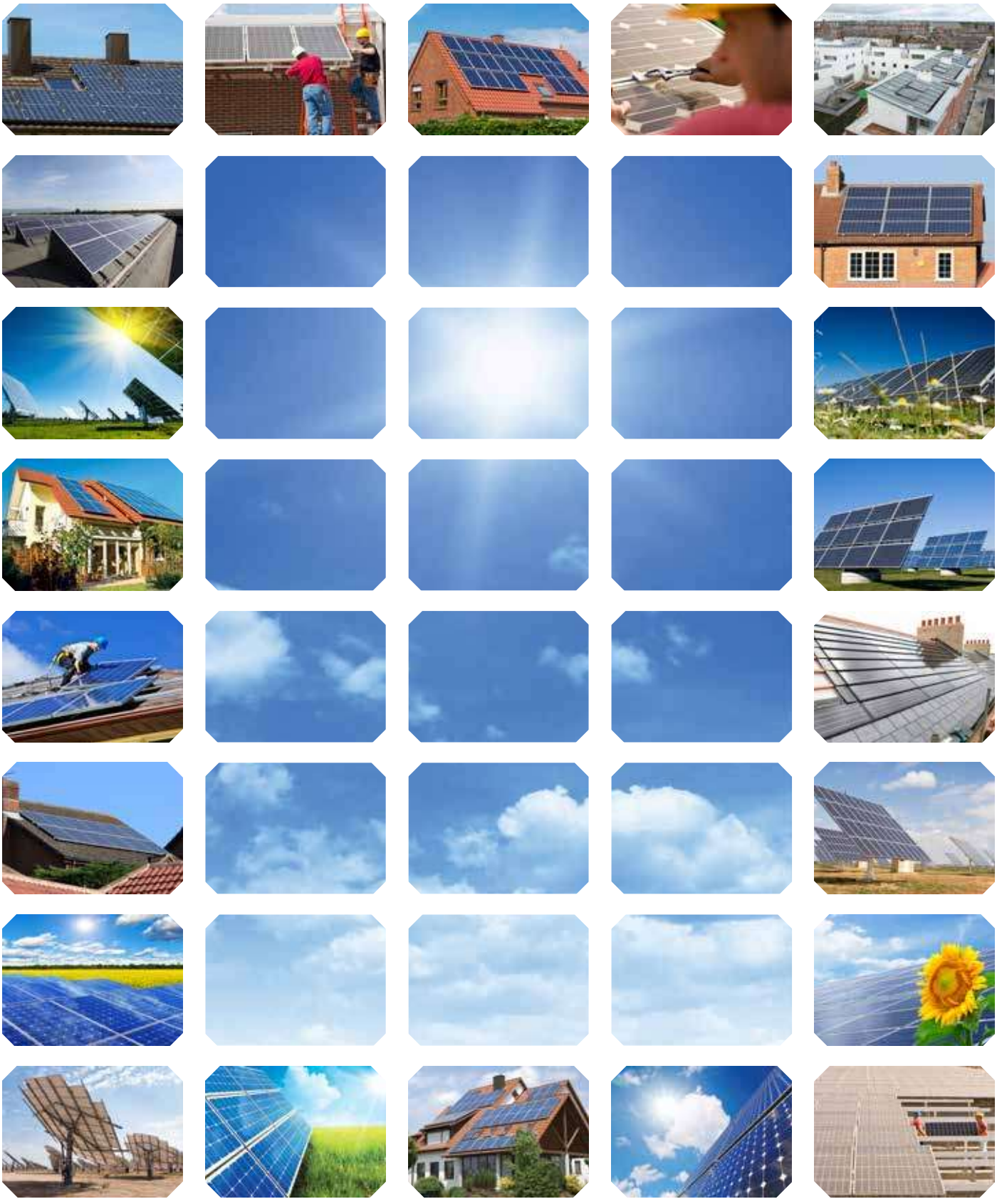
"Brighter Solutions"

Solar Product Range

IMO

IMO is at the forefront of control component technology specifically developed for the renewable energy market and in particular solar energy. Whether meeting the demands of safe and efficient DC switching or delivering tracking solutions that help to maximise solar energy conversion rates, you can be sure that IMO products have been developed to meet the highest technical and commercial standards.



"Keeping Solar Safe"

Contents

IMO Solar Guide - Abbreviations

AC	Alternating Current
DC	Direct Current
I_e	Rated Operational Current
IMO	IMO Precision Controls
I_{sc}	Short-Circuit Current
I_{th}	Thermal Current
MPPT	Maximum Power Point Tracking
PV	Photovoltaic
V_{oc}	Open-Circuit Voltage

References

BS 7671	Requirements for Electrical Installations
IEC/EN 60364-7-712	Low-voltage electrical installations. Part 7-712: Requirements for special installations or locations. Photovoltaic (PV) power systems
IEC/EN 60529	Specification for degrees of protection provided by enclosures (IP code)
IEC/EN 60947-1 **UL 60947-1**	Low-voltage switchgear and controlgear. Part 1: General rules
IEC/EN 60947-3 **UL 60947-3**	Low-voltage switchgear and controlgear. Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
UL 60947-4-1	Low-voltage switchgear and controlgear. Contactors and motor-starters. Electromechanical contactors and motor-starters
IEC/EN 61215	Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC/EN 61646	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
Nema 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
UL 94	Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 508	Industrial Control Equipment
UL 508i	Manual Disconnect Switches intended for use in Photovoltaic Systems
DTI/Pub URN 06/1972	Photovoltaics in Buildings, Guide to the installation of PV systems 2nd Edition

Guide to Installation of PV Systems – 3rd Edition

Other Relevant References

G83/1-1	Recommendations for Connection of Small-scale Embedded Generators (Up to 16A per Phase) in Parallel with Public Low-Voltage Distribution Networks
G59/2	Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed Distribution Network Operators
NFPA70 2017	National Electrical Code

Introduction to PV design

A Photovoltaic (PV) power system primarily converts sunlight directly into electricity using a photovoltaic cell array. The conversion of the solar radiation into electric current is carried out using the photoelectric effect found when some semiconductors that are suitably “doped” generate electricity when exposed to solar radiation.

As an individual PV-cell gives a relatively low output, a number of PV-cells are connected in series to supply higher voltages and connected in parallel in order to offer higher current capability. These cell arrays are referred to as PV-panels, and a number of interconnected panels are referred to as PV-strings. If there is a requirement for increased capacity then a larger system can be constructed whereby the PV-strings are connected in parallel to form a PV-array that gives a DC output current equivalent to the sum of all the PV-string outputs.

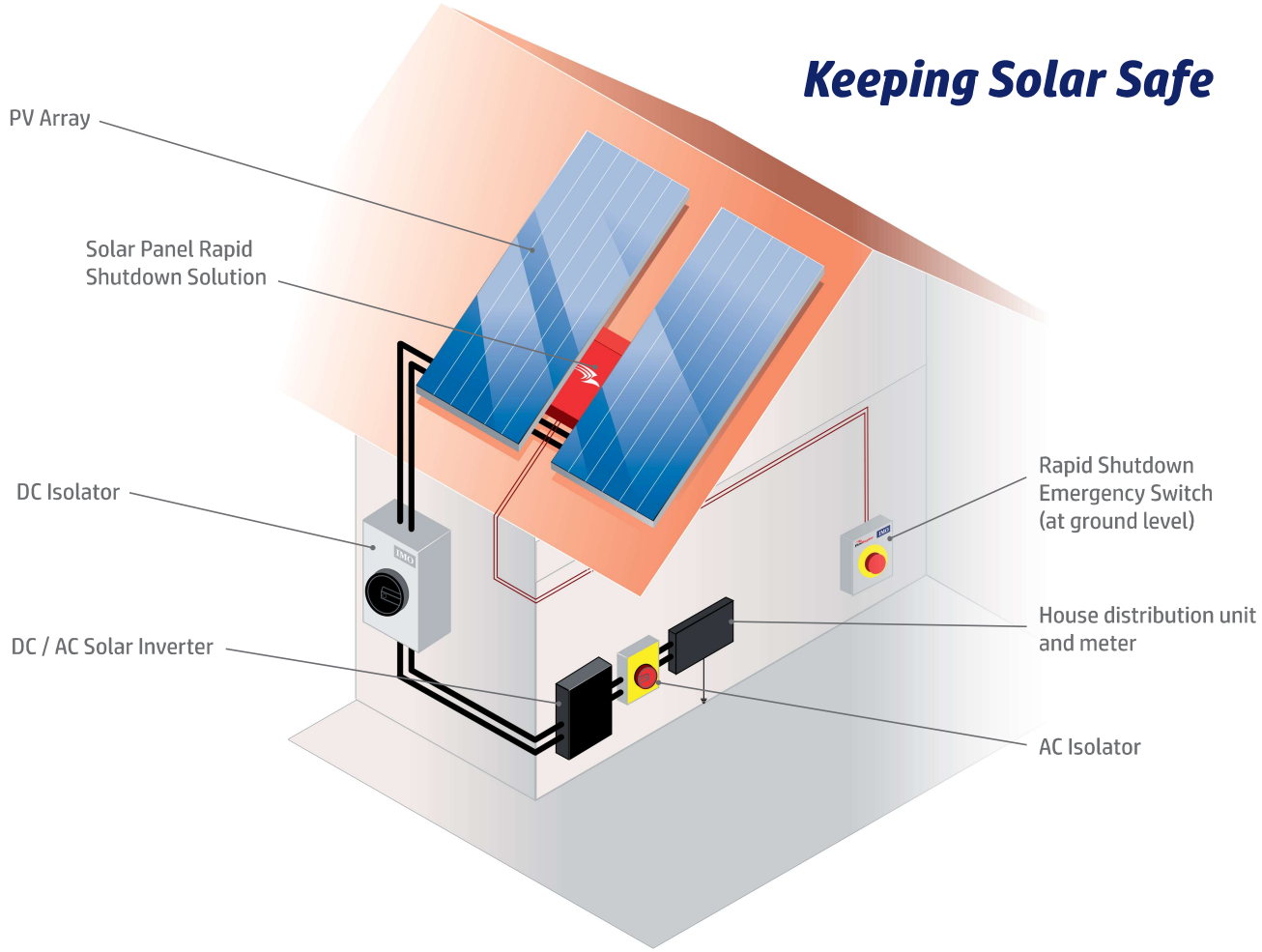
The main advantages of photovoltaic (PV) electricity generation are as follows:

- no fossil fuel usage and subsequent emission of pollution
- no nuclear fuel usage and disposal or storage of radioactive materials
- local distributed generation where needed
- installed system reliability and extended life
- reduced operating and maintenance costs
- ease of upgrading and replacement if necessary due to modularity of installation

When considering PV panels it is important to ensure that the units comply with all relevant standards for both electrical performance and for building requirements. It is recommended that, where possible, they comply with either IEC 61215 or IEC 61646, depending upon the structure of the cells. Once chosen the panels should be mounted in a location that maximises their exposure to sunlight for as long as possible and limits the possibility of shading, or future potential shading.

An inverter should be chosen to match the overall power capacity of the PV array, and like the arrays, it should operate as efficiently as possible. When considering the inverter, one using a Maximum Power Point Tracking (MPPT) system is preferential as this is a technique that grid connected inverters use to get the maximum possible power from one or more photovoltaic devices.

Where the PV installation is tied into the domestic grid system then the rules and procedures designated in G83 should be referred to and followed by a competent installer who is associated with a suitable accreditation scheme such as MCS.



Utilisation Categories

Utilisation Categories as are covered in the European Standards EN 60947-1 & EN60947-3 and define an equipment's intended application. The list of both AC and DC categories for low-voltage switchgear and controlgear are stated in EN 60947-1 Annex A along with the relevant product standards.

Manufacturers of both switchgear and controlgear should include in their technical product data all the operational ratings for the utilisation categories for which a product is designed and as such this should remove the confusion for users and designers in their selection of the correct product.

If we consider PV installations where there are requirements for switchgear being used on the DC side then the system falls typically within two categories below (for which the relevant standard is EN 60947-3)

DC-21 Switching of resistive loads, including moderate overloads
DC-22 Switching of mixed resistive and inductive loads, including moderate overloads

DC-PV1 Switching of single PV string(s) without reverse and overcurrents
DC-PV2 Switching of several PV strings with reverse and overcurrents

Compliance to the EN60947-3 utilisation categories involves the products completing a number of tests, these include the "Making and Breaking Capacity" (section 7.2.4.1/D7.2.4.1) and "Operational Performance" (section 7.2.4.2/D7.2.4.2). Verification of the operational making and breaking capacities are stated by reference to the rated operational voltage and rated operational current according to Table 3 and Table D7 (see extracts below).

Test Conditions for Making & Breaking Capacities

Utlilisation categories	Rated operational categories	Making			Breaking			Number of operating cycles
		I/I_e	U/U_e	L/R ms	I_c/I_e	U_r/U_e	L/R ms	
DC-21A - DC-21B	All values	1.5	1.05	1	1.5	1.05	1	5
DC-22B	All values	4	1.05	2.5	4	1.05	2.5	5
DC-PV1	All values	1.5	1.05	1	1.5	1.05	1	5
DC-PV2	All values	4	1.05	1	4	1.05	1	5

Test Conditions for Number of On Load Operating Cycles

Utilisation categories	Number of operating cycles per hour	Number of operating cycles					
		A categories			B categories		
		Without current	With current	Total	Without current	With current	Total
DC-21A/B & DC-22B	120	8,500	1,500	10,000	1,700	300	2,000
DC-PV1 & DC-PV2	120	9,700	300	10,000	-	-	-

Utilisation categories	Rated operational categories	Making			Breaking		
		I/I_e	U/U_e	L/R ms	I_c/I_e	U_r/U_e	L/R ms
DC-21A - DC-21B	All Values	1	1	1	1	1	1
DC-22B	All Values	1	1	2	1	1	2
DC-PV1	All Values	1	1	1	1	1	1
DC-PV2	All Values	1	1	1	1	1	1

I=making current I_c=breaking current I_e=rated operational current
U=applied voltage U_e=rated operational voltage U_r=operational frequency or d.c recovery voltage

PV Installation Isolation

PV installations consist of the DC side, the Inverter and the AC side with isolation required for both the PV-array to the inverter and for the AC supply from the load, particularly where the system is connected to the Distributed Network, this is a stipulation in G83/1. In some instances the "Guide to Installation of PV Systems" allows inverter and DC string isolation to be provided by the same device, for example the PV plug and socket connectors, but this is only deemed suitable for smaller systems and the connectors must be labelled appropriately. Generally IMO would always recommend the use of a suitably rated DC isolator.

DC Isolator Selection

BS 7671 states that a method of isolation must be provided on the DC side of a PV installation and this can be provided by a switch-disconnector as classified under EN 60947-3 this is also covered by "Guide to the installation of PV systems". The Guide also stipulates that the switch must isolate all live conductors (typically double pole to isolate PV array positive and negative conductors).

BS 7671 specifies that isolators that are in compliance with EN 60947-3 are appropriate for use in PV systems. The isolator rating must consider the maximum voltage and current of the PV string being switched and these parameters then adjusted in accordance with the safety factors stipulated in current standards. This should then be the minimum required rating of the isolator.

$$\text{Voltage} = N_S \times V_{OC} \times 1.15 \qquad \text{Current} = N_P \times I_{SC} \times 1.25$$

N_S - Number of panels connected in series
V_{OC} – Open-Circuit Voltage (from module manufacturer's data)
N_P - Number of strings connected in parallel
I_{SC} – Short-Circuit Current (from module manufacturer's data)

The isolator should also be suitable for use in the appropriate application which in PV installations is normally considered to be either DC-21A, DC-21B, DC-22A or DC-22B. Normally isolation of the DC supply from the inverter would not be a regular occurrence and therefore generally ratings for DC-21B or DC-22B would, as a minimum, be necessary; although category A types (as previously covered in Utilisation Categories) would be advantageous due to their capability of a higher number of switching operations, and therefore a longer guaranteed life.

AC Isolator Selection

AC Isolators are used in both stand-alone grid or network distributed systems. If connected to the distributed network then G83/1 stipulates the PV system must be connected directly to an isolation switch that is wired so as to isolate both the live and neutral conductors, capable of being secured in the "OFF" position and in an accessible location within the installation. In a stand-alone system IMO recommend that a lockable OFF isolation switch is similarly used within the installation. BS 7671 specifies that isolators that are in compliance with EN 60947-3 are appropriate for use in PV systems.

Unlike a DC isolator that is required to switch both the positive and negative conductors, an AC isolator should be chosen with regards to the supply being single phase, which is typically found in domestic installations or three phase, which is typical for commercial or industrial installations. Ideally for single phase a 2pole isolator should be used to switch the live and neutral line (earth constantly connected) whilst a 4pole isolator would be used to switch the 3 voltage lines and neutral (earth constantly connected).

The isolator rating should be based on the inverter output which is normally specified per phase, that is line to neutral, and for example maybe shown as 20A at 230VAC; if this output is from a three phase unit then the AC isolator must be rated to for the line-to-line voltage which would typically be 415VAC.

With both AC and DC isolators the ambient temperature of the environment in which the switch is mounted must be considered as most industrial switches are nominally rated for use in 35°C. However, if the isolator is to be used in an area where solar activity is prevalent, thereby making more efficient use of the installation and greater yield, or in an enclosed space such as a loft or that of an inverter enclosure, then an isolator capable of handling the elevated temperatures should be selected.

All IMO Solar Isolators are capable of being installed in areas where high ambient temperatures of up to +45°C can be found. In installations of higher temperatures, our open style product can be used up to +65°C, however, you should ensure safe operating conditions and correct mounting of the product.

Why use an IMO DC Solar Isolator?

IMO Precision Controls offers a range of True DC Isolators specifically designed for use in Solar PV installations in accordance with EN 60364-7-712. The IMO design incorporates a user independent switching action so as the handle is moved it interacts with a spring mechanism which, upon reaching a set point, causes the contacts to "SNAP" over thereby ensuring a very fast break/make action. This mechanism means that the disconnection of the load circuits and suppression of the arc, produced by a constant DC load, is normally extinguished in 3ms using the specific pole suppression chambers incorporated within the design.

Many alternative solutions, particularly those based upon an AC isolator designs which use bridge contacts, have been modified and rated for DC operation. These types of product have a switching speed that is directly linked to operator speed therefore, slow operation of the handle results in slow contact separation of the contacts which can produce arcing times of 100ms or more. Also in these switches the contact surface is also the surface upon which arcs tend to form; therefore, any surface damage or sooting caused by the arcing is likely to have a detrimental effect on the isolator's contact resistance and its longevity.

The IMO Solar Isolator range is offered in a number of configurations all rated for installation and use as switch-disconnects and all with options allowing for "LOCKABLE OFF" operation. Although able to offer the industry standard two position 90° handle operation from LOCKABLE OFF-ON, IMO have also introduced a **SAFE-LOCK** patented handle that allows for three rotational positions relating to ON-OFF-LOCK. The facility offered by this design gives a LOCK position that is removed from the OFF setting ensuring the handle can be placed in its own unique position when locked, which is fully compliant with IEC 60947-1 section 8.2.5.2.1 for classification as an isolator or switch disconnector. When this design is used within the IMO enclosed Solar Isolators it ensures that engineering access can only be attained to the enclosure when the handle is in the OFF position; whilst the "LOCK" position ensures secure power isolation combined with non-access to the enclosure (when the isolator block is secured with supplied screws) and thereby significantly reducing the risks of tampering when maintenance/ repair is carried out on equipment in-line after the isolator, **SAFE-LOCK**. Once any work has been undertaken the locking mechanism can then be removed and the isolator returned to its normal operational mode.

IMO Solar Isolators use a rotary "knife contact" mechanism so when the unit is operated the handle movement gives a double make/ break per contact set. As DC load switching creates arcing the design is such that this only occurs on the corners of the switching parts meaning that the main contact is made on an area where no arcing has occurred. The rotary contact mechanism methodology used in the IMO Solar Isolators means that, when the isolator is operated, a self-cleaning action occurs on the arcing points and contact surfaces thereby producing good high vibration resistant contact integrity, with reduced contact resistance. This IMO contact system ensures that power loss per pole is kept as low as possible and consistent over the life of the product unlike conventional style isolators where entrapment of contaminants, and then subsequent compression on lateral operation, can lead to variable and increasing contact resistance and hence per pole losses.

As indicated in the section about **Utilisation Categories**, the IMO product is satisfactory for use in installations classified as either DC-PV1, DC-PV2, DC-21A, DC-21B or DC-22A, and so suitable for a high number of "off load" operations (without current) and also a high number of operating cycles "on load" (with current).

Unlike a number of DC isolators on the market, the IMO solar isolator is also polarity independent, which means that there is no requirement for specific directional wiring of the PV supply. A further advantage of the IMO contact mechanism is that, in the event of the supply to earth failure, the high short circuit current pulls the contacts together thereby giving a high short circuit withstand current of up to 2400A (product dependent). PV residential installations are typically 1000VDC however, IMO Solar Isolators already have the capability to operate up to 1500VDC.

In the move towards safer installations of PV systems, whether it be in a domestic or industrial environment, consideration has to often be given to the materials and the risk of fire hazard that they pose. Ratings referred to under the UL 94 category are deemed generally acceptable for compliance with this requirement as this cover tests for flammability of polymeric materials used for parts in devices and appliances. Although there are 12 flame classifications specified in UL 94, there are 6 which relate to materials commonly used in manufacturing enclosures, structural parts and insulators found in consumer electronic products. These are 5VA, 5VB, V-0, V-1, V-2 and HB.

IMO DC Isolator Approvals

Country	RoHS	USA, UL508i	US, CAN, UL60947-1	Europe CE	CCC China	IEC CB Europe	ESV Australia
SI16/SIM16/SIME16	✓	✓	✓	✓	✓	✓	✓
SI25/SIM25/SIME25	✓	✓	✓	✓	✓	✓	✓
SI32/SIM32/SIME32	✓	✓	✓	✓	✓	✓	✓
SI38/SIM38/SIME38	✓	✓	✓	✓	✓	✓	✓
SI40/SI55/SI65	✓	✓	✓	✓	✓*	✓	✓

* Please note that the SI65 does not have CCC approval for China

It is because of this that the IMO Solar Isolator range is constructed of materials that significantly reduce the risk of a fire hazard and in particular our enclosed installation style products for which the main plastic enclosure is rated at UL 94V-0 and the handles are UL 94V-2 rated. The classification criteria for each of these ratings is found in of the UL 94 Table 8.1 (see extract below).

Criteria conditions	V-0	V-1	V-2
Afterflame time for each individual specimen t1 or t2	≤10s	≤10s	≤30s
Total afterflame time for any condition set (t1 plus t2 for the 5 specimens	≤50s	≤250s	≤250s
Afterflame puts afterglow time for each individual specimen after the second flame application (t2+t3)	≤30s	≤60s	≤60s
Afterflame or afterglow of any specimen up to the holding clamp	No	No	No
Cotton indicator ignited by flaming particles or drops	No	No	Yes

The installation requirements and environments of PV systems can vary significantly and the IMO Solar Isolator has been designed such that it can offer a wide range of configurations depending upon the users' requirement. Also the IMO Solar Isolator range includes models that, when mounted in accordance with their respective instructions and with the appropriate IMO handle, offer suitable protection up to IP66 (EN 60529) and NEMA 4X (Nema 250, UL508).

With the advent of more worldwide installations and the requirements laid down in many country's national wiring publications for the use of DC switches in PV installations, the IMO Solar Isolators have also been assessed and tested under the latest UL standard UL508i which has been specifically written to cover the use of "Manual Disconnect Switches intended for use in Photovoltaic Systems".

This UL508i standard specifically covers switches rated up to 1500 V that are intended for use in an ambient temperatures of -20°C to +50°C, and that are suitable for use on the load side of PV branch protection devices. In order to comply with this standard the IMO DC Isolators has to pass an overload test, at +50°C, of 50 cycles at 200% of rated current; followed by an endurance test of 6000 cycles (6 cycles/min) at rated load (Ith) and a further 4000 cycles with no current.

The IMO DC Isolator has successfully attained certification under the UL508i standard and as such is suitable for use as a disconnection method for the isolation of the output of DC PV array where it is to be connected to a DC/AC inverter.

Examples of Typical PV Installations

Single String System – 3kW Output Single Phase

Consider two potential configurations for a typical 3kW system which would supply 13A at 230VAC:

Inverter: Input: 600VDC (V_{OC}), 16A (I_{DC}), 32A ($I_{DC\ max}$) Output: 230VAC (V_{AC}), 13A (I_{AC}), 17.2A ($I_{AC\ max}$)

Solar Panel: 60V (V_{OC}), 8A (I_{SC}) No. of panels: 8

Calculation: V = 8 x 60 x 1.15 = 552V I = 8 x 1.25 = 10A

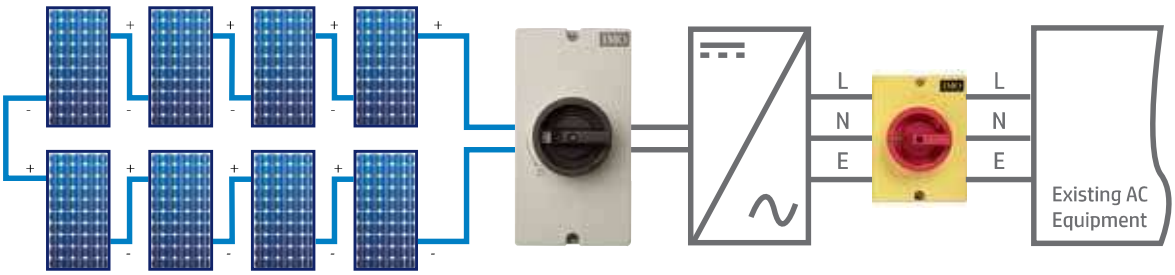
For this configuration, the IMO SI16-PEL64R-2 rated at 16A for 700VDC is suitable for the DC switch and the PE69-3020 rated at 20A is suitable for the AC switch.

Inverter: Input: 750VDC (V_{OC}), 15A (I_{DC}), 28A ($I_{DC\ max}$) Output: 230VAC (V_{AC}), 13A (I_{AC}), 16A ($I_{AC\ max}$)

Solar Panel: 60V (V_{OC}), 8A (I_{SC}) No. of panels: 10

Calculation: V = 10 x 60 x 1.15 = 895.62V I = 8 x 1.25 = 10A

For this configuration, the IMO SI25-PEL64R-2 would still be suitable as it is rated at 16A for 800VDC, however the IMO SI25-PEL64R-2 rated at 16A for 900VDC would allow for a greater margin of safety. The PE69-3020 rated at 20A is suitable for the AC switch.



PV Arrays

DC Isolator
600V: SI16-PEL64R-2
750V: SI25-PEL64R-2

Inverter
3kW

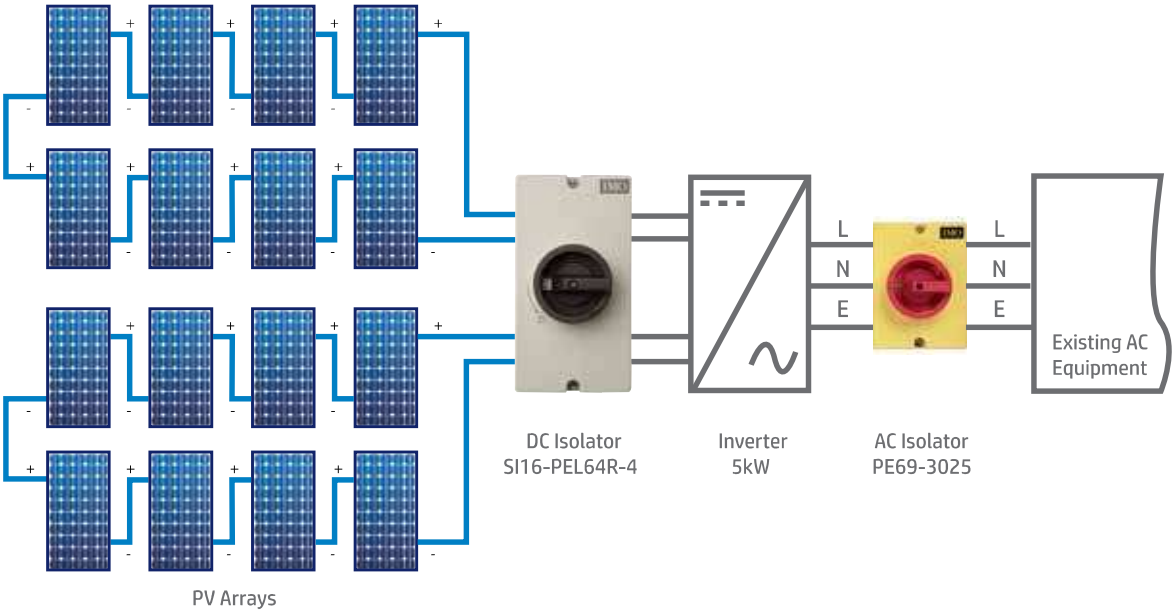
AC Isolator
PE69-3020
PE69-3020

Dual String System – 5kW Output Single Phase

Consider a typical 5kW system which would supply 22A at 230VAC:

Inverter:	Input (per string): 600VDC (V_{OC}), 18A (I_{DC}), 36A ($I_{DC\ max}$)	Output: 230VAC (V_{AC}), 25A ($I_{AC\ max}$)	
Solar Panel:	64.9V (V_{OC}), 6.46A (I_{SC}), 5.98A (I_{mpp}), 327Wp (P_{nom})	No. of panels:	8 per string
Calculation:	V = 8 x 64.9 x 1.15 = 597.08V	I = 6.46 x 1.25 = 8.08A	

For this configuration, each string is to be switched at these levels so the IMO SI16-PEL64R-4 rated at 16A for 700VDC per string is suitable for the DC switch and the PE69-3025 rated at 25A is suitable for the AC switch.



High Voltage Multi-string System – 12.5kW Output Three Phase

Inverter:	Input (per string): 900VDC (V_{OC}), 18A (I_{DC}), 36A ($I_{DC\ max}$)	Output: 4000VAC (V_{AC}), 20A ($I_{AC\ max}$)	
Solar Panel:	64.9V (V_{OC}), 6.46A (I_{SC}), 598A (I_{mpp}), 327Wp (P_{nom})	No. of panels:	12 per string
Calculation:	V = 12 x 64.9 x 1.15 = 895.62V	I = 6.46 x 1.25 = 8.08A	

For this system there are several options to consider. If each string is to be switched individually then the SI25-PEL64R-2 rated at 11A for 1000VDC is suitable for the DC switch. If there is a requirement to isolate the strings as pairs then the SI25-PEL64R-4 is suitable. If all strings are to be isolated using one DC isolator then the IMO SI25-PEL64R-8 is suitable. The PE69-3025 rated at 25A is suitable for the AC switch in each case.

Alternatively, if the requirement is to still have the capability of isolating each string individually whilst retaining a single housing unit, then an IMO distribution box populated with SI25-DBL-2 is suitable. These devices use the same switch block as the SI25-PEL64R-2 so have the same rating of 11A at 1000VDC.

This document is meant as a guide and IMO Precision Controls shall not be liable in any event whatsoever for any indirect, special or consequential damages, arising out of the use of the products covered by this document at any time or howsoever caused by the goods. IMO Precision Controls excludes any warranty, condition or statement, express or implied, statutory or otherwise, as to quality, merchantability, or fitness of the goods for any particular purpose.

Over 6 Million Installed Units

ZERO FAILURES

In solar installation, the DC isolator is like a vehicle air-bag. You never know it really works until you need it. So it's good to know that the IMO SI has now surpassed six million installed units without a single recorded electrical failure.

Not surprising considering the product carries all the most important approvals including UL508i, IEC/EN 60947-1, UL 60947-1, IEC/EN 60947-3, UL 60947-4-1, CE, RCM and CCC. In fact, the IMO SI solar isolator has been tested by some of the most rigorous examiners and OEM manufacturers in the world, passing with flying colours every single time.

As ever, the SI range has a guaranteed arc supression time of 3mS, in built arc cooling chambers, operator independent switching mechanism and Safe-Lock handle, making it one of the safest DC isolators available, no matter who uses it or how slowly they operate it.

Why take a risk on safety? Insist on TRUE DC, contact us for a quotation and see why the IMO SI TRUE DC Isolator is the sensible choice for the PV installer.

Keep Solar Safe

SAFE-LOCK®

IMO

www.imopc.com