CHAPTER 13

POWER CAPACITORS

Section I-CONSIDERATIONS

13-1. Description of power capacitors.

Power capacitors for use on electrical distribution systems provide a static source of leading reactive current. Power capacitors normally consist of aluminum foil, paper, or film-insulated cells immersed in a biodegradable insulating fluid and sealed in a metallic container. Depending on size and rating, they are available as either single- or three-phase units. Power capacitors are rated for a fundamental frequency, voltage, and kilovar (kilovoltamperes-reactive) capacity and are generally available in voltage ratings up to 34,500 volts and 200 kilovar. Individual units may be connected in series and multiples to provide banks of various capacities and voltage ratings.

13-2. Types of power capacitors.

The terms "series capacitor" and "shunt capacitor" are used to identify the type of connection and do not indicate a difference in the power capacitor construction.

a. Series power capacitors. Series power capacitors are primarily used for voltage regulation and receive very limited application in electrical distribution systems. In the usual application for power service, the series-capacitor kilovar rating is too low to improve the power factor significantly.

b. Shunt power capacitors. The shunt power capacitor is a capacitive reactance in shunt with the electrical load or system and is fundamentally provided for power-factor improvement. The benefits of improved voltage level, released system capacity, reduced system losses, and the reduction in the power bill all stem from the improvement in power factor.

13-3. Application of power capacitors.

Shunt capacitors are used on distribution circuits to reduce the kilovoltampere load on a low power factor circuit. Fixed shunt capacitors are used to improve the voltage level and switched shunt capacitors are used to improve voltage regulation. Capacitor installations will generally be connected grounded wye because of undesirable effects of other connections. All capacitor banks should be equipped with a means to disconnect them from the electric system. Some systems utilize ungrounded connections to minimize interference and because this connection is considered easy to fuse.

13-4. Permissible power capacitor dielectrics.

Capacitors containing polychlorinated biphenyl (PCB) should have been disposed of under the procedures of the Environmental Protection Agency to implement the Toxic Substances Control Act of 1976. If not disposed of, they should have been marked as containing PCB's. ANSI/IEEE 18 now requires an impregnant identification visible from the ground with a glue color used to designate a nonPCB liquid.

Section II-MAINTENANCE AND INSPECTION

13-5. Ensuring safe capacitor deenergizing.

Capacitors retain a charge after they are deenergized. After capacitors are deenergized allow at least 5 minutes for discharge and then short the capacitor terminals to ground and to each other. These grounding provisions should remain until work on the installation is completed. Although most power capacitors have a discharge resistor installed to automatically discharge them after they are disconnected from the circuit, it is not advisable to depend entirely on such resistors for safety.

13-6. Power capacitor inspection schedule.

The initial inspection should be made within 24 hours after energizing a new capacitor installation. This inspection should be made at a time of maximum circuit voltage, usually during the first period of light load on the circuit. In addition to visual observations, this inspection should include voltage and current readings to ensure that voltages and currents do not exceed capacitor rating limits. Operating kilovars (the sum of the fundamental frequency kilovars and any harmonic frequency kilovars) should not exceed 135 percent of the capacitor rating. Routine maintenance and inspection should be accomplished at least four times per year.

13-7. Ventilation of power capacitors.

Power capacitors are very efficient but do generate some heat which must be adequately ventilated. Make sure that airflow around the individual capacitor units is not obstructed. Be especially careful in checking vertical capacitor banks, where heated air around the lower units rises to the top rows.

Improperly ventilated housings on such installations may result in excessive operating temperatures.

13-8. Temperature influence on power capacitors.

Modern power capacitors are designed for operation at a maximum ambient temperature as given in table 13-1 (which occurs at rated voltage and frequency and while subjected to the direct rays of the sun). Conditions resulting higher operating temperatures may injure the insulation and should be avoided. Capacitors are designed for continuous operation at a maximum ambient temperature of 40 degrees C. Capacitors that are normally deenergized, or operate intermittently at or below an ambient temperature of minus 20 degrees C, should be carefully inspected. At extremely low temperatures liquid insulation can crystallize which decreases insulation strength and failure may occur when the capacitor is re-energized. For installations where low temperature is a problem, units should be kept energized.

13-9. Exposure influence on power capacitors.

Care should be taken to eliminate or minimize exposure of capacitors to damaging fumes or vapors, salt air, unusual dampness, contamination, abnormal shock, or vibration. Corroded or rusted capacitor cases and mountings should be cleaned and painted. Capacitor bushings and busbar supports, subject to accumulation of dust or foreign materials, should be cleaned periodically. The intervals will depend on the severity of the condition.

13-10. Voltage influence on power capacitors.

Shunt capacitors cause a voltage rise at the point where they are located and are likely to operate at overvoltages. Capacitors are designed to operate continuously up to 110 percent of rated voltage rms; provided that the crest voltage, including all harmonics, does not exceed 1.2 times the square root of 2 times the rated rms voltage; and provided that the 135 percent maximum permissible rated kilovars has not been exceeded. Since operation in excess of voltage and temperature limits may shorten the life of a capacitor, the voltage should be checked periodically to ensure that it is within design limitations.

13-11. Fuses for power capacitors.

A capacitor fuse is not used for overload protection in the same manner as a fuse is used for overload protection of other electric apparatus. The current rating has to allow for inrush current, and capacitor fuse ratings typically range from 165 to 250 percent of the capacitor current rating. Fuse ratings should always be those recommended by the manufacturer, since the fuse's time-current characteristic must be matched to the capacitor's tank-rupture time-current characteristic. The blowing of a properly-rated fuse may indicate a capacitor fault, as well as a circuit overcurrent operating condition. When inspection reveals blown fuses, do not replace such fuses until a check determines that the capacitor unit is still serviceable. When fuses are replaced, be sure they are of proper voltage and current ratings and in compliance with the capacitor manufacturer's recommendations.

Table 13-1. Maximum ambient temperatures for continuous operation[1,2]

Mounting arrangement	Ambient air temperature in degrees C: 24 hour aver-	Normal annual[4]
Isolated capacitor	46	 35
Single row of capacitors	40	 25
Multiple rows and tiers of capacitors	35	20
Metal enclosed or housed equipments	35	 20

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[2]For switched or continuous operation in outdoor locations with unrestricted ventilation and direct sunlight.
[3]The 24-hour arithmetic average of hourly readings during the hottest day expected at that location.
[4]As defined in the reports of the US Weather Bureau.

Section III-TESTS

13-12. Field tests for power capacitors.

Field tests differ depending on whether a power capacitor is being put into service or whether it is being checked after it has been in service. Switched capacitor banks must be checked for correct switching operation.

a. Before service tests. Experience has shown that these tests may not be necessary on all capacitors. Tests consist of lo-second voltage applications not in excess of 75 percent of factory test voltages used for terminal-to-terminal tests. Factory terminal-to-terminal test voltages are applied for 10 seconds at 4.3 times rates voltage rms for dc input, and at twice rated voltage rms for ac input. If terminal-to-case tests are made, refer to the manufacturer's instructions or ANSI/IEEE 18 for ac test voltages.

b. After being in service tests. These tests are only necessary in determining the operating condition of a power capacitor after exposure to possible damage or other trouble indications. The dielectric strength may be measured by applying the same voltage as given for the before service test. The capacitance can be determined by applying a known voltage and frequency of a good wave shape. Short-circuited or open-circuited capacitors will be indicated by this test. Tests for terminal resistance and liquid tightness may also be desirable, as covered in later paragraphs.

c. Capacitor bank automatic switching. Switched capacitor banks should be inspected for proper operation every year. The maintenance schedule given in table 13-2 is based on the indicated types of on-off controls. For oil switches, open and close operations between maintenance periods should not exceed 2,500.

Table 13-2. Capacitor bank oil switch maintenance[1]

Type of control	Maintenance schedule, years
Time clock.	3
Voltage.	3
Dual temperature.	5
Temperature only.	8
Time clock and temperature ..	8

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13-13. Terminal tests of power capacitors.

Terminal tests may be those measuring resistance, as recommended by ANSI/IEEE 18, or may be handbook-recommended insulation or voltage tests.

a. ANSI/IEEE 18 resistance tests. Two-bushing capacitors can be tested to determine whether their insulation resistance (in reference to terminal-to-terminal or terminal-to-case) is in agreement with a value recommended by the manufacturer. When an internal discharge resistor is present, however, the reading obtained will be that of the discharge resistor. This is much lower than the dielectric resistance, which may also need to be obtained from the manufacturer. This testing will indicate whether the internal discharge resistor is operable. Remember, that the internal discharge device provided in a capacitor is not a substitute for the recommended practice of manually discharging the residual stored charge before working on a capacitor.

b. Handbook tests. These are not standard industry tests, but have been recommended by facility engineers as a method of determining the capacitor condition.

(1) *Terminal-to-terminal voltage test.* The purpose of this test is to determine whether a capacitor unit is functioning in accordance with its rating. Capacitor units found to be internally defective are more economically replaced than repaired.

(a) Procedure. With the capacitor unit insulated from ground, apply a terminal-to-terminal voltage equal to the rated capacitor voltage, in accordance with figure 13-l. Voltage should be applied for one minute with the test circuit fused. Fuse rating should be that recommended for the capacitor, or if that size is not readily available, one rated twice the normal load current. Measure the voltage and current. The ammeter should be provided with a short circuiting switch. The switch should be opened only after it has been determined that no short circuit exists.

(b) Interpretation. Blowing of the fuse indicates a short-circuited capacitor. Absence of current indicates an open-circuited capacitor. Good capacitors should have current readings of 100 to 115 percent of rated value, with the case and internal temperature at 25 degrees C. Current readings above 115 percent of rated current may indicate an internal short or the presence of harmonics in the test voltage. If waveform of the test voltage is suspect, the test should be repeated using an alternate source of electric power.

(2) *Terminal-to-case insulation test.* The purpose of this test is to determine the adequacy of the insulation to ground of a given capacitor unit. This test may be applied to two bushing, single-phase capacitor units, but not to capacitor units where the case is used as a terminal.

(a) Procedure. With the capacitor unit insulated from ground, apply a voltage equal to twice rated voltage between case and terminals (all terminals connected together) in accordance with figure 13-2. Voltage should be applied for one minute, with the test circuit fused and containing sufficient impedance to limit the current, should the capacitor under test be shorted.

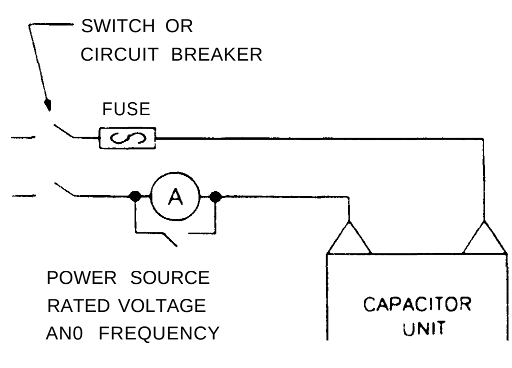

Figure 13-1. Terminal-to-terminal voltage test circuit.

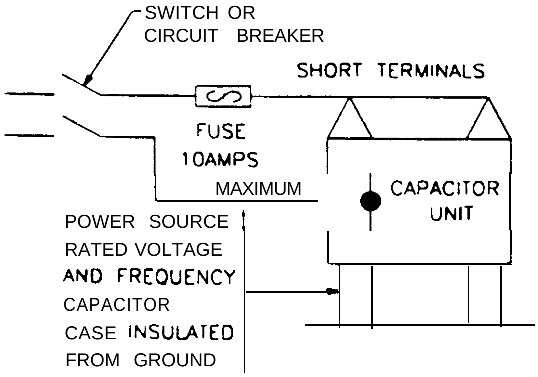

Figure 13-2. Terminal-to-case insulation test circuit

(b) *Interpretation.* Failure to pass this test indicates an internal flashover and the capacitor should be replaced.

13-14. Leak tests of power capacitors.

Capacitor cases do develop leaks. Since capacitor installations are normally made up of a number of individual units, it is sometimes difficult to ascertain the unit or units that are leaking.

a. Procedure. If the unit at fault cannot be found by visual inspection, the suspected capacitors should be removed; thoroughly cleaned; and placed in an oven for a minimum of *4* hours. The temperature of the capacitor case should not be allowed to exceed the manufacturer's recommendations.

b. Interpretation. Place the capacitors horizontally on a sheet of clean paper (brown wrapping paper is suggested) with the suspected point of leakage on the bottom. Leaky capacitors should be replaced.