Checking Capacitor Banks for Failed Capacitors

Introduction

This technical note provides background information on capacitance testing of medium voltage double bushing capacitors commonly used in capacitor banks and harmonic filter banks with rated line voltages greater than 2.4kV. Due to their relatively low capacitance (0.20uF to 100.00uF), testing of the capacitors can be done with many standard digital multi-meters (DMM's). Meters such as the Fluke 110, 170, and 180 series can provide the required data necessary to determine the presence of a failed capacitor. Although other test methods are available, such as live testing, this technical note is centered on testing capacitors in their de-energized state.

Medium Voltage Capacitors can be internally fused or externally fused. External fuse operation (as evidenced by a blown fuse indicator for current limiting fuses, or a "dropped out" fuse link for expulsion style fuses) may indicate a failed capacitor. The fuse operation, however, does not guarantee a failed capacitor as the fuse may have opened due to a faulty fuse or from surges due to lightning or switching operations. It is therefore recommended that externally fused capacitors be tested before replacement in situations where the external fuse has blown. For internally fused capacitors, testing is required as the fuse is not visible.

Test Procedure

The following test procedure requires the capacitor/harmonic filter bank to be grounded and disconnected. Normal high voltage disconnect, grounding, and test procedures should be followed and should only be conducted by individuals that are qualified in the operation and maintenance of medium and high voltage harmonic filter banks and capacitor banks. A suggested procedure, but not a necessarily all inclusive procedure is as follows:

1. De-energize the capacitor bank per the recommendations of the capacitor bank manufacturer. All necessary safety procedures should be followed.
2. Isolate the capacitor bank (i.e. provide a visible disconnect) from the medium or high voltage system.
3. Wait at least five minutes after de-energization before proceeding to the next step.
4. Ground the capacitor bank. It is important that each phase as well as the neutral (for ungrounded banks) be grounded. For banks equipped with vacuum switches, phase bus grounding should take place on the load side of the vacuum switches.

5. In addition to the phase bus grounding and before coming into contact with an individual capacitor, each capacitor should be individually grounded by touching its terminals with a grounded tip at the end of a high voltage stick.
6. Disconnect the line-side terminal of the capacitor to be tested. This may involve the removal of a fuse link for externally fused capacitors.
7. After bank grounding, proceed to the appropriate section below for the type of capacitor.

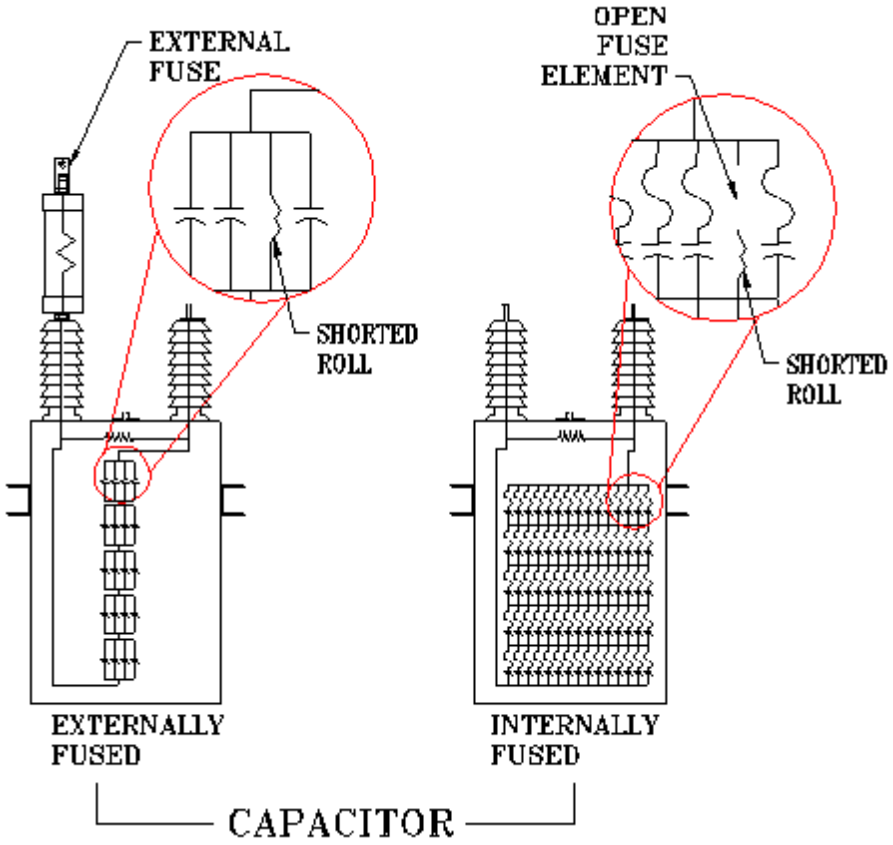

Figure 1 - Internal Construction of Externally Fused and Internally Fused Capacitors of Equal Ratings

Externally Fused and Fuseless Capacitor Bank Testing

IEEE Std. 18 (IEEE Standard for Shunt Power Capacitors) specifies the standard ratings of capacitors designed for shunt connection to alternating current transmission and distribution systems should have a capacitance rating of 0 to +10% of its nominal nameplate value. In reality, most manufactures produce capacitors in the 0 to +2% of its nominal nameplate rating. It is desirable to detect, remove, and replace open capacitors, shorted capacitors, and partially failed capacitors. Each of these conditions can be detected with a DMM as follows:

Shorted Capacitors - Typically the DMM will show over-load or -O.L- for a completely shorted capacitor.

Open Capacitors - Typically the DMM will show a "di.sc" or a very low capacitance reading (capacitance reading in the 0 to 1 nF).

Partially Failed Capacitors - Typically the DMM will show a capacitance reading that is more than 10% greater than the capacitors nominal value as shown in Table-1.

The values listed in Table-1 are for industry standard shunt capacitors. For double bushing capacitors not listed in Table-1, a program at the following web address can be used to calculate the nominal capacitance value based on nameplate data. http://www.nepsi.com/cap_calculation.htm

In almost all cases, capacitors utilized in externally fused capacitor banks and fuseless capacitor banks will fail in the partially failed condition or the shorted condition as noted above.

Internally Fused Capacitor Bank Testing

As with externally fused capacitors, IEEE Std. 18 specifies capacitance readings in the 0 to +10% range. In reality, internally fused capacitors will be in the 0 to +2% range. These capacitors will show signs of failure in the following three ways:

Shorted Capacitors - Typically the DMM will show over-load or -O.L- for a completely shorted capacitor.

Open Capacitors - Typically the DMM will show a "di.sc" or a very low capacitance reading (capacitance reading in the 0 to 1 nF).

Partially Failed Capacitors - Typically the DMM will show a capacitance reading that is less than the capacitors nominal value as shown in Table-1.

It should be noted that internally fused capacitors are composed of many parallel and series groups of smaller capacitors called "sections" or "rolls". Each roll is protected by a fuse element that opens upon roll failure (See Figure 1). Capacitor manufactures generally recommend capacitors be removed after the second roll failure. Detection of this failure can be difficult for the following reasons:

- The total capacitance loss for a single roll failure can be as little as 1.5%. A double roll failure can result in a 3% loss of capacitance.
- Capacitance over the capacitor operating temperature range can vary on the order of +/-2% (See Figure 2).
- DMM accuracy for capacitance readings is in the 1% to 2% range.
- Manufacturer tolerance is typically 1% to 2%, but can be higher.

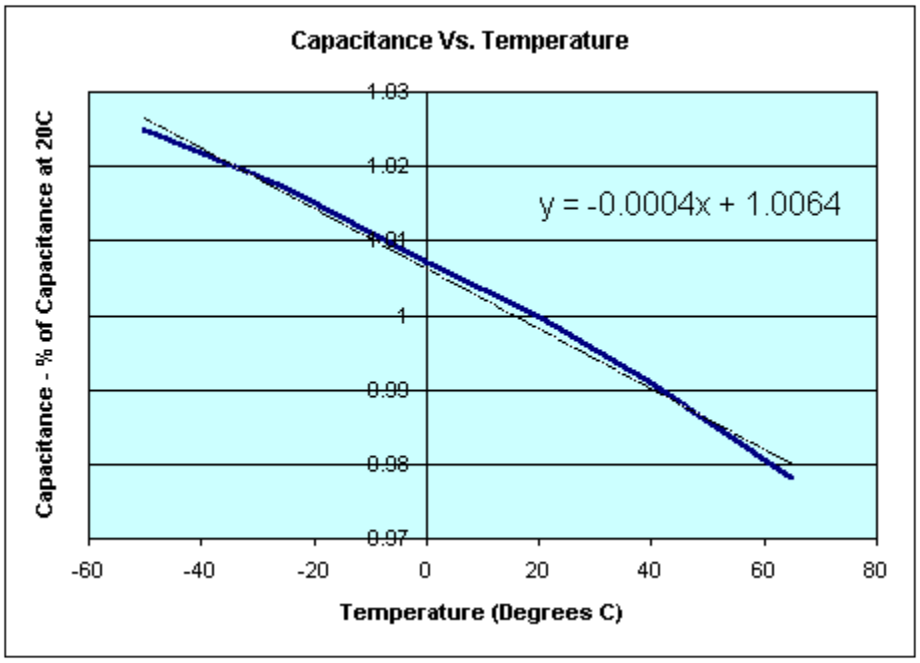

Figure 2 - Capacitance Vs. Temperature for Film-Foil Capacitors

Due to the above, accurate capacitance records are required to detect imminent capacitor failure when using internally fused capacitors.

Table 1 - Single Bushing Capacitor
Capacitance , Reactance and Current Rating Table

2400 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	2400	115.200	23.027	20.8
100	2400	57.600	46.053	41.7
150	2400	38.400	69.080	62.5
200	2400	28.800	92.106	83.3

2770 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	2770	153.458	17.286	18.1
100	2770	76.729	34.572	36.1
150	2770	51.153	51.858	54.2
200	2770	38.365	69.144	72.2
300	2770	25.576	103.715	108.3

4160 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	4160	346.112	7.664	12.0
100	4160	173.056	15.328	24.0
150	4160	115.371	22.993	36.1
200	4160	86.528	30.657	48.1
300	4160	57.685	45.985	72.1

4800 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	4800	460.800	5.757	10.4
100	4800	230.400	11.513	20.8
150	4800	153.600	17.270	31.3
200	4800	115.200	23.027	41.7
300	4800	76.800	34.540	62.5
400	4800	57.600	46.053	83.3

6640 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	6640	881.792	3.008	7.5
100	6640	440.896	6.017	15.1
150	6640	293.931	9.025	22.6
200	6640	220.448	12.033	30.1
300	6640	146.965	18.050	45.2
400	6640	110.224	24.066	60.2
500	6640	88.179	30.083	75.3
600	6640	73.483	36.099	90.4

Table 1 - Continued

7200 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	7200	1036.800	2.559	6.9
100	7200	518.400	5.117	13.9
150	7200	345.600	7.676	20.8
200	7200	259.200	10.234	27.8
300	7200	172.800	15.351	41.7
400	7200	129.600	20.468	55.6
500	7200	103.680	25.585	69.4
600	7200	86.400	30.702	83.3

7620 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	7620	1161.288	2.284	6.6
100	7620	580.644	4.568	13.1
150	7620	387.096	6.853	19.7
200	7620	290.322	9.137	26.2
300	7620	193.548	13.705	39.4
400	7620	145.161	18.274	52.5
500	7620	116.129	22.842	65.6
600	7620	96.774	27.411	78.7

7960 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	7960	1267.232	2.093	6.3
100	7960	633.616	4.187	12.6
150	7960	422.411	6.280	18.8
200	7960	316.808	8.373	25.1
300	7960	211.205	12.560	37.7
400	7960	158.404	16.746	50.3
500	7960	126.723	20.933	62.8
600	7960	105.603	25.119	75.4

8320 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	8320	1384.448	1.916	6.0
100	8320	692.224	3.832	12.0
150	8320	461.483	5.748	18.0
200	8320	346.112	7.664	24.0
300	8320	230.741	11.496	36.1
400	8320	173.056	15.328	48.1
500	8320	138.445	19.160	60.1
600	8320	115.371	22.993	72.1

Table 1 - Continued

9540 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	9540	1820.232	1.457	5.2
100	9540	910.116	2.915	10.5
150	9540	606.744	4.372	15.7
200	9540	455.058	5.829	21.0
300	9540	303.372	8.744	31.4
400	9540	227.529	11.659	41.9
500	9540	182.023	14.573	52.4
600	9540	151.686	17.488	62.9

9960 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	9960	1984.032	1.337	5.0
100	9960	992.016	2.674	10.0
150	9960	661.344	4.011	15.1
200	9960	496.008	5.348	20.1
300	9960	330.672	8.022	30.1
400	9960	248.004	10.696	40.2
500	9960	198.403	13.370	50.2
600	9960	165.336	16.044	60.2

11400 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	11400	2599.200	1.021	4.4
100	11400	1299.600	2.041	8.8
150	11400	866.400	3.062	13.2
200	11400	649.800	4.082	17.5
300	11400	433.200	6.123	26.3
400	11400	324.900	8.165	35.1
500	11400	259.920	10.206	43.9
600	11400	216.600	12.247	52.6

15125 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	15125	4575.313	0.580	3.3
100	15125	2287.656	1.160	6.6
150	15125	1525.104	1.739	9.9
200	15125	1143.828	2.319	13.2
300	15125	762.552	3.479	19.8
400	15125	571.914	4.638	26.4
500	15125	457.531	5.798	33.1
600	15125	381.276	6.957	39.7

Table 1 - Continued

19920 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	19920	7936.128	0.334	2.5
100	19920	3968.064	0.669	5.0
150	19920	2645.376	1.003	7.5
200	19920	1984.032	1.337	10.0
300	19920	1322.688	2.006	15.1
400	19920	992.016	2.674	20.1
500	19920	793.613	3.343	25.1
600	19920	661.344	4.011	30.1

20800 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	20800	8652.800	0.307	2.4
100	20800	4326.400	0.613	4.8
150	20800	2884.267	0.920	7.2
200	20800	2163.200	1.226	9.6
300	20800	1442.133	1.839	14.4
400	20800	1081.600	2.453	19.2
500	20800	865.280	3.066	24.0
600	20800	721.067	3.679	28.8

21600 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	21600	9331.200	0.284	2.3
100	21600	4665.600	0.569	4.6
150	21600	3110.400	0.853	6.9
200	21600	2332.800	1.137	9.3
300	21600	1555.200	1.706	13.9
400	21600	1166.400	2.274	18.5
500	21600	933.120	2.843	23.1
600	21600	777.600	3.411	27.8

22130 Volt Capacitors

KVAR	Voltage (Volts)	Reactance (Ohms)	Capacitance (uF)	Rated Amps
50	22130	9794.738	0.271	2.3
100	22130	4897.369	0.542	4.5
150	22130	3264.913	0.812	6.8
200	22130	2448.685	1.083	9.0
300	22130	1632.456	1.625	13.6
400	22130	1224.342	2.167	18.1
500	22130	979.474	2.708	22.6
600	22130	816.228	3.250	27.1

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