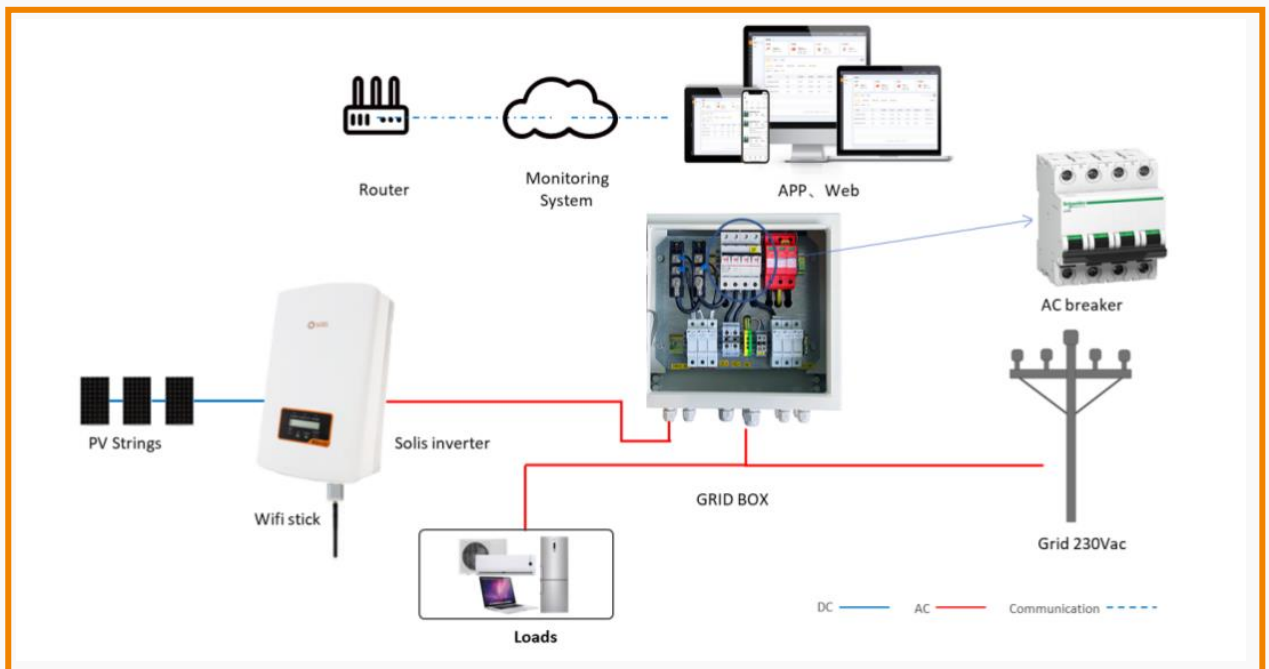


How to select Suitable Circuit Breakers for inverters in PV-system

Background

In solar PV systems, circuit breaker selection is something that is easily overlooked, and time should be taken to select the correct solution. If the circuit breaker is not appropriate, it will cause frequent tripping of the equipment, overheating damage and even system fire. In this Solis Seminar, we will discuss how to select circuit breakers in photovoltaic systems.



Types of Circuit Breaker

In a solar PV system, the choice of a series of circuit breakers depends on several factors:

- Electrical characteristics of the system
- Environment
- Loads and the requirements of the installation type:
- **Ambient temperature at the circuit breaker**

For PV systems, equipment is usually installed outdoors (ground mount systems, flat roof systems, etc.). A higher outdoor temperature is usually presumed than for installations in buildings, so it can be expected that the temperature in the distribution board will be higher. This will also affect the flow rate and operating temperature of the circuit breaker.



For the selection of circuit breakers in solar PV systems, temperature is the most important consideration. According to the IEC 60947-2 standard any circuit breaker has a datasheet detailing the derating/increasing current value of the ambient temperature. You should select the appropriate circuit breaker equipment according to the on-site ambient temperature and the size of the system current.

Rating	Ambient temperature (°C)													
(A)	10	15	20	25	30	35	40	45	50	55	60	65	70	
16	18.4	18.7	18	18	17	16.6	16	15.6	15.2	14.8	14.5	14	13.8	
25	28.8	28	27.5	25	26.3	25.6	25	24.5	24	23.5	23	22	21	
32	36.8	36	35.2	34.4	33.6	32.8	32	31.3	30.5	30	29.5	29	28.5	
40	46	45	44	43	42	41	40	39	38	37	36	35	34	
50	57.5	56	55	54	52.5	51	50	49	48	47	46	45	44	
63	72	71	69	68	66	65	63	61.5	60	58	57	55	54	
80	92	90	88	86	84	82	80	78	76	74	72	70	68	
100	115	113	110	108	105	103	100	97.5	95	92.5	90	87.5	85	
125	144	141	138	134	131	128	125	122	119	116	113	109	106	
160	184	180	176	172	168	164	160	156	152	148	144	140	136	
200	230	225	220	215	210	205	200	195	190	185	180	175	170	
250	288	281	277	269	263	256	250	244	238	231	225	219	213	

Influence of adjacent devices

If several miniature circuit breakers are installed directly side by side with high load on all poles, a correction factor has to be applied to the rated current (see table). If distance pieces are used, the factor is not to be considered.

Example

Installation of 8 adjacent miniature circuit breakers S201-C16 at 40 °C ambient temperature

Rated current $I_n = 16$ A
Max. operating current at 40 °C = 15.1 A (see table above)
Factor $F = 0.75$ (see left table)
 $I_n = 15.1 \text{ A} \times 0.75 = 11.33 \text{ A}$
Result: The operating current can only add up to max. 11.33 A

No. of adjacent devices	Factor F
1	1
2, 3	0.9
4, 5	0.8
≥ 6	0.75

Mutual heating of circuit breakers

For large solar PV power stations with multiple inverters, there are usually multiple circuit breakers in the distribution board, which are closely mounted next to each other. These circuit breakers will provide their maximum current at the same time therefore, the temperature of the circuit breakers will affect each other more quickly, possibly leading to premature tripping.




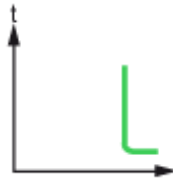


Type of the connected devices

If a solar PV system is connected to the grid, it will be tripped by the current and voltage impact of the load feeder network. When we choose a circuit breaker, we need to consider the components of the load in this grid in order to choose the most suitable circuit breaker.

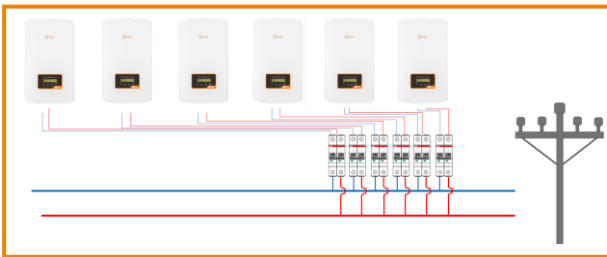
Table 2: Different type breaker, instantaneous or short-time-delayed.



Type	Tripping unit	Application
	Low setting type B	Sources producing low short-circuit- current levels (standby generators) Long lengths of line or cable
	Standard setting type C	Protection of circuits: general case
	High setting type D or K	Protection of circuits having high initial transient current levels (e.g." motors, transformers, resistive loads)
	12 In type MA	Protection of motors in association with contactors and overload protection

2 Example

Examples for the thermal ratings of circuit breakers in parallel operation of PV plant.



PV plant with 6 Solis-1P8K-5G inverters.

The required technical specifications can be found in the datasheet of the Solis-1P8K-5G inverter:

- Maximum output current = 34.7 A
- Its maximum fuse protection = 50 A

The choice of cable as well as wiring method, ambient temperature and other potential conditions limit the maximum fuse protection of the cable.

In our example, we assume that the selected cable (6mm²) has ideal routing and can withstand a nominal current of 35A.

The maximum possible nominal current for the cable used and the maximum possible fuse protection of the Solis-1P8K-5G limit the maximum possible nominal current for the circuit breakers.

• Selecting the Correct Circuit Breaker

Using the same example system and assuming the load that has no motors, transformers etc., based on the calculated current of 34.7A,



we choose a 40A circuit breaker with a thermal tripping characteristic of B and no gap between the circuit breakers. We then verify whether our selected value is appropriate by checking the thermal adaptability of the circuit breaker:

The load factor meets the specifications of the datasheet:

- Reduction at permanent load $> 1 \text{ h} = 0.9$
(Permanent loads of more than 1 hour are possible in PV plant.)
- Reduction factor when 6 circuit breakers are directly arranged next to each other = 0.75
(If one circuit breaker is used or the distance between each other is enough, the coefficient is equal to 1.)
- The increase in the nominal current in the distribution board when the ambient temperature is $40^{\circ}\text{C} = 1.0$

Temperature Re-Rating Values

Maximum Ambient Temperature												
°F	158	140	122	104	86	77	68	50	32	14	-4	-13
°C	70	60	50	40	30	25	20	10	0	-10	-3	-25
Current	0.75	0.83	0.92	1	1.07	1.11	1.14	1.21	1.27	1.33	1.39	1.42

• Result

The nominal load current of the circuit breaker is calculated as:

$$I_{bn} = 40 \text{ A} \times 0.9 \times 0.75 \times 1.0 = 27\text{A}$$

• Conclusion

Since the maximum current carrying capacity for fault-free operation is lower than the maximum output current of the inverter used, the selected circuit breaker cannot be used in this example. The circuit breaker will trip during rated operation.

• Solution 1

Use a 50A circuit breaker. There is enough space ($> 10\text{mm}$) for heat dissipation between the circuit breakers, and the maximum current carrying capacity is 40.5 A

($I_{bn} = 50\text{A} \times 0.9 \times 0.9 = 40.5\text{A}$), and the circuit breaker will not trip under rated operation.

• Solution 2

Use a 63A circuit breaker. Maximum current carrying capacity is 42.5 A

($I_{bn} = 63\text{A} \times 0.75 \times 0.9 \times 1 = 42.5\text{A}$), and the circuit breaker will not trip under rated operation.