Designing UL Compliant Photovoltaic Wire
Get Connected to the Promising U.S. Solar Market

2008 was an exceptional year for the photovoltaic (PV) market. According to the European Photovoltaic Industry Association (EPIA), the global installed capacity has more than doubled as compared to the previous year, growing from 2.4 GW to 5.6 GW. The credit goes to the explosive growth of installations in Spain. Driven by attractive government incentives, Spain added 2.5 GW of new capacity in a single year and became the biggest PV market in the world. Germany ranked second, followed by the United States, South Korea, Italy and Japan.

While the impact of the global financial crisis on PV demand in the near-term is still unclear, 2009 has seen significant policy adjustments in the leading PV markets that are changing the landscape of global solar demand.

PV market outlook

The solar boom in Spain is expected to end, given that the government has greatly reduced its support for solar energy. Feed-in tariffs (FiT) were cut by 30 percent in 2009 and, more importantly, a strict cap was set at 500 MW per annum for the feed-in-tariff program from 2009 to 2011. In this context, EPIA forecasts a massive drop in annual additions. The 2009 installations will be limited to 375 MW and there will be little room for growth in the next four years.

Coincidentally, at the beginning of 2009, Germany also decreased feed-in tariffs by nearly 10 percent. In addition, a growth path was defined for 2009 to 2011. If new annual installations exceed the planned upper limit for the year, the FiT degression rate for the following year will be increased by 1 percent, and vice versa. Against this backdrop, the German market growth will likely slow down over the coming years.

However, the outlook for the U.S. market is sunny. Along with state-level financial incentive programs, strong support at the federal level comes from the Emergency Economic Stabilization Act of 2008 (EESA) and the American Recovery and Reinvestment Act of 2009 (ARRA). These are intended to boost PV installations of varied scales and include an 8-year extension of residential and commercial solar investment tax credit (ITC) through 2016; lifting of tax credit cap for residential PV installations; elimination of the electric utility exception to the ITC; a temporary grant program for commercial solar customers; and a government loan guarantee program for renewable energy and transmission projects. EPIA believes the Untied States will emerge as one of the top PV markets worldwide by 2013, with annual installations exceeding 1 GW either this year or the next.

The Japanese and Italian PV markets, both with promising support mechanisms coming into effect in early 2009, are predicted to stay on a growth trajectory as well.

Table 1: Outlook for Major PV Markets until 2013
Source: European Photovoltaic Industry Association

Country	Scenario	PV Installations (MW)							
		2006	2007	2008	2009E	2010E	2011E	2012E	2013E
Spain	Moderate	88	560	2511	375	500	500	550	800
	Policy-driven				375	500	600	650	1500
Germany	Moderate	850	1100	1500	2000	2000	2300	2600	3000
	Policy-driven				2500	2800	3200	3600	4000
USA	Moderate	145	207	342	340	1000	1200	1500	2000
	Policy-driven				1200	3000	3400	3900	4500
South Korea	Moderate	20	43	274	100	150	220	300	400
	Policy-driven				200	350	450	700	1000
Italy	Moderate	13	42	258	400	600	750	950	1250
	Policy-driven				500	800	1100	1400	1600
Japan	Moderate	287	210	230	400	500	700	1000	1100
	Policy-driven				500	1000	1200	1500	1700

Notes:
Moderate scenario – no major enforcement of existing support mechanisms
Policy-driven scenario – wide implementation of new or follow-up support mechanisms

When it comes to the wire and cable for PV module interconnection, only those wire or cable types specified in the National Electrical Code® (NEC) can be used if the modules are to be sold in the United States – a huge, yet relatively untapped, PV market. The next part of this article will provide an introduction to the UL requirements for PV wire that may be helpful for manufacturers who are interested in entering the field.

North American requirements for PV module interconnecting cables
Sec. 690.31(B) of the 2008 NEC® specifies that single-conductor Type USE-2 service-entrance cable and single-conductor photovoltaic (PV) wire are suitable for installation in exposed outdoor locations for photovoltaic module interconnections within the photovoltaic array. Since PV modules operate at elevated temperatures and are exposed to a variety of environmental conditions, the insulation of the module interconnection conductors is required to be sunlight resistant and rated for wet locations at a temperature rating of 90ºC or above.

The UL Standards used for investigating USE-2 wire (TYLZ) and PV wire (ZKLA) are UL 854 Service-Entrance Cables and UL Subject 4703 Outline for Photovoltaic Wire, respectively.

Differences between PV wire and USE-2 wire
Whereas USE-2 wire has long been accepted for PV module interconnections, PV wire is newly addressed in the 2008 edition of the NEC. Though their construction and performance requirements are similar, some variations between PV wire and USE-2 wire do exist due to their unique installation conditions. Below is a comparison of these two types of wires, based on their usage, construction and testing requirements:

- **Usage –** PV wire, with 90ºC wet rating and up to 150ºC dry rating, is dedicated for interconnecting PV modules. USE-2 wire is designated as underground service entrance cable typically for connecting to the terminals of service equipment. It is limited to installations in maximum 90ºC wet and dry conditions.

Both USE-2 wire and PV wire can be rated 600 V. However, PV wire can also be rated 1000 V and 2000 V to accommodate photovoltaic modules intended for use in systems with a system voltage greater than 600 V.

Per the NEC, USE-2 wire is suitable for use in grounded PV arrays only but PV wire can be used within both grounded and ungrounded PV arrays.

- **Construction** – PV wire comes with a thicker insulation or jacket to provide additional mechanical protection against the physical abuse that USE-2 wire typically receives.

  PV wire employs stranded copper conductors to make it flexible enough for the intended application. On the contrary, USE-2 wire can employ either solid or stranded conductors made of copper, copper-clad aluminum or aluminum since it is typically installed in locations not subject to movement or mechanical damages.

  The minimum conductor size for USE-2 wire is 14 AWG, but PV wire can employ a smaller conductor size down to 18 AWG.

- **Insulation and jacket materials** – both PV wire and USE-2 wire use thermoset insulation and jacket typically made of XLPE or EPCV. Nevertheless, other thermoset materials such as CP over EP, CP over EPCV, SBR/IIR/NR and EP are also available. PV wire may also be constructed similar to Type UF but uses an additional 15 mils of 90ºC wet and dry rated integral PVC insulation and jacket.

- **Testing requirements** – because USE-2 wire is typically installed underground or in similar locations where a flame may not propagate but PV wire can be exposed in an installation, a flame test is required only for PV wire. On the other hand, an overload test and mechanical abuse tests including crushing resistance and impact resistance are applicable only to USE-2 wire.

  As for sunlight resistance and flexibility at low temperature tests, PV wire must comply with more stringent requirements. It undergoes a 720-hour weatherometer and -40ºC cold chamber conditioning. The requirements for USE-2 wire are 300-hour weatherometer and -25ºC cold chamber conditioning.

In summary, when compared to USE-2 wire, PV wire has superior sunlight resistance and low-temperature flexibility in addition to a thicker insulation or jacket and a proven level of flame resistance. Given that PV wire can facilitate the use of ungrounded PV arrays as well as transformerless inverters, it is anticipated to grow in popularity for module interconnections.

For more information on UL certification service for PV wire, please contact your local UL office. Contact information can be found at http://www.ul.com/global/eng/pages/corporate/ulworldwide/.

Technical content of this article is provided by Leo Chung, UL Conformity Assessment Services, Hong Kong.