Low Voltage Network Quality

ABB

Low Voltage Network Quality
Power factor correction
Harmonic flickering
Dynamic flicker compensation

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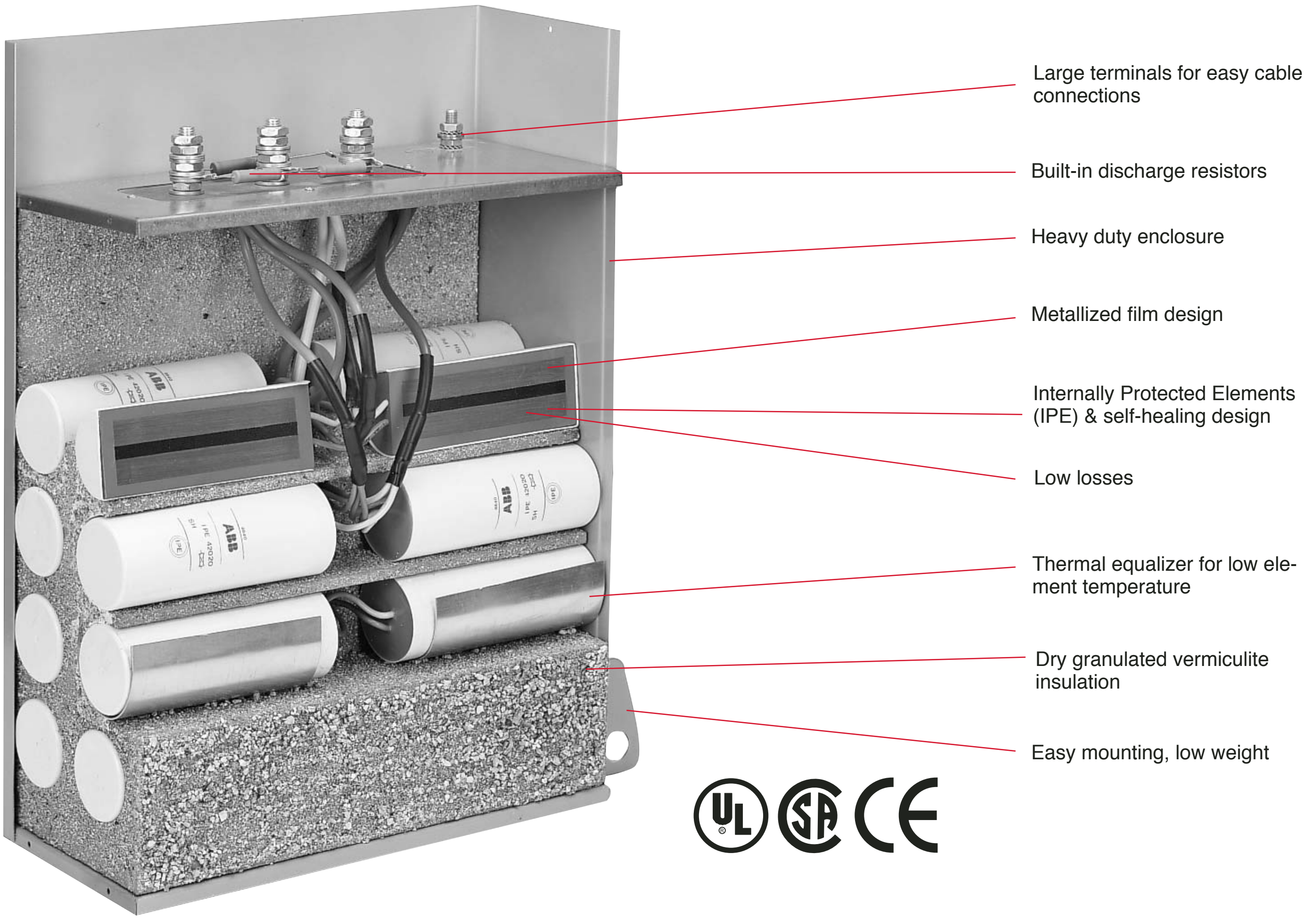
General information
General description & capacitor construction



Principal Components of a 3-Phase Capacitor

The principal components of a 3-phase ABB capacitor include:

1. Sequential Protection System:

• Self-Healing Capacitor Elements
One or more self-healing capacitor elements are installed for each phase. These elements are connected in Y or Δ. In case of dielectric breakdown, the fault is cleared by evaporation of the metalized layer around the breakdown with negligible loss of capacitance and continued operation of the capacitor!

• Internally Protected Elements
A unique Sequential Protection System including the IPE design (IPE - internally protected elements) ensures that each individual element can be disconnected from the circuit at the end of the element's life.

• Nonflammable Dry Vermiculite Filler
Vermiculite is a dry, granular insulating material that is solid, inert and fire proof. This material fills all open spaces in the enclosure to isolate the capacitor elements and exclude free oxygen.

2. Discharge Resistors
Discharge resistors (one for each phase) are sized to ensure safe discharge of the capacitor to less than 50 volts in one minute or less as required by the NEC.

3. Terminal Studs
Large terminal studs are located inside the enclosure at the top of the capacitor for quick and easy cable connections.

4. Enclosure
All ABB enclosures are made of welded heavy gauge steel. Available enclosure types include Indoor NEMA 1, Outdoor Raintight, and Indoor Dusttight. (RAL 7035, Light Gray)

What is a Metallized-Film Element?

Metallized-film is a microscopically thin layer of conducting material (called an electrode), usually aluminum or zinc on an underlying layer of insulating film. The electrod thickness averages only .01 microns while insulating (polypropylene) film ranges from 5 to 10 microns in thickness depending upon the design voltage of the capacitor (the higher the voltage rating, the thicker the insulating film).

Advantages of Metallized-Film Elements

There are two electrode layers separated by one layer of insulating film. Thousands of these layers are tightly wound around a core in such a manner that the edge of one electrode is exposed on one side of the element and the edge of the other electrode is exposed on the other side of the element. See Fig. 1 & 2.

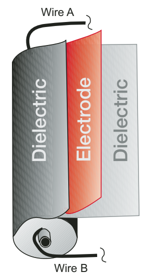


Fig. 1

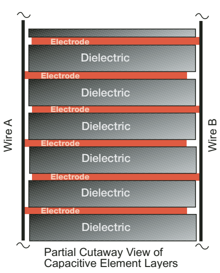


Fig.2

Wires are then connected to each side of the element. The element is enclosed in a container and then filled with a hardening protective sealant.

General information
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1. Self-Healing Design
Self-healing refers to a process where a short circuit between electrodes vaporizes the electrode around the fault (see Fig. 14) until the fault is eliminated. The element continues to function with negligible loss of performance (see Fig. 15*).*

2. Low Internal Losses
Due to the high dielectric efficiency of the metallized-film, the internal losses are extremely low. ABB metallized-film design losses are limited to .5 watts per kvar including the losses across the discharge resistors.

3. Small Element Size
Due to the thin electrode and dielectric, metallized-film elements are small and compact in size resulting in smaller, more powerful capacitors.

The capacitance of any element design is inversely proportional to the separation between electrodes. In other words, if the separation between conducting surfaces is cut in half, the effective capacitance is doubled in addition to reducing the physical size of the element by half.

More About Self Healing Elements

“Self-healing” is a characteristic which is unique to metallized electrode capacitors. All capacitor normally experience insulation breakdown as a result of the accumulated effect of temperature, voltage stress, impurities in the insulating medium, etc. When this happens in a non-"metallized" design,

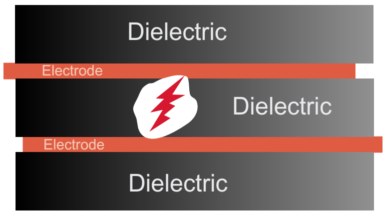

Fig. 3. Two electrodes short circuit through a fault in a dielectric layer.

the electrodes are short-circuited and the capacitor ceases its production of reactive power. In an ABB metallized-film unit, however, these individual insulation breakdowns do not mean the shutdown of the capacitor. The faults self-heal themselves and the capacitor continues operation.

The conducting electrode is very thin; when a short circuit develops as a result of a fault in the insulating dielectric, the thin electrode vaporizes around the area of the fault. This vaporization continues until sufficient separation exists between the faulted electrodes to overcome the voltage level. Fig. 15 illustrates the process of self-healing.

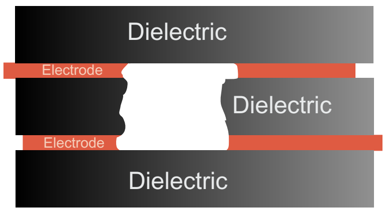

Fig. 4 illustrates "self-healing". The electrode layers in the area where they were short circuiting have been vaporized, thereby eliminating the short circuit.

The entire process of self-healing takes "microseconds" and the amount of electrode which is lost is negligible in comparison to the total surface area of the element. The result is the metallized-film unit may self-heal hundreds of times during its long life and still retain virtually all of its rated capacitance.

The IPE Sequential Protection System

ABB ’s metallized-film self healing capacitor elements will have a longer life than their conventional foil design counterparts for the above reason. However, accumulated effects of time, temperature, voltage stress, etc., eventually effect capacitor life.

ABB's sequential protection system featuring patented Internally Protected Elements (IPE) design provides increased protection to facilities and personnel not available from other capacitor designs. This proven design allows for self-healing throughout the life of the capacitor to insure the maximum length of reliable service and still provide short circuit protection in each element when self-healing can no longer continue. This is accomplished by a combination of unique winding construction and an internal fuse link (See Fig. 5) within each element which

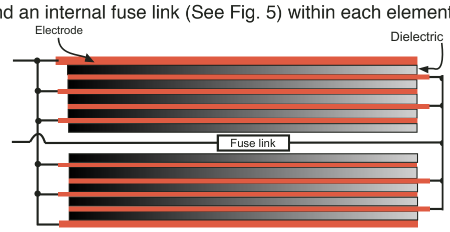

Fig. 5

safely and selectively disconnects each individual element. ABB capacitors do not rely on mechanical pressure interrupters and additional line fuses have disadvantages associated with that kind of construction.

What are Discharge Resistors?

As all the capacitor elements store electrical power like a battery, the capacitor will maintain a near full charge even when not energized. As this is a potentially dangerous condition to unsuspecting plant personnel that might be inspecting the capacitor terminals and wiring, discharge resistors are connected between all of the terminals. When the capacitor is shut off, these discharge resistors drain the capacitor elements of their stored electrical charge. It is recommended, however, that capacitor terminals should ALWAYS be short-circuited before touching the terminals.

What is the Significance of Dry Type Design?

ABB low voltage capacitors contain no free liquids and are filled with a unique nonflammable granular material called vermiculite. Environmental and personnel concerns associated with leakage or flammability of conventional oil-filled units are eliminated; and kvar for kvar, vermiculite filled units weigh 30% to 60% less than their oil filled counterparts.

Vermiculite is routinely used in the United States as an insulating material in the walls and ceilings of new buildings. Its properties have been extensively documented and recognized as an ideal material for safety and environmental considerations.

General information
Options for correcting power factor

Options for Correcting Power Factor

There are three primary methods of correcting power factor:

• Individual Capacitor Units - One capacitor unit for each inductive load.

• Banks of Capacitor Units - Large Capacitor System connected to the line at some central point in the distribution system.

• Combination of Above - Where individual capacitors are installed on the larger inductive loads and banks are installed on main feeders or switchboards, etc.

Individual Capacitor Units

Power factor correction is best achieved with individual capacitor units located directly at the inductive load (in most cases a motor). This has many of the advantages of capacitor bank installations including some advantages capacitor bank installations cannot offer.

Advantages of individual capacitor units:

• Increased Distribution System Capacity - Only individual capacitor units can improve power consumption efficiency throughout the entire distribution system all the way to the load! Therefore, where wiring is being overloaded by induction motors, increased system capacity can be obtained by reducing the load and adding individual power factor correction units.

• Stabilized Voltage Levels - Voltage drops to individual inductive load are reduced thereby decreasing heat damage caused by excessive currents.

• Lower Losses - When individual capacitor units are installed directly at the terminals of an inductive load such as a motor or transformer, the line losses are reduced.

• Capacitor & Load Can Be Switched ON/OFF Together This ensures that the motor cannot operate without the capacitor; and also ensures that the capacitor only operates when needed.

Fixed and Automatic Capacitor Banks

Group installation of capacitors is achieved in two ways:

• Fixed Capacitor Banks - Individual capacitors racked in a common enclosure with no switching or stepping capability.

• Automatic Capacitor Banks - Individual capacitors racked in a common enclosure with switching capability. The capacitors are turned on and off by a micro-processor based controller. The controller also provides network data and alarm conditions to the user. Network data consists of power factor, volts, amps and harmonic distortion.

Advantages of fixed or automatic bank systems

• More Economical - Capacitor banks are more economical than individual capacitor units when the main reason for power factor correction is to reduce utility power bills and/or reduce the current in primary feeders from a main generator or transformer. Large banks or racks of capacitors are installed at the main switchboard or at the substation thereby increasing power factor and obtaining the advantages of lower power consumption.

• Lower Installation Costs - The cost of installing one fixed or automatic capacitor bank unit will be less than installing a number of individual capacitors at inductive loads.

• Switching - Automatic capacitor banks can switch all or part of the capacitance automatically depending on load requirements. This way, only as much power factor correction as needed for the given load is provided. (This switching capability is a primary advantage over fixed capacitor banks where over-capacitance, leading power factor and resulting overvoltages can occur should the load decrease.)

• Monitoring - Automatic capacitor bank controllers provide network data and alarm conditions to the user. Network data consists of power factor, volts, amps and harmonic distortions.

General information
Sizing capacitors at the motor load

Sizing Capacitors at the Motor Load

When the determination is made that power factor correction capacitors ARE a good investment for a particular electrical system, you need to know:

- How many capacitors are needed?
- What sizes are appropriate?

The capacitor provides a local source of reactive current. With respect to inductive motor load, this reactive power is the magnetizing or “no-load current“ which the motor requires to operate.

A capacitor is properly sized when its full load current rating is 90% of the no-load current of the motor. This 90% rating avoids overcorrection and the accompanying problems such as overvoltages.

One Selection Method:Using Formulas

If no-load current is known . . .

The most accurate method of selecting a capacitor is to take the no-load current of the motor, and multiply by .90 (90%). Take this resulting figure, turn to the appropriate catalog page, and determine which kvar size is needed, catalog number, enclosure type, and price.

EXAMPLE: Size a capacitor for a 100hp, 460V 3-phase motor which has a full load current of 124 amps and a no-load current of 37 amps.

1. Multiply the no-load current figure of 37 amps by 90%.

37 no load amps X 90% = 33 no load amps

2. Turning to the catalog page for 480 volt, 3-phase capacitors, find the closest amp rating to, but NOT OVER 33 amps. See Table 1, sample catalog pricing chart. Per the sample chart the closest amperage is 32.5 amps. The proper capacitor unit, then is 27 kvar and the appropriate catalog number depends on the type enclosure desired.

NOTE: The formula method corrects power factor to approximately .95

If the no load current is not known . . .

If the no-load current is unknown, a reasonable estimate for 3-phase motors is to take the full load amps and multiply by 30%. Then take that figure and multiply times the 90% rating figure being used to avoid overcorrection and overvoltages.
EXAMPLE: Size a capacitor for a 75hp, 460V 3-phase motor which has a full load current of 92 amps and an unknown no-load current.

1. First, find the no-load current by multiplying the full load current times 30%.
   92 (full load amps) X 30% = 28 estimated no-load amps
2. Multiply 28 no-load amps by 90%.
   28 no-load amps X 90% = 25 no-load amps
3. Now examine the capacitor pricing and selection chart for 480 volt, 3-phase capacitors. Refer again to Table 1. Here it will be seen that the closest capacitor to 25 amps full load current without going over is a 20 kvar unit, rated at 24.1 amps.
4. The correct selection, then, is 20 kvar!

TABLE 1
480 VOLT, 60 Hz., 3-Phase

Enclosure Size	kvar Rating	Rated Current Per Phase	Approx. Shipping Weight (Lbs.)	Indoor – Nema 1 Catalog Number	Outdoor – Nema 3 Catalog Number	Indoor – Nema 12 Catalog Number
	1.5	1.8	8	C44G1.5	C44R1.5	C44D1.5
	2	2.4	8	C44G2	C44R2	C44D2
	2.5	3.0	8	C44G2.5	C44R2.5	C44D2.5
	3	3.6	8	C44[illegible]	C44R3	C44D3
	[illegible]	4.2			C44R3.5	
	20	24.1	13	C44G20	C44R20	C44D20
	22.5	27.1	13	C44G22.5	C44R22.5	C44D22.5
	24	28.9	13	C44G24	C44R24	C44D24
	25	30.1	13	C44G25	C44R25	C44D25
	27	32.5	13	C44G27	C44R25	C44D27
	30	36.1	13	C44G30	C44R30	C44D30
	32.5	36.1	13	C44G32.5	C44R[illegible]	C44D32.5
	35	42.1	22	C44G35		
	37.5	45.1	[illegible]	C44G37.5		

General information
Sizing capacitors at the motor load
Using charts

An Alternate Selection Method — Using Charts

TABLE 2: Suggested Maximum Capacitor Ratings for T-Frame NEMA Class B Motors

Induction motor rating (HP)	NOMINAL MOTOR SPEED 3600 R/MIN Capacitor rating (kvar)	3600 R/MIN Line current reduction (%)	1800 R/MIN Capacitor rating (kvar)	1800 R/MIN Line current reductions (%)	1200 R/MIN Capacitor rating (kvar)	1200 R/MIN Line current reduction (%)	900 R/MIN Capacitor rating (kvar)	900 R/MIN Line current reduction (%)	720 R/MIN Capacitor rating (kvar)	720 R/MIN Line current reduction (%)	600 R/MIN Capacitor rating (kvar)	600 R/MIN Line current reduction (%)
3	1.5	14	1.5	23	2.5	28	3	38	3	40	4	40
5	2	14	2.5	22	3	26	4	31	4	40	5	40
7.5	2.5	14	3	20	4	21	5	28	5	38	6	45
10	4	14	4	18	5	21	6	27	7.5	36	8	38
15	5	12	5	18	6	20	7.5	24	8	32	10	34
20	6	12	6	17	7.5	19	9	23	12	25	18	30
25	7.5	12	7.5	17	8	19	10	23	12	25	18	30
30	8	11	8	16	10	19	14	22	15	24	22.5	30
40	12	12	13	15	16	19	18	21	22.5	24	25	30
50	15	12	18	15	20	19	22.5	21	24	24	30	30
60	18	12	21	14	22.5	17	26	20	30	22	35	28
75	20	12	23	14	25	15	28	17	33	14	40	19
100	22.5	11	30	14	30	12	35	16	40	15	45	17
125	25	10	36	12	35	12	42	14	45	15	50	17
150	30	10	42	12	40	12	52.5	14	52.5	14	60	17
200	35	10	50	11	50	10	65	13	68	13	90	17
250	40	11	60	10	62.5	10	82	13	87.5	13	100	17
300	45	11	68	10	75	12	100	14	100	13	120	17
350	50	12	75	8	90	12	120	13	120	13	135	15
400	75	10	80	8	100	12	130	13	140	13	150	15
450	80	8	90	8	120	10	140	12	160	14	160	15
500	100	8	120	9	150	12	160	12	180	13	180	15

Applies to three-phase, 60Hz motors when switched with capacitors as a single unit.

Another method of selecting the proper capacitor employs the use of only a selection chart shown in Table 2 or 3. These tables take other variables such as motor RPM into consideration in making recommendations for capacitor applications. They are convenient because they only require that the user know the horsepower and RPM of the motor. Both tables estimate the percentage reduction in full load current drawn by the motor as a result of the capacitor's installation.

WARNING!

Never oversize capacitors or exceed 1.0 power factor or resulting problems with the motor can occur!!

If calculations or a kvar determination chart indicate a kvar rating not found in a pricing and selection chart, always refer to the next lower kvar rating!

EXAMPLE: A manufacturer needs to determine the proper capacitors required for a 1200 RPM, 75HP T-Frame NEMA class B motor.
1. First find 75 in the horsepower column of the chart.
2. Locate the 1200 RPM capacitor rating (kvar) column. Note the figure of 25 kvar.
3. Now refer to the appropriate pricing and selection chart Table 1, page 19.5. The appropriate kvar rating is 25 kvar. Depending on the desired enclosure, the price and catalog number can then be easily determined.

NOTE

Using the above charts for selecting capacitors will correct power factor to approximately .95.

TABLE 3: Suggested Maximum Capacitor Ratings for U-Frame NEMA Class B Motors

NEMA Motor Design A or B
Normal Starting Torque
Normal Running Current

H.P. Rating	3600 RPM kvar	3600 RPM %AR	1800 RPM kvar	1800 RPM %AR	1200 RPM kvar	1200 RPM %AR	900 RPM kvar	900 RPM %AR	720 RPM kvar	720 RPM %AR	600 RPM kvar	600 RPM %AR
3	1.5	14	1.5	15	1.5	20	2	27	2.5	35	3.5	41
5	2	12	2	13	2	17	3	25	4	32	4.5	37
7.5	2.5	11	2.5	13	2	15	4	22	5.5	30	6	34
10	3	10	3	11	3.5	14	5	21	6.5	27	7.5	31
15	4	9	4	10	5	13	6.5	18	8	23	9.5	27
20	5	9	5	10	5	11	7.5	18	10	20	10	25
25	5	6	5	8	7.5	11	7.5	13	10	20	10	21
30	5	5	5	8	7.5	11	10	15	15	22	15	25
40	7.5	8	10	8	10	10	15	16	15	18	15	20
50	10	7	10	8	10	9	15	12	20	15	25	22
60	10	6	10	8	15	10	15	11	20	15	25	20
75	15	7	15	8	15	9	20	11	30	15	40	20
100	20	8	20	8	25	9	30	11	40	14	45	18
125	20	6	25	7	30	9	30	10	45	14	50	17
150	30	6	30	7	35	9	40	10	50	17	60	17
200	40	6	40	7	45	8	55	11	60	12	75	17
250	45	5	45	6	60	9	70	10	75	12	100	17
300	50	5	50	6	75	9	75	9	80	12	105	17

Applies to three-phase, 60Hz motors when switched with capacitors as a single unit.