White Paper of Lightning Protection for PV Module Array

光伏组件阵列防雷防护白皮书

Foreword

前言

Along with the continuous development of the PV technology and the preliminary realization of the fair-price power grid, the quantity, the scale and the application scale of the grid-connected photovoltaic power generation system are being expanded. Thunder and lightning are natural phenomena which will seriously damage buildings and electrical equipment. To ensure the safe and reliable operation of the grid-connected photovoltaic power generation system, the lightning protection design of the grid-connected photovoltaic power generation system attracts more and more attention. This White Paper aims to analyze the lightning protection of the PV module array and the corresponding scheme.

随着光伏技术的不断发展，平价电网的初步实现，光伏并网发电系统的数量、规模和应用规模都在不断扩大。雷电是一种常见的自然现象，会对建筑物和电气设备造成严重破坏。为确保太阳能光伏平网发系统安全可靠运行，太阳能并网发电系统的防雷设计也越来越受重视，本白皮书旨在分析光伏组件方阵的防雷情况和对应的方案。

Contents 目录

1. Knowledge about Lightning 认识雷电

Strong updraft results in the separation of the charges in the cloud. There forms an electric field between the cloud and the ground, the negative charges at the lower end have the positive charges of the ground sensed, and then a large charged capacitor is generated between the thundercloud and the ground. When the potential difference between the thundercloud and the ground is high up to a certain extent (about 103v/cm ~ 104v/cm), the atmosphere will suffer from breakdown. A prominent object on the ground is easy to make a discharge. The principle is point discharge so usually the iron tower of a mobile base station may be struck by lightning easily. Most of the lightning current is repeated, generally a piece of lightning includes 3—4 pieces of discharge and repeated discharge always develops along the passage of the first discharge. The reason for repeated discharge is that the volume of thundercloud is too large, which makes the density distribution of charges different at each part and the conductivity different as well, and as a result, the charges contained by it cannot be discharged completely at a time.

强烈的上升气流造成了云内电荷的分离。云与大地间就形成电场，其下端的负电荷使大地被感应出正电荷，此时雷云与大地之间就成为一个大的已充电的电容器，当雷云与地间的电势差高到一定程度（约 103v/cm ~ 104v/cm ）时，大气会被击穿。地面上突出的物体比较容易放电。其原理为尖端放电，所以通常移动基站铁塔比一般建筑物更容易遭受雷击。雷电流大多数是重复的，通常一次雷电包含 3～4 次放电重复放电都是沿着第一次放电通路发展的。重复放电的原因是雷云体积太大，电荷在各部分密度分布不同，导电性能也不一样，所以它所包含的电荷不可能一次放完。

1.1 Direct Lightning 直击雷

Direct lightning is the process where the cloud discharges to the ground, called for “cloud-to-ground lightning” for short. Direct lightning will make a direct discharge to a PV module, which produces strong impact current and thus serious thermal collapse and mechanical disruption, causing great damage to the array of the module or even burnup of the complete string of modules. The protection measures cover lightning rods, downlead, and lightning protection net.

直击雷是云对地之间的放电过程，简称“地闪”。直击雷会直接对光伏组件放电，由于它有强大的冲击电流，产生极大的热破坏和机械破坏，对组件方阵的危害大，严重会导致整串组件烧毁。防护措施有避雷针、引下线、防雷网设计。

1.2 Inductive Lightning 感应雷

Generally speaking, inductive lightning is not as strong as direct lightning but its occurrence probability is much higher than that of direct lightning. Direct lightning will cause disaster to the ground only when the thundercloud strikes the ground, while inductive lightning is likely to happen and result in disaster no

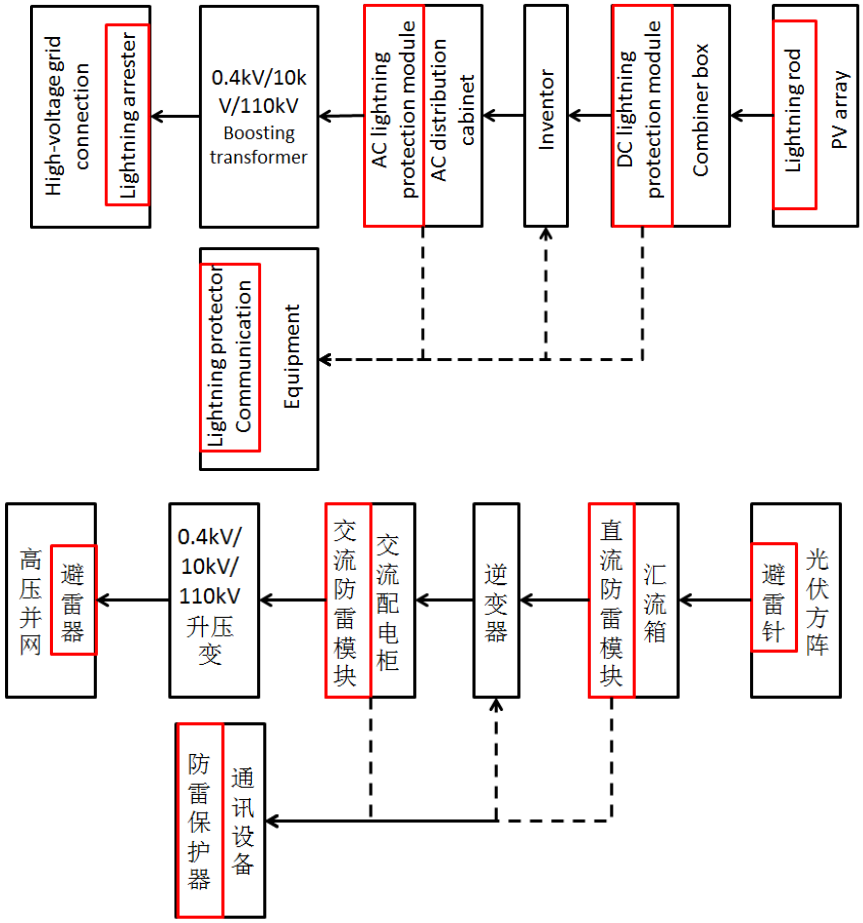
matter when thundercloud strikes the ground or another thundercloud. Protection measures need to make sure the equipotential connection among modules, cables, and various electrical devices as well as the surge protection design of the electrical equipment of lightning protection instruments.

一般来说， 感应雷没有直击雷那么猛烈，但它发生的几率比直击雷高得多。直击雷只发生在雷云对地闪击时才会对地面造成灾害，而感应雷则不论雷云对地闪击或者雷云对雷云之间闪击，都可能发生并造成灾害。防护措施需要保证组件，线缆，各种电器设备之间等电位连接，防雷元器件电气设备电涌保护设计等。

2. Basic Lightning Protection for Module Array 组件方阵的防雷基本保护

For the design of the lightning protection of a PV power station, please refer to GB50057-2010 *Design Code for Protection of Structures Against Lightning*. The typical lightning protection plan for a large grid-connected PV power station is shown in the following figure:

光伏电站防雷设计可参考 GB50057-2010《建筑物防雷设计规范》，大型并网光伏电站典型防雷方案如图所示：



The rack of the PV module array uses metal materials, occupies a large space and is generally placed on the top of a building or an open ground, which may easily be invaded and damaged by direct lightning in case of a thunderstorm. At present, crystalline silicon modules are divided into two types: One is the type of back-sheet modules with aluminum alloy frames, fixed by rigid materials like angle irons or box irons, which are all metal materials with good conductivity; and the other is the type of frameless double-glass modules which are installed on their metal racks by use of fixtures or hooks bonded with structural adhesive.

光伏组件方阵的支架采用金属材料并占用较大空间且一般放置在建筑物顶部或开阔地，在雷暴发生时，尤其容易受到直击雷的侵入而毁坏。目前晶硅组件目前分为两种：一种边框采用铝合金的背板组件，均采用角钢、槽钢等钢性物质固定，均为导电性能良好的金属材料；另外一种是无边框双玻组件，采用夹具装置或者结构胶粘接的挂钩安装在金属支架上。

2.1 Consideration about Site Selection 选址考虑

In accordance with the national standard, *Technical Code for Protection of Building Electronic Information System Against Lightning*, lightning areas are classified into four ones on the basis of thunderstorm days

根据国家标准《建筑物电子信息系统防雷技术规范》，将雷区根据雷暴日划分为 4 个。

Category 雷区类别	Annual number of thunderstorm days 年平均雷暴日(d)	Regions of China 中国地区
Area with fewer thunderstorms 少雷区	d ≤20	Northwest China 我国西北地区
Area with more thunderstorms 多雷区	20＜d＜ 40	A large part to the north of the Yangtze River 长江以北大部分
High-thunderstorm area 高雷区	40＜ d＜ 60	Area to the south of the Yangtze River 长江以南地区
Strong thunderstorm area 强雷区	d＞ 60	Area to the south of Northern Latitude 23° 北纬 23°以南地区

It is recommended that the site of a solar PV power system shall be selected at a position far away from areas which are easy to suffer from lightning stroke or where thunder and lightning can easily happen.

建议太阳能光伏发电系统的选址应尽量避免将光伏电站建筑在雷电易发生的和易遭受雷击的位置。

2.2 Strict Grounding 严格接地

There are two categories of the grounding systems for PV power stations: One category is strong current grounding, mainly referring to grounding for lightening protection and the other is weak current grounding, mainly working grounding and safety grounding. For different types of grounding, the requirements are different. The ground resistance of the grounding for lightning protection is usually within the range of 4~30Ω while that of the working grounding is typically between 0.5Ω and 10Ω; and generally it is specified that the ground resistance shall not exceed 10Ω when the total capacity of the low-voltage electrical equipment is not higher than 100kVA. During the design of grounding systems, there shall be enough gaps among various grounding systems so as to avoid the ground potential counterattack among the grounding systems. Due to a limited floor space of a solar power station, the design of a shared grounding system is adopted during the design of the grounding systems and the ground resistance is lower than 10Ω. The design of the grounding system for a PV equipment is similar to the design of an annular grounding system, where the grid size is 20*20m, the fixed metal racks are connected to the grounding system every 10m, the grounding system goes through anti-corrosion treatment and is laid in a place at least 0.5m deep in soil, and cross fixtures are used to mutual connection to make a grid form.

光伏电站接地系统通常有两大类：一是强电接地，主要指防雷接地；二是弱电接地，主要指工作接地、安全接地等。 不同类型接地， 其要求也不一样。防雷接地的接地电阻值一般在 4~30Ω 范围内；工作接地的接地电阻值一般在 0.5~10Ω 范围内；一般规定低电压电力设备总容量不超过 100kVA 时，接地电阻允许不超过 10Ω。在接地系统设计时，要保证各接地系统之间避免在地下电位反击就必须保证各接地系统在地下要有足够的间距。由于太阳能电站占地面积有限，为此在接地系统设计时，采用了共用接地系统的设计方案，且接地电阻小于 10Ω。光伏设备的接地系统设计问环形接地系统设计，网格大小为 20*20m，固定的金属支架大约每隔 10m 连接至接地系统，接地系统防腐处理，铺设至少 0.5 米深的土壤中，使用十字夹相互连接成网格状，接地系统防腐处理。

3 Protection Against Direct Lightning (External Lightning Protection) 直击雷的防护（外部防雷）

The measures for protection of a roof-type PV array against direct lightning shall be combined with those for protection of the relevant building against direct lightning; and the lightning arrester specially designed for the roof shall be applied. Based on the features of the ground PV electric field, for the lightning protection of the equipment and the buildings at the ground PV power station, the requirements in the *Design Code for Protection of Structures Against Lightning* can be referred to, in combination of the lightning overvoltage protection measures in the *Overvoltage Protection and Insulation Coordination for AC Electrical Installations*; and generally independent lightning rods, strips and conductors can be used as lightning arresters. For a lightning rod, its protection scope and height shall be calculated with the

rolling-ball method. Outside the PV array, the distance from an independent lightning rod (conductor) to the edge of the array shall be longer than 3m; inside the array, the short lightning rod can be set at the rear of the PV module or the metal frame (rack) of the PV module. At present, for a large PV system, the damage of one group of solar panels has only a little influence on the overall generating capacity. The most economic and feasible plan for a module with an aluminum frame is to utilize the metal frame of the PV module as the lightning arrester for protection against direct lightning and ground all the racks reliably after equipotential connection. When the metal frame or fixture of the PV array module is used as a lightning arrester, the thickness of its material shall meet the following requirements: The thickness of hot-dip galvanized steel or stainless steel shall be no less than 0.5mm and that of aluminum alloy shall be no less than 0.65mm.

屋面光伏方阵防直击雷接闪措施应与建筑物直击雷接闪措施相结合，采用屋面专设接闪器。根据地面光伏电场的特点，地面光伏发电场建筑和设备的防雷，参照《建筑物防雷设计规范》要求，结合《交流电气装置的过电压保护和绝缘配合》对雷电过电压的保护措施，通常可采用独立避雷针、避雷带和避雷线作为防雷接闪器。其中避雷针必须按滚球法计算其保护范围和高度。光伏方阵外独立接闪针（线）与方阵边缘应大于 3 米，方阵内接闪短针可设置在光伏组件后方，也可以设置在光伏组件的金属框（支）架上。目前对于大型的光伏系统，一组太阳能发电板的损坏, 对整体发电量影响甚小。带有铝边框组件最为经济可行的方案是利用光伏组件金属边框作为防直击雷的接闪器，所有支架均进行等电位连接后可靠接地。光伏方阵组件的金属边框或者金属夹件作为接闪器使用时，其材料厚度应符合下列规定：热镀锌钢、不锈钢的厚度不小于 0.5mm，铝合金的厚度不小于 0.65mm。

4. Protection Against Inductive Lightning (Internal Lightning Protection)感应雷的防护（内部防雷）

The measures for protection of the PV array against inductive lightning are space shielding, equipotential grounding and surge protection for electrical equipment. Equipotential connection shall be done for all the metal parts including metal frames and racks to prevent flashover and breakdown among them. Space shielding is to realize the electromagnetic shielding of the circuit and the equipment from the outside so as to keep off electromagnetic pulse and induction of high voltage. Shielding can be achieved by sealed conductive shell, coaxial sleeve or cable conduit with a cable passing inside, or placement of a highly-exposed guard line on the cable inside the cable duct. The shell of the shielding device shall be connected to the grounding grid of the PV array.

光伏方阵防感应雷措施是空间屏蔽，等电位接地和电气设备的防浪涌保护。应将所有的金属部件包括金属边框，支架等电位连接，防止互相之间的闪络和击穿。空间屏蔽是实现线路和设备对外界的电磁屏蔽各类，防止电磁脉冲和感应高电压。屏蔽可以采用密封的导电壳层，同轴外套或内通电缆

的电缆管，或者在电缆沟中电缆上面敷设高裸露保护线等方式。屏蔽装置的外壳应连接到光伏阵列的接地网上。

5. Conclusion 结语

For the lightning protection of a large grid-connected PV power station, there is no definite national standard at present. However, from the perspective of prevention from personal injury and equipment damage due to lightning strike as well as from influence on the safe operation of the power grid, a large area of lightning protection design is necessary; and the lightning protection standard shall not be reduced with the reason of undefined national standards and reduction of construction costs. During the lightning protection design for a large grid-connected PV power station, national and industrial regulations such as the *Design Code for Protection of Structures Against Lightning* (GB50057-2010) and the *Overvoltage Protection for Photovoltaic (PV) Power Generating Systems-Guide* (SJ/T11127-1997) shall be referred to in an overall way, so as to confirm the key points of the lightning protection of different buildings and equipment and the lightning protection scheme as per the best cost performance on the premise of guaranteeing safe lightning protection. Trina Solar will continuously do research and monitoring as well as update this White Paper when appropriate.

大型并网光伏电站的防雷目前虽然没有明确的国家标准，但从防雷击人身伤亡和设备损毁，进而影响电网运行安全的角度出发，大面积的防雷设计是必要的，决不能以国家规定不明确和降低工程造价为理由，降低防雷标准。大型并网光伏电站的防雷设计应综合参考《建筑物防雷设计规范》（GB50057-2010）、《光伏（PV）发电系统过电压保护导则》（SJ/T11127-1997）等国家行业规定，在保障防雷安全的前提下，明确电站不同建筑、设备的防雷重点，按照最佳性价比确定防雷方案。天合光能会持续不断进行研究和监控，并在适宜时候更新该白皮书。

The right to interpret this White Paper shall belong to Trina.

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