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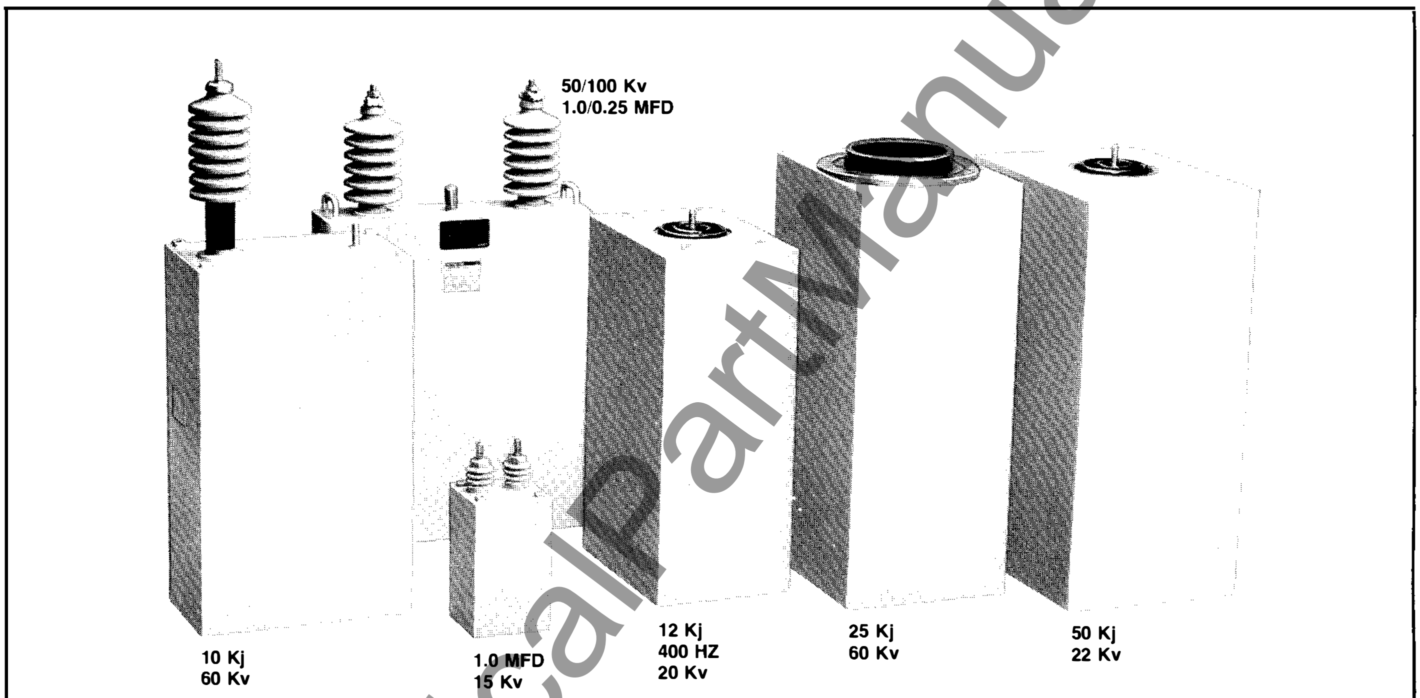
Energy Storage Capacitors

WEMCOL Dielectric Fluid



Energy Storage Capacitors

Application

Although all power capacitors are energy storage devices, it is common to attach this definition to a specific application where capacitors are used as a large energy source. "Energy Storage" capacitors store electrical energy obtained from a relatively small source and release it on demand in a large impulse. Capacitors offer the best source of energy when fast discharge is a requirement.

Industry and government agencies and laboratories have made use of energy storage capacitors in many different applications such as lasers, pulse-forming networks, high frequency discharge, plasma arc research, surge generators, etc. Activities in new research and development have greatly increased, with the emphasis on much higher energy density capabilities.

Specification

Energy Storage capacitor specifications for an intended application should consider all of the following areas:

Total Energy
The energy available for discharge is expressed in joules, and is calculated as:

$$\text{joules (watt-seconds)} = \frac{CV^2}{2}$$

C = capacitance (farads)
V = peak dc charging voltage (volts)

Rated Voltage and Voltage vs Time
The charging time and nature of the charging voltage is usually of long duration when compared with the rapid discharge required when the energy of the capacitors is released.

The magnitude of the voltage applied to the capacitors has a direct relationship to the total energy of the capacitors as shown above (½ CV^2).

Peak Current During Charging/Discharging

C = capacitance (farads)
f_r = circuit ringing frequency (Hz)
L = inductance (henries)
R = resistance (ohms)
V = voltage (volts)
I = current (amps)
i = instantaneous current (amps)
t = time (seconds)

The instantaneous value of current in an oscillatory circuit is calculated as follows:

$$i = 2\pi fCVe^{-Rt/2L} \sin 2\pi ft$$

$2\pi fCV$ = undamped peak current
$e^{-Rt/2L}$ = damping factor (δ)
$\sin 2\pi ft$ = oscillatory function

The peak discharge current occurs at 1/4 the period of the circuit ringing frequency. At peak current the oscillatory function is unity, and the expression for peak current is:

$$I\text{ peak} = 2\pi fCVe^{-R/8Lf}$$

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In under-damped circuits, where $1/LC >> R^2/4L^2$, the expression for peak current is:

$$I\ peak = 2\pi\ CV = V\sqrt{C/L}$$

In over-damped circuits, where $R^2/4L^2 > 1/LC$, the expression for current vs time is:

$$i = \frac{V}{L\sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}} e^{-Rt/2L} \sinh\left(\sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}\right)$$

and the time to peak current is expressed as:

$$t_p = \frac{1}{\sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}} \tanh^{-1}\left(\frac{2L}{R}\sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}\right)$$

Note: Angles are in rads.

Duty Cycle
The application dictates how fast the stored energy of the capacitors is discharged and how often the "charge-discharge" cycle will be repeated.

Ambient Conditions
Consideration must be given to ambient conditions when applying energy storage capacitors, including the following:

a. temperature range
b. vibration and shock
c. safety code requirements
d. dimensional restrictions

Other
Various other factors which affect the useful life and the internal construction may also be considered.

a. % failure rate after X hours of operation
b. capacitance tolerance (±10% standard)
c. internal inductance

Capabilities

Westinghouse is one of the largest manufacturers of power capacitors for the electric utility industry in the world, with over 60 years as a technological leader in developing more reliable, lighter, smaller capacitors. These innovations include the first ultrasonic partial discharge detector for production testing; the first 500 Kv shunt capacitor bank; extended-foil, all-film power capacitors; and designed, manufactured, and tested large capacitor energy storage/protection systems for the Tokamak TFTR.

The Westinghouse manufacturing know-how and technical expertise provide the basis for the continued development of energy storage capacitor systems. Present capabilities include the following:

- **Total Energy** — up to 50 Kilojoules
- **Voltage** — up to 100 Kv DC
- **Capacitance** — 200 + microfarads
- **Peak Current** — 250 KA
- **% Reversal (Voltage)** — 90 + %
- **Repetition Rates** — 400 HZ
- **Inductance** — as low as 40 nanohenries
- **Physical Size** — as large as 12 x 16 x 27 inches

Facilities

The Westinghouse Capacitor Dept. is part of the Transmission and Distribution Components Division, a 434,000 sq. ft. manufacturing facility located in Bloomington, Indiana.

Capacitor sections are wound on automatic computer-controlled winding machines in a clean room environment controlled for temperature, pressure, humidity, and dust.

Quality control procedures and tests occur before and during the manufacturing cycle including:

- Extensive testing on every shipment of film, foil, and fluid on receipt
- Testing every capacitor winding for capacitance and dielectric strength before assembly
- Testing every winding assembly for resistance, capacitance, and dielectric strength before inserting into the case
- Preliminary leak testing of every capacitor before fluid impregnation cycle
- Final testing of every capacitor

The Westinghouse facility in Bloomington also includes engineering and test labs in general mechanical and electrical, high voltage (800 kilovolt surge generator), high current (150 KA), high power (30 MVA), ceramics, materials, capacitor impregnation and test, RIV measurement, and a model shop.

In addition, the Capacitor Dept. has access to the facilities, personnel, and resources of the Westinghouse Corporate Research and Development Center in Pittsburgh, PA. The staff of the center includes 1700, 40% of which are scientists and engineers.

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