cells.
15. The apparatus of any one of claim 2 or claim 8 or claim 12, wherein the tool positioning system is a 3-axis motion system or a robotic arm system.
16. A method of dismantling photovoltaic (PV) modules using the apparatus of any one of claims 1 to 15, the method comprising:
 - providing a PV module on one end of the conveyor elements;
 - separating a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;
 - separating a junction box and a back support from the frameless PV module by the PV module dismantling station to recover the junction box and the back support and obtain a partially disassembled PV module; and
 - separating encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a cover glass panel and obtain encapsulated solar cells.
17. The method of claim 16, wherein the PV module is a glass-backsheet PV module, a glass-glass PV module or a combination thereof.
18. A vehicle comprising the apparatus of any one of claims 1 to 15 in its hold; wherein the vehicle is configured to receive PV modules on one end of the one or more

conveyor elements of the apparatus through an opening in its hold to dismantle the PV modules.

19. A method for on-site dismantling of PV modules, the method comprising:
 - providing the vehicle of claim 18;
 - providing PV modules on one end of the one or more conveyor elements of the apparatus;
 - dismantling the PV modules by operation of the apparatus; and
 - recovering dismantled components of the PV modules.