CPRIM Artifacts - Detailed risks identified by HAZOP, with the respective parameters and guidewords.

ID	Component	CPS layer	Parameters	Guidewors	Deviation	Causes	Consequences	Identified risk
100.	Photovoltaic panel	Physical	ambient temperature	above	Ambient temperatures above specified limits (T > +50° C)	Climate variation (heatwave, seasonal effects) and inappropriate installation location	Thermal stress, loss of efficiency due to natural wear	Ambient temperatures above specified limits can cause thermal stress on photovoltaic panels, resulting in physical damage and increased maintenance and replacement costs.
101.	Photovoltaic panel	Physical	ambient temperature	below	Ambient temperature below the limit of the technical specification for the environment (T < -40°C)	Climate change (extreme events such as snowfall or seasonality) and inappropriate installation location	Thermal stress and reduction in energy generation	Extreme weather conditions, such as snowstorms, can lower ambient temperatures below specified limits, reducing the efficiency of photovoltaic panels and causing financial impacts on the solar power plant.
102.	Photovoltaic panel	Physical	operational temperature	above	Panel temperature above the technical specification limit for operation (T > +85°C)	Inappropriate installation, overheating due to factors such as dirt	Damage to photovoltaic cells (delamination) and loss of efficiency	Increased ambient temperatures above specified limits can generate thermal stress on photovoltaic panels, resulting in physical damage and additional costs for maintenance and replacement.
103.	Photovoltaic panel	Physical	operational temperature	below	Panel temperature below the technical specification limit for operation (T < -40°C)	Inappropriate installation, cooling due to snow accumulation	Thermal stress, cell damage and lack of energy generation	Decreased ambient temperatures below specified limits can cause excessive cooling of photovoltaic cells, leading to breakage or cracking and reducing power generation efficiency from the panel.
104.	Photovoltaic panel	Physical	humidity	above	Plate exposed to humidity above 85RH% (high)	Area with a large amount of water vapor such as vegetated areas	Condensation of moisture inside the board, loss of electrical insulation with risk of shock	Areas with high relative humidity (>0.85%) can cause water condensation inside photovoltaic cells, reducing thermal insulation and increasing the risk of electrical shocks.
105.	Photovoltaic panel	Physical	humidity	above	Cables exposed to humidity above 85RH%	Area with a large amount of water vapor such as vegetated areas	Cable oxidation and corrosion	Areas with high relative humidity can lead to oxidation and corrosion of cables in the photovoltaic power plant.
106.	Photovoltaic panel	Physical	voltage	above	Voltage above the technical specification limit (t > 1000 Vdc)	Atmospheric discharges, high transient overvoltages	Damage from atmospheric discharges (lightning), short circuit and fire	Lightning strikes can cause overvoltages in the photovoltaic power system, irreversibly damaging solar cells, leading to short circuits and fires.
107.	Photovoltaic panel	Physical	mechanical resistence	low	Mechanical resistance lower than technical specification	Hailstone speeds above 50mph, impacts on installation	Micro cracks or fissures in the cells, short circuit	The impact speed of hailstones exceeding 50 mph can cause microcracks or fissures in photovoltaic cells, reducing their mechanical strength and increasing the risk of short circuits in the system.
108.	Photovoltaic panel	Physical	snow load	above	Snow load above technical specification limit: 5400Pa (550 Kg/m2) Max from the front side	Climate change (extreme events such as snowfall)	Damage to cells and reduction of energy generation	Excessive snow accumulation on photovoltaic panels can damage the solar cells, reducing the system's capacity to generate power.
109.	Photovoltaic panel	Physical	wind speed/force	above	Wind load above technical specification limit: 5400Pa (550 Kg/m2) Max from the front side; 2400Pa from the rear	Climate change (extreme events such as hurricanes)	Loss of fixation due to vibration, internal circuit breakage	Extreme weather conditions, such as strong winds above the specified limit, can result in panel detachment and internal damage to photovoltaic cells, resulting in reduced efficiency in power generation.
110.	Inverter	Cyber-physical	DC operational voltage	above	Direct current overvoltage (above 900V)	Elevation of electrical voltage above the limit of the technical specification	Inverter shutdown and short circuit	Increasing DC above specified technical limits can generate overvoltage, resulting in inverter shutdown and possible short circuits.
111.	Inverter	Cyber-physical	DC operational voltage	below	Direct current undervoltage (below 252V)	Reduction of inverter supply voltage below specification or faulty circuits	Inverter shutdown or insufficient input voltage to turn on the power supply at night	Defects in the inverter's electrical circuits can cause a decrease in DC voltage, resulting in insufficient input voltage to power the source during nighttime.
112.	Inverter	Cyber-physical	electric current	above	Circulation of leakage currents and atmospheric discharges (36A)	Lack of electrical grounding	Burning equipment and electrical accidents	Lack of electrical grounding can compromise protection against leakage currents and lightning strikes, resulting in equipment damage and electrical accident risks.
113.	Inverter	Cyber-physical	AC power	below	Output power (AC) below input power (DC)	Oversized panels	Longer inverter operating time with lower efficiency and loss of electrical energy	Oversized installation of photovoltaic panels can result in lower output power than the input power, leading to prolonged operation of the inverter with lower efficiency and electrical energy loss.
114.	Inverter	Cyber-physical	AC voltage	above	Alternating current overvoltage (above 480V)	Receiving direct current above the configured level, installation problem and poorly sized infrastructure	Inverter shutdown or burnout of electronic equipment	AC elevation above specified technical limits and inadequate infrastructure can generate overvoltage, resulting in the photovoltaic inverter shutdown or burning electronic equipment connected to the grid.
115.	Inverter	Cyber-physical	AC voltage	below	Alternating current undervoltage (below 320V)	Reduction in equipment supply voltage, installation problems and poorly sized infrastructure	Interruption of the equipment operation	A decrease in equipment's supply voltage can cause AC undervoltage, interrupting equipment operation.
116.	Inverter	Cyber-physical	frequency	increase	Increase in frequency above the technical specification limit (63Hz)	Network disconnections	Mass shutdown (inverter and equipment connected to it) or change in energy injection	Increased frequency above the technical specification limit, usually caused by an excessive energy supply compared to demand, can cause network disconnections, resulting in the massive shutdown of photovoltaic inverters and connected equipment.
117.	Inverter	Cyber-physical	operational temperature	above	Inverter overheating for temperature above technical specification (T > +60°C)	Climate changes, inappropriate installation location and poor sizing	Reduction of inverter power (temperature derating) and, in extreme cases, complete inverter shutdown	Climate change, improper installation, and inadequate sizing can cause inverter overheating, reducing system-generated power and, in extreme cases, complete inverter shutdown.
118.	Inverter	Cyber-physical	operational temperature	below	Cooling of the inverter to temperatures below technical specifications (T < -25°C)	Climate change (extreme events such as snowfall or seasonality) and inappropriate installation location	Thermal stress and reduction in energy generation	Excessive cooling of the inverter, often due to climate changes such as snowstorms, can cause temperature sensor failures and metal component corrosion, compromising the equipment's proper functioning and resulting in economic losses for the photovoltaic system.