DISCHARGE RESISTORS

Power capacitors store electrical charges that after their disconnection can turn out to be dangerous for people during operation of inspection and maintenance. To reduce these voltages to safe values, discharge resistors must be used.

IEC 831 Standard sets up that the voltage in terminals of a capacitor must not exceed 75 V after 3 minutes since its disconnection.

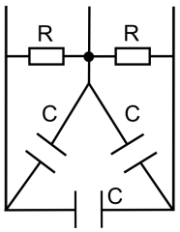
Calculation of discharge resistors

A capacitor discharge comes by a law of exponential type. Calculation of the value of the discharge resistor is done by means of the following expression:

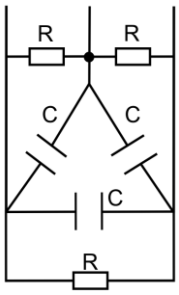
$$R \leq \frac{t}{k * C * log_e \left(\frac{U_N\sqrt{2}}{U_R}\right)}$$

t = Discharge time from U_N to U_R in seconds (180 s in IEC 831)
R = Discharge resistor value (M⍰)
C = Capacitance per phase (µF)
U_N = Capacitor rated voltage (V)
U_R = Allowable residual voltage (75 V in IEC 831)
k =Coefficient according to connection mode: k = 1 for three resistors (delta connection)
k = 3 for two resistors ("V" connection)

By applying the formula to the most usual cases it is obtained:



U_N = 230 V	400 V	500 V
$R \leq \frac{122.7}{C}$	$R \leq \frac{89.08}{C}$	$R \leq \frac{80.22}{C}$



U_N = 230 V	400 V	500 V
$R \leq \frac{40.90}{C}$	$R \leq \frac{29.69}{C}$	$R \leq \frac{26.74}{C}$

Example: calculation of the resistor for a capacitor of Q = 50 kvar and U_N = 400 V 50 Hz

$$Q = 3 * \omega * C * U_N^2 \longrightarrow C = \frac{50000}{3*2*3{,}14*50*400^2} = 332\mu F$$

Value of the resistor will be given by:

$$R \leq \frac{89.08}{C} = \frac{89.08}{332} = 0{,}268\ M\Omega \qquad (268k\Omega)$$

Power of the resistors is calculated taking into account that capacitors can work with overvoltage of since up to the 10% of their rated value:

$$P = \frac{(1.1 * U_N)^2}{R} = \frac{(1.1 * 400)^2}{268000} = 0.72\ W$$

Comparison between IEC 831 and the old IEC 70 Standards

IEC 70 Standard, nowadays cancelled by the IEC, established discharge values of 50 V after one minute of disconnection. These requirements imply different discharge resistor values than those of nowadays. By applying t = 60 s and U_R = 50 V to the previous formula it is obtained:

U_N = 230 V	400 V	500 V
$R \leq \frac{32.04}{C}$	$R \leq \frac{24.73}{C}$	$R \leq \frac{22.65}{C}$

U_N = 230 V	400 V	500 V
$R \leq \frac{10.68}{C}$	$R \leq \frac{8.24}{C}$	$R \leq \frac{7.55}{C}$

By repeating the calculation for the 50 kvar 400 V capacitor, value of the resistor would be:

$$R \leq \frac{24.73}{C} = \frac{24.73}{332} = 0.0745\ M\Omega \qquad (74.5\ k\Omega)$$

And the dissipated voltage:

$$P = \frac{(1.1 * U_N)^2}{R} = \frac{(1.1 * 400)^2}{74500} = 2.6\ W$$

This value implies a dissipation heat considerably higher to the one get according to the present Standard, what can involve several problems. Let's take as example an equipment composed by 12 capacitors of 50 kvar 400 V and let's see some working parameters related to resistors:

CHARACTERISTIC	R (IEC 70)	R (IEC 831)	REMARKS
Resistor	74.5 kΩ	268 kΩ	
Power dissipated by the resistors	93.6 W	25.9 W	68 W of losses more in R (IEC 70): Higher working temperature for the whole equipment: regulator, contactors, fuses, capacitors, etc.
Surface temperature of the resistors	137 ºC	78 ºC	Very high working temperature in R (IEC 70): higher risk for workers and higher possibility of failures in the resistors
Energy consumed by the resistors (per year)	819 kWh	227 kWh	Almost four more times active energy consumption

Attention: Discharge resistors mentioned in this document have as objective to protect people from possible electrical discharges. Nevertheless, these resistors **do not guarantee** an enough fast discharge in the case of Automatic capacitor banks (see **TS 03-011I Fast discharge resistors**).