Low Voltage Power Capacitors

CAPACITOR SELECTION TABLE FOR POWER FACTOR CORRECTION OF ELECTRICAL MOTORS

Reactive power is required by an asynchronous motor for the magnetic field. The amount of reactive power consumption of a motor depends on various parameters such as power rating, loading, rated speed, and design. The capacitor output should be maximum 90 % of the apparent power of a asynchronous motor under no-load conditions. This is important to avoid dangerous self excitation of the motor. A measurement of the motor current under no-load conditions can be easily performed or may be obtained from the manufacturer.

GUIDELINE VALUES FOR CAPACITOR SELECTION

MOTOR POWER RATING kW	CAPACITOR OUTPUT SELECTION kvar
Up to 3.9	Approximately 55 % of nominal motor power
4.0 to 4.9	2
5.0 to 5.9	2.5
6.0 to 7.9	4
8.0 to 10.9	4
11.0 to 13.9	5
14.0 to 17.9	6
18.0 to 21.9	7.5
22.0 to 29.9	10
30.0 and above	Approximately 35 % of nominal motor power

CAPACITOR SELECTION TABLE FOR POWER FACTOR CORRECTION OF TRANSFORMERS

For power factor correction of transformers only the no-load reactive power has to be covered. The required capacitor output for three-phase transformers depends on the short-circuit voltage and is between 3 % and 12 % of the rated transformer output. In case harmonics are present on the high voltage side, the capacitor can form a series resonance circuit with the inductance of the transformer. Therefore the capacitor output has to be selected very carefully together with power utilities and the transformer manufacturer. The following formula can be used to check whether a certain capacitor output will create problems for specific harmonic orders on high voltage side:

$$n = \sqrt{S/Q_C}$$

n = Harmonic order

Q_C = Rated capacitor output in kvar

S = Short circuit power at the point of capacitor connection in kVA

GUIDELINE VALUES FOR CAPACITOR SELECTION

TRANSFORMER RATING kVA	CAPACITOR OUTPUT IN kvar AT TRANSFORMER PRIMARY VOLTAGES		
	5 kV TO 10 kV	15 kV TO 20 kV	25 kV TO 30 kV
50	4.0	5.0	6.0
75	5.0	6.0	7.5
100	6.0	7.5	10.0
160	10.0	12.5	15.0
250	15.0	16.7	20.0
315	16.7	20.0	25.0
400	20.0	25.0	30.0
630	30.0	33.3	40.0
1000	45.0	50.0	55.0
1250	50.0	55.0	60.0

CALCULATION AND SELECTION OF REQUIRED CAPACITOR RATING

$Q_C = P \times (\tan \varphi 1 - \tan \varphi 2) = P \times (\tan \arccos \cos \varphi 1 - \tan \arccos \cos \varphi 2)$

Q_C = Required capacitor output (kvar)
P = Real power (kW)
$\varphi 1$ = Phase angle of actual power factor
$\varphi 2$ = Phase angle of target power factor
cos $\varphi 1$ = Actual power factor
cos $\varphi 2$ = Target power factor

The table below shows the values for typical power factors according to the formula "tan $\varphi 1$ - tan $\varphi 2$":

	TARGET POWER FACTOR									
	0.70	0.75	0.80	0.85	0.90	0.92	0.94	0.96	0.98	1.00
ACTUAL POWER FACTOR										
0.40	1.27	1.41	1.54	1.67	1.81	1.87	1.93	2.00	2.09	2.29
0.45	0.96	1.10	1.23	1.36	1.50	1.56	1.62	1.69	1.78	1.98
0.50	0.71	0.85	0.98	1.11	1.25	1.31	1.37	1.44	1.53	1.73
0.55	0.50	0.64	0.77	0.90	1.03	1.09	1.16	1.23	1.32	1.52
0.60	0.31	0.45	0.58	0.71	0.85	0.91	0.97	1.04	1.13	1.33
0.65	0.15	0.29	0.42	0.55	0.68	0.74	0.81	0.88	0.97	1.17
0.70	0.00	0.14	0.27	0.40	0.54	0.59	0.66	0.73	0.82	1.02
0.75		0.00	0.13	0.26	0.40	0.46	0.52	0.59	0.68	0.88
0.80			0.00	0.13	0.27	0.32	0.39	0.46	0.55	0.75
0.85				0.00	0.14	0.19	0.26	0.33	0.42	0.62
0.90					0.00	0.06	0.12	0.19	0.28	0.48

The required capacitor output may be calculated as follows:

select the factor k
(matching point of actual and target power factor)

calculate the required capacitor rating with the formula:

$Q_C = k \times P$

Example: Actual power factor = 0.70
Target power factor = 0.96
Real power P = 35 kW
Capacitor output Q_C = ?

$Q_C = k \times P = 0.73 \times 35 \text{ kW} = 25.5 \text{ kvar}$

Capacitor output in case of voltage and/or frequency different to the capacitor nominal voltage:

$$Q_{new} = \left(\frac{U_{new}}{U_{cn}}\right)^2 \times \frac{f_{new}}{f_{cn}} \times Q_{cn}$$

Note $U_{new} < U_{cn}$

U_{new} = Supply voltage the capacitor is required for

f_{new} = Frequency the capacitor is required for

Q_{new} = Capacitor output at U_{new} and f_{new}

U_{cn} = Rated capacitor voltage

f_{cn} = Rated capacitor frequency

Q_{cn} = Rated capacitor output at U_{cn} and f_{cn}

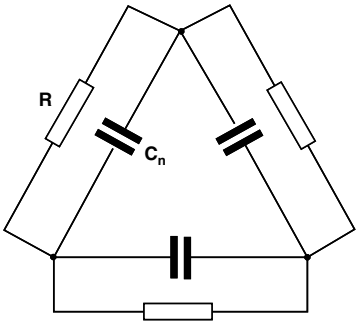
DISCHARGE RESISTORS

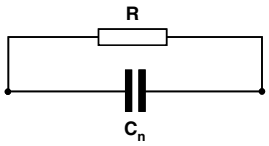
ESTAprop MKP-type capacitors will be provided complete with discharge resistors. After the capacitor is disconnected from the source of supply, discharge resistors are required for discharging each unit within 3 min to 75 V or less from initial nominal peak voltage (according IEC-standard 60831-1 + 2). Discharge resistors have to be connected directly to the capacitors. There shall be no switch, fuse cut-out, or any other isolating device between the capacitor unit and the discharge resistors.

Annotation: Our capacitors are discharged to 50 V or less within 1 min to comply also with UL standard 810.

MAXIMUM RESISTOR VALUE

$$R \leq \frac{60\ s}{C_n \times I_n\left(\frac{U_n \times \sqrt{2}}{50\ V}\right)}$$



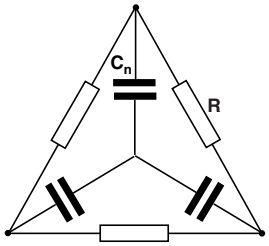


MINIMUM REQUIRED POWER RATING OF THE RESISTORS (W)

$$P = \frac{U^2}{R}$$

MAXIMUM RESISTOR VALUE

$$R \leq \frac{60\ s}{1/3 \times C_n \times I_n\left(\frac{U_n \times \sqrt{2}}{50\ V}\right)}$$



Example: PhMKP 400.3.25
(Delta Connection)

C_n = 165.8 µF

$$=> R \leq \frac{60\ s}{165.8 \times 10^{-6}\ F \times I_n\ \left(\frac{400\ V \times \sqrt{2}}{50\ V}\right)}$$

$R \leq 149.1\ k\Omega$

(a thick film discharge resistor with 145 kΩ is used)

Note

- Attention: Terminals have to be short-circuited before handling.

CROSS SECTION OF CONNECTING CABLE BETWEEN MAIN SUPPLY AND CAPACITOR BANK, FUSE RATING

Cross section for connecting cable and fuse rating have to be selected in accordance with the standard VDE 0100 part 523. Values mentioned below are guideline values valid for operation under normal conditions and at an ambient temperature of 40 °C. Higher values shall be selected if conditions differ from normal (e.g. high harmonic distortion or higher ambient temperature).

OUTPUT kvar	RATED VOLTAGE 230 V, 50 Hz			RATED VOLTAGE 400 V, 50 Hz			VOLTAGE 415 V, 50 Hz		
	RATED CURRENT A	FUSE A	CABLE/ mm²	RATED CURRENT A	FUSE A	CABLE/ mm²	RATED CURRENT A	FUSE A	CABLE/ mm²
2.5	6.3	16	2.5	3.6	10	1.5	3.5	10	1.5
5.0	12.6	25	4	7.2	20	2.5	7.0	20	2.5
6.67	16.7	35	6	9.6	20	2.5	9.3	20	2.5
7.5	19	35	6	10.80	20	2.5	10.4	20	2.5
8.33	21	35	6	12	20	2.5	11.6	20	2.5
10.0	25	50	10	14.4	25	4	13.9	25	4
12.5	31	63	16	18	35	6	17.4	35	6
15.0	38	63	16	21.7	35	6	20.9	35	6
16.7	42	80	25	24.1	50	10	23.2	50	10
20.0	50	100	35	28.9	50	10	27.8	50	10
25.0	63	125	50	36.1	63	16	34.8	63	16
30.0	75	125	50	43.3	80	25	41.7	80	25
33.3	84	160	70	48.1	80	25	46.3	80	25
40.0	100	160	95	57.7	100	35	55.6	100	35
50.0	125	250	120	72.2	125	50	69.6	125	50
60.0	-	-	-	86.6	160	70	83.5	160	70
66.7	-	-	-	96.3	160	70	92.8	160	70
70.0	-	-	-	101	160	70	97	160	70
75.0	-	-	-	108	160	70	104	160	70
83.3	-	-	-	120	200	95	116	200	95
100.0	-	-	-	144	250	120	139	250	120

CAPACITOR BANK INTERNAL WIRING

The internal wiring of capacitor banks can be normally done with a lower cross section. Various parameters such as cabinet inside temperature, quality of cable, maximum cable isolation temperature, single or multicore cable, and temperature rating have to be taken into consideration for selection of the appropriate value.

The contrary requirement for limiting the inrush current and reduction of cable losses is another important aspect in this matter if no inrush current limiting devices are used.

CALCULATION OF THE REQUIRED RATED CAPACITOR OUTPUT IN DETUNED FILTER CIRCUITS (FACTORS TO BE MULTIPLIED WITH THE REQUIRED OUTPUT PER STEP)

SUPPLY VOLTAGE 400 V							
RATED VOLTAGE [1] OF CAPACITOR V	DETUNING FACTOR IN %						
	5	5.5	6	7	12.5	13	14
440	1.150	1.143	1.137	1.125	-	-	-
525	1.637	1.628	1.619	1.602	1.507	1.499	1.481

SUPPLY VOLTAGE 415 V							
RATED VOLTAGE [1] OF CAPACITOR V	DETUNING FACTOR IN %						
	5	5.5	6	7	12.5	13	14
440	1.068	1.062	1.057	-	-	-	-
525	1.520	1.512	1.504	1.488	1.400	1.392	1.376

SUPPLY VOLTAGE 440 V							
RATED VOLTAGE [1] OF CAPACITOR V	DETUNING FACTOR IN %						
	5	5.5	6	7	12.5	13	14
525	1.352	1.345	1.338	1.324	1.246	1.239	1.224

SUPPLY VOLTAGE 480 V							
RATED VOLTAGE [1] OF CAPACITOR V	DETUNING FACTOR IN %						
	5	5.5	6	7	12.5	13	14
525	1.136	1.130	1.125	1.113	-	-	-
660	1.796	1.787	1.777	1.758	1.654	1.645	1.626

Example:

Required output per step at supply voltage: 50 kvar

Supply voltage: 400 V

Detuning factor: 7 %

Rated voltage of the capacitor: 440 V

Factor of the table: 1.125

Required rated output of the capacitors: 50 kvar x 1.125 = 56.25 kvar

Selection: for instance: 2 x PhMKP 440.3.28, 1

Note

[1] For filter circuits the capacitor rated voltage has to be chosen always higher than the supply voltage.
i.e.: Fundamental voltage increased by the reactor and harmonics.