Workshop Exercises - Determining cable sizes and protection in an off-grid PV system

1. An array consists of 3 parallel strings. These connect to a controller and then to a battery bank. For this exercise, assume the main battery protection is not sized to protect the array cable. Each string has 2 modules in series, with the following characteristics:
   - V_{mod} = 24V
   - I_{sc} = 5.4A
   - $I_{mod\ reverse}$=15A

   a) What size array cable and array fuse are required?

   b) What size string cable is required? Does it meet the voltage drop requirements? Is string protection required? If so, what size?
   (Assume length of string cable as 8m)

A table showing current carrying capacities of different sizes has been provided to assist you.

Conductor Size (mm^2)	**Current Rating (A)**	**Voltage Rating (VDC)**
2.5	21	1000
4	27	1000
6	34	1000
10	48	1000
16	63	1000

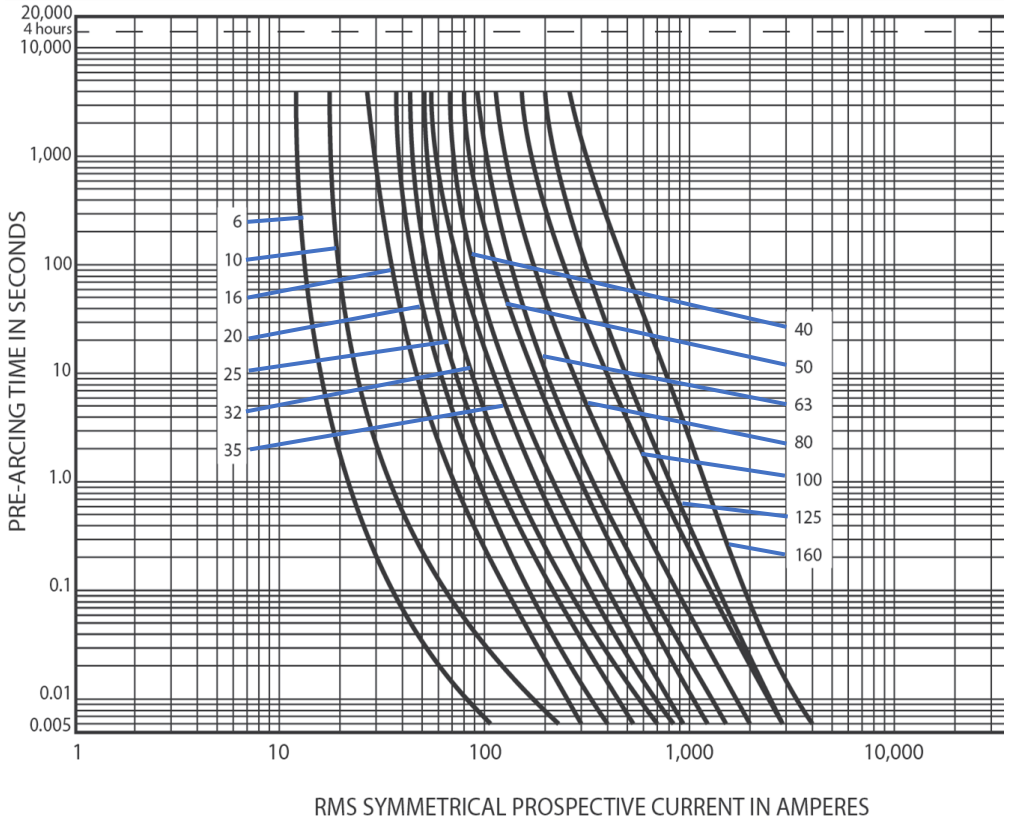
Table 1: Current carry capacities of cables

2. The distance between the inverter and the batteries is 2 metres. The continuous current is 111A and surge current is 277A. What is the minimum size cable that would ensure that I have less than 2% voltage drop (System voltage is 24V)? What would need to be checked with respect to the surge current? Use the CCC table below as a reference.

Cond. size	Unenclosed space		Spaced from surface		Touching		Enclosed conduit in air		Partially surrounded by thermal insulation		Completely surrounded by thermal insulation		Buried direct		Underground ducts				Single phase voltage drop mV/A.m	
mm^2																				
	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al	Cu	Al
1	16		16		13		13		11		6		18		18		21		51.6	
1.5	21		21		16		18		14		8		23		23		26		33.0	
2.5	30		29		23		24		20		12		32		32		36		18.0	
4	40		39		31		32		25		16		41		41		47		11.2	
6	51		49		40		41		33		20		52		52		58		7.50	
10	69		67		54		54		44		27		69		69		77		4.46	
16	92	72	89	69	72	56	70	54	56	43	36	28	122	95	89	69	99	77	2.81	4.68
25	124	96	119	92	97	75	94	73	75	58	48	38	158	123	116	90	129	100	1.78	2.95
35	153	119	145	113	119	92	112	87	90	70	59	46	190	147	139	108	155	120	1.29	2.14
50	187	145	177	137	146	113	138	107	110	86	–	–	225	174	168	130	186	145	0.96	1.58
70	238	184	223	173	184	143	170	132	136	105	–	–	277	215	206	160	228	177	0.680	1.10
95	295	229	276	214	230	178	212	164	169	131	–	–	332	257	252	195	278	215	0.507	0.804
120	344	267	321	249	267	208	242	188	193	150	–	–	378	294	287	223	316	245	0.415	0.644
150	395	307	367	285	308	239	282	219	225	175	–	–	424	329	329	255	354	274	0.352	0.535
185	459	357	424	331	358	279	320	249	256	199	–	–	480	374	373	291	408	317	0.301	0.439
240	549	427	505	394	428	334	381	298	305	238	–	–	556	434	438	342	472	368	0.255	0.352
300	636	495	582	456	495	388	–	–	–	–	–	–	628	491	496	388	546	425	0.229	0.300
400	744	583	676	535	577	456	–	–	–	–	–	–	713	564	575	454	621	487	0.209	0.256
500	867	685	780	624	668	535	–	–	–	–	–	–	805	644	649	520	721	570	0.194	0.226
630	1014	808	897	730	770	627	–	–	–	–	–	–	904	737	750	611	816	652	0.181	0.202

3. Using the given table and figure, select the minimum required fuse for a typical 2.3kVA sine wave inverter (24V DC - 230V AC).

	Continuous	60 minute	12 sec surge
Power (W)	2300	2600	4800
Inverter efficiency	0.94	0.94	0.94
Current (A)	102	115	212.7



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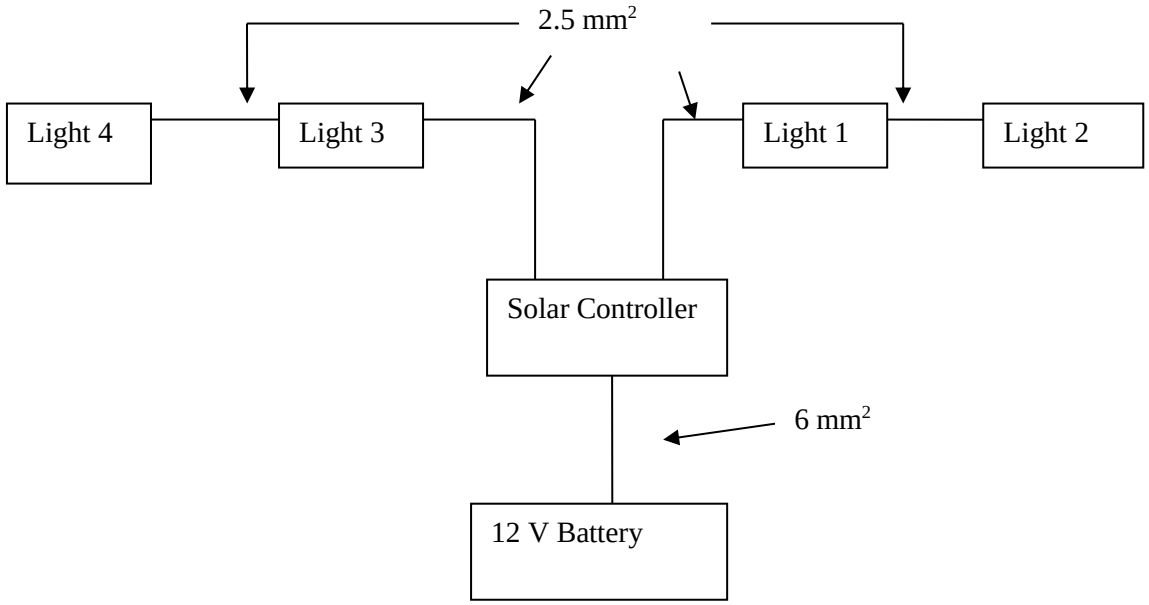

Each of the four lights above are 12V DC 20W lights. The light switches are on the light.

Assuming the following distances:

- Battery Bank to Solar Controller is 3 metres
- Solar Controller to light 1 is 5 metres.
- Solar Controller to light 3 is 8 metres
- Light 1 to Light 2 is 8 metres
- Light 3 to Light 4 is 10 metres.

Suppose all the lights are on, what is the voltage drop expressed as a voltage and as a percentage between the battery and light 4. The single line between the batteries, controller and lights represent both the positive and negative cables. The lights are wired in parallel.

The distance of cable between PV Array and the MPPT controller is 25 meters. The Maximum current is 9A. The cable you are using is 16mm^2. The maximum power point voltage is 334.4V. Calculate the percentage voltage drop in the cable.

Attempt if there is time.

5. The distance of cable between PV Array and the MPPT controller is 25 meters. The Maximum current (short circuit current) is 9A. The cable you are using is 16mm^2. The maximum power point voltage is 334.4V. Calculate the percentage voltage drop in the cable.

6. Assuming:

    - The inverter continuous and surge rating are 800VA and 1500VA respectively,
    - the distance between the inverter and the battery bank is 3 metres,
    - the maximum allowed voltage drop is 5%,

- the inverter efficiency is 85%,
- the system voltage is 24V.

Calculate the minimum cable size that would be appropriate for the above inverter based on voltage drop? Would this cable be suitable considering the continuous current, Yes or No? If no, what size cable is required? What would need to be checked with respect to the surge current?

$$A_{dc\_cable} = \frac{\left(2 \times L_{dc\_cable} \times I_{dc} \times \rho\right)}{Loss \times V_{mp\_string}}$$