

POWER FACTOR CORRECTION

BK - T - 95

Capacitor banks



Introduction

A capacitor bank is a fundamental component of power factor correction systems that optimises inductive reactive power intake. While choosing a capacitor bank, it is essential to determine the total power and its distribution at each of its steps, as well as to match the parameters of additional equipment to the capacitors installed in the bank. A properly designed capacitor bank reduces the costs of reactive power consumption to the minimum.

Construction

The BK-T-95 capacitor banks are built in enclosures, or sets of enclosures suitable for indoors, for positioning against a wall. The enclosures have different sizes depending on the power and the number of stages (see fig. 1-3). Enclosures numbered I, II and III can be mounted hanging on a wall. Standardly for this type of capacitor banks, supply entry is at the left side of a unit. Enclosures marked with IV are designed to be placed against a wall, above the cable duct (bottom supply entry). Capacitor banks with atypical supply entries (e.g. top) are available on request. A standard enclosure is made from powder coated sheet steel with protection degree IP41. On individual requests capacitor banks can be provided in an outdoor version (IP54). It is also possible to order banks in enclosures with higher IP for installation in especially difficult conditions, such as high dustiness or humidity. They can be also fitted with non-standard locks. For proper heat circulation the size of an enclosure depends on the power of installed compensators. The essential element of a BK-T-95 capacitor bank is a set of capacitors divided into stages, each with a particular kvar rating. In case of compensation of capacitive reactive power, the regulating element is a set of reactors divided into steps of requisite powers. Each stage of the bank consists of a switching output in the regulator, fuse protection, capacitor/reactor switching device (contactor or thyristor switch), filtering reactor, three-phase power capacitor (or three-phase regulating inductor) and an indicator light signalling the state of the switching device. Proper operation of the indicators can be verified by pressing the lamps test button. The kind of enclosure used depends on the number of stages of the bank. All BK-T-95 banks are fitted with additional devices protecting them against harmful phenomena in the supply voltage. Each capacitor bank has a phase failure relay that switches its control off if any of feeding phases decays. It also has surge protection installed onto its main busbar. Because of the need to minimise disturbances occurring during connection of a reactor and a capacitor, banks with filtering reactors can be fitted with a separate surge protection for each stage (on request). High-power banks (>150kvar) and those with filtering reactors can have single- or dual-circulation automatic ventilation system to protect the capacitors against increased temperatures. In the BK-T-95/Hr series each filtering reactor has a built-in thermal breaker that disconnects the reactor in case of overheating. The reactor compartment has its own ventilation system. The outdoor version of the bank has automatic heating of the regulator's electronics. Busbars are normally made from copper, but cheaper, aluminium version is also available. In capacitor banks consisting of multiple enclosures, each enclosure has its busbars led out and ready for supply connection. On request, multi-enclosure banks with single cable entry (busbar bridge) can be provided. Twelve Electric also offers upgradable banks that can have their power increased (by expanding with more stages) or filtering reactors added later. An upgrade can be installed by third parties. For individual orders, we manufacture custom capacitor banks in untypical enclosures with

dimensions and colour specified by a Customer. The construction of our capacitor banks allows installation inside standard enclosures from other manufacturers. In case of installation into a switchboard without a spare supply section, we provide capacitor banks with additional protection fitted inside or outside the enclosure (isolator or switch-fuse).

Operation principles

The number of stages and the power of each should be chosen in a way ensuring coverage of reactive power demand in the state of maximum load as well as effective compensation of reactive power in the periods of low power intake. One of the most important elements of a capacitor bank is a power factor regulator, the features and parameters of which in a great measure determine the quality of the entire bank's operation. The regulator analyses running measurement data in real time and decides whether to include or exclude individual stages of the bank. The switching processes in a BK-T-95 capacitor bank take place automatically as the MRM-12 microprocessor regulator controls the contactors (or thyristor switches) using its output signals and engages consecutive capacitors. An important feature of Twelve Electric's capacitor banks is the possibility to individually choose the power of the first stage capacitor, which is essential for the effectiveness of conducted power factor correction. Thanks to the freedom of power selection on each stage, especially on the first one, BK-T-95 banks allow efficient power factor correction considering the specifics of reactive power intake alterations. It has to be mentioned that the power of the first stage of a capacitor bank not only decides on the accuracy of compensation of low reactive power loads, but also determines the number and power of consecutive stages of the bank. It is obvious that a bank with a larger number of stages is a more effective, but also more expensive solution. In order to conduct power factor correction satisfactorily, a capacitor bank should be selected with consideration of the specifics of the load circuit. Accurate matching of the regulator's operation mode to the load is possible thanks to availability of three different characteristics. Power stepping is also very important for the effectiveness of the regulation process. A power capacitor bank can have standard stepping that is 1:2:4... (multipliers of the first stage capacitor size), or other, depending on individual needs, e.g.: uniform stepping 1:1:1... allowing the bank to work in the circular switching mode. Thanks to the MRM-12 regulator, our capacitor banks can correct power factor by using seven different regulation algorithms. Correct power on individual stages gives measurable benefits, for example: using the circular switching for rapidly altering loads makes the bank reaction speed independent from the time of capacitor discharge. Information shown on the regulator's display helps to monitor the capacitor bank operation. It provides information on the actual supply network $\cos\phi$, current transformer load percentage and the number of stages active. With three different response time settings available it is easy to find the right regulation dynamics. For additional control there are indicator lamps on the enclosure door. Switched by auxiliary contacts they indicate closure of associated contactors.

Types of capacitor banks

The BK-T-95 series capacitor banks manufactured by Twelve Electric are designed for automatic power factor correction in three-phase LV networks with nominal voltage from 210V, 400V up to 660V. They can be used for both central and group compensation. The banks are made in a variety of enclosures, power ranges, stepping and additional equipment for precise matching of the bank to a Customer's individual needs every time. There are four types of BK-T-95 capacitor bank build (see fig.1-3 for dimensions).

Build I:



number of stages: max. 4
reactive power: max. 60 kvar
recommended power: 37,5 kvar
cooling: gravitational
enclosure dimensions (W x H x D): 500x790x250 mm
equipment: MRM-12 regulator, phase failure relay, active stages indicator lamps
fitting: standing (wall mountable), cable entry at the left side of the bank

Build II:



number of stages: max. 5
reactive power: max. 90 kvar
recommended power: 60 – 75 kvar
cooling: gravitational
enclosure dimensions (W x H x D): 750x915x250 mm
equipment: MRM-12 regulator, phase failure relay, active stages indicator lamps

fitting: standing (wall mountable), cable entry at the left side of the bank

Build III:



number of stages: max.6
reactive power: max.127,5 kvar
recommended power: 120 kvar
cooling: gravitational
enclosure dimensions (W x H x D): 1000x1140x250 mm
equipment: MRM-12 regulator, phase failure relay, active stages indicator lamps, main busbar surge protection
fitting: standing (wall mountable), cable entry at the left side of the bank

Build IV:



number of stages: max. 15 (8 per enclosure)
reactive power: max. 320 kvar (per enclosure)
moc całkowita: 480 – 750 kvar
cooling: forced
enclosure dimensions (W x H x D): see fig.2-3
equipment: MRM-12 regulator, phase failure relay, active stages indicator lamps, main busbar surge protection, ventilation system
fitting: standing, on the top of cable duct

Note: When it is necessary to use a high-power capacitor bank with the number of stages exceeding the number of regulator outputs, the excess stages are controlled by time delayed relays switching the capacitors with a preset delay (cascade). It is also possible to order a custom capacitor bank with individually specified dimensions, colour and equipment to let it be adapted to all kinds of untypical, yet technically reasonable power supply systems. Additional equipping of the capacitor bank with reactors or replacing the contactors with thyristor switches allows matching the bank to the specifics of reactive power intake. We also offer filtering reactor banks for compensation of capacitive loads.

Capacitor banks versions

Capacitor banks manufactured by Twelve Electric are available in many configurations. There are five basic kinds of capacitor banks depending on different specifics of a supply network load:

– **standard capacitor bank: BK-T-95**

It is equipped with a MRM-12 power factor regulator and intended for installation in systems with low level of harmonic distortion ($THDI \leq 8\%$). It is designed for facilities with small number of nonlinear loads and low dynamics of reactive power intake alterations. Capacitor banks above 150kvar are fitted with automatic ventilation system. There is surge protection on the main busbar. The banks have a capacitor engagement indication system.

– **capacitor bank with higher harmonics filters: BK-T-95/Hr**

It is used in supply networks with significant harmonic distortion. It is the right choice for power supply systems loaded mainly with power-electronic devices, such as: frequency converters, inverters, rectifiers, water chillers, etc. Beside standard equipment the bank is fitted with higher harmonics filtering reactors letting it operate with distortions in the supply current and voltage. Filtering of higher harmonics extends the lifetime of the bank and the capacitors, and prevents frequent and expensive replacing.

Each stage of a BK-T-95/Hr capacitor bank has a filtering reactor added in series into the capacitor's supply circuit and can be fitted with additional surge protection. The capacitors used in the bank have their nominal voltage increased to 440V-480V. Due to higher heat emission the BK-T-95/Hr banks have bigger dimensions and are equipped with a dual circulation automatic ventilation system. Depending on a spectrum of harmonics there are three versions of BK-T-95 banks with different kinds of filtering reactors used ($p=5.67\%$, 7% or 14%). The choice of reactors should follow higher harmonics spectrum analysis determining which harmonics to filter.

– **dynamic capacitor bank with discharging reactors: BK-T-95/SR**

This version of the capacitor bank allows compensation of devices with very dynamic characteristics of power intake alterations. Use of type DNE discharging reactors gives discharge times of less than 1s while keeping the traditional system of capacitors control, based on contactors switching capacity currents. The BK-T-95/SR banks are a more economical solution compared to the BK-T-95/D type. They provide quasi-follow-up power factor correction.



– **dynamic capacitor bank controlled by thyristor switches: BK-T-95/D**

It is destined for installation in networks with rapidly altering characteristics of the load. Since thyristor switches are fitted instead of contactors, the capacitors can be energised anytime without several seconds wait for discharge. Furthermore, use of thyristor switches limits transient state occurrences accompanying switching processes and worsening the quality of power supply. It also increases the speed of switching response. Apart from these advantages thyristor technology helps to prevent switching voltage impulses reducing capacitor lifetime. The BK-T-95/D capacitor banks are suitable for compensation of unstable reactive power intake, e.g.: lifts, arc furnaces, welding machines groups. Due to power electronic components' high heat emission the dynamic capacitor banks are put into larger enclosures.

– **dynamic capacitor bank with filtering reactors: BK-T-95/Hr-D**

This version of capacitor bank allows power factor correction in difficult conditions, that is such with high level of distortions in the supply network and dynamically changing load. The BK-T-95/Hr-D capacitor bank is a combination of thyristor technology and higher harmonics filtering reactors. Fast thyristor switches limit switching voltage impulses while filtering reactors prevent harmonics absorption by working capacitors. This way the capacitor bank allows very fast power factor correction and ensures long lifetime of capacitors. The bank is fitted with dual circulation ventilation system (separate cooling of reactors chamber) and an increased number of fans.

– **regulating reactor bank for compensation of capacitive loads: BK-T-95/C**

The BK-T-95/C bank is made on compensating reactors. It is designed for power factor correction in networks with capacitive characteristics. It is mainly used for compensation of long sections of MV cable networks with no significant load. The MRM-12 regulator controls the bank by switching an appropriate number of reactors on or off accordingly to the condition of the network, in order to change the characteristics of the load to inductive, and

to keep power factor at the solicited level. Because of the heaviness of reactors making the bank and the amount of heat they produce, the enclosure is usually open and selected individually in accordance with measurements preceding the design.

Usage benefits

Our banks characterise by low dimensions and easiness of installation and startup. Their outstanding regulative parameters allow precise maintenance of solicited power factor and avoidance of additional costs of excess reactive power consumption. Our almost twenty years long experience in the field of power factor correction lets us offer you high quality products made from components with verified reliability, such as: our own MRM-12 regulator or capacitors made for category D climate conditions. Twelve Electric's banks require minimum attendance from continuity maintenance services. The supervision needed is reduced to periodic technical checks and monitoring of the cost calculation section allowing verification of the power factor correction process. Correct choice of components, concerning raising factors related to the flow of capacity currents, guarantees high reliability, efficiency and safety of the system.

Standards:

IEC 61921:2003; PN – EN 61921:2004 (U)
PN – EN 60439 – 1:2003; PN – EN 60529:2003

Certificate:

Attestation no. 0903/NBR/07 issued by the Electrotechnical Institute

Technical parameters:

Nominal voltage <i>(specify when ordering)</i>	210, 400, 500, 525, 660 V
Maximal auxiliary voltage	230 V
Nominal measuring current	5 A
Nominal frequency	50 Hz
Current transformer nominal secondary current <i>(phase L1)</i>	5 A ± 20 %
Number of stages switchable directly by the regulator	3° ÷ 15°
Ambient temperature	-25°C* ÷ +40°C
Protection degree <i>(custom IP available)</i>	IP41 <i>(indoor version)</i> IP44, 51, 54, 66 <i>(outdoor version)</i>
Safety category	II

*) for version with temperature stabiliser

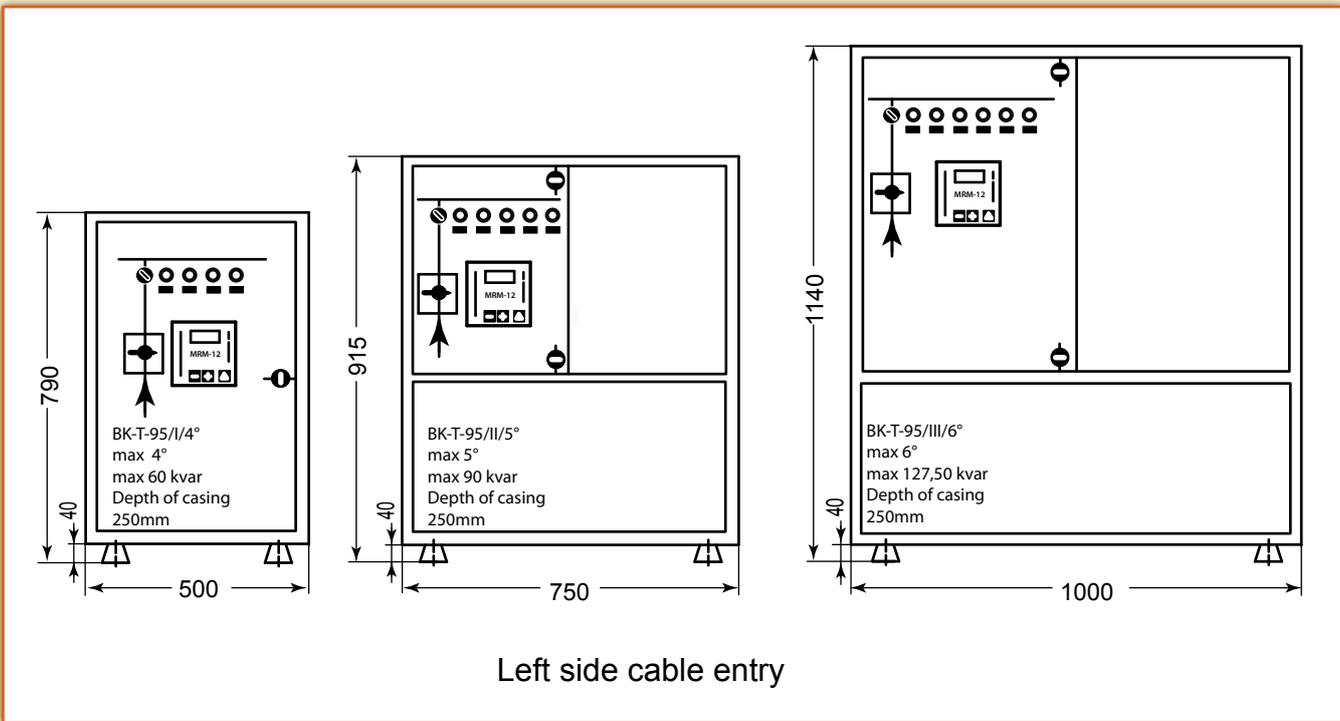


Fig.1. Dimensional drawing of BK-T-95 capacitor bank, I, II, III series.

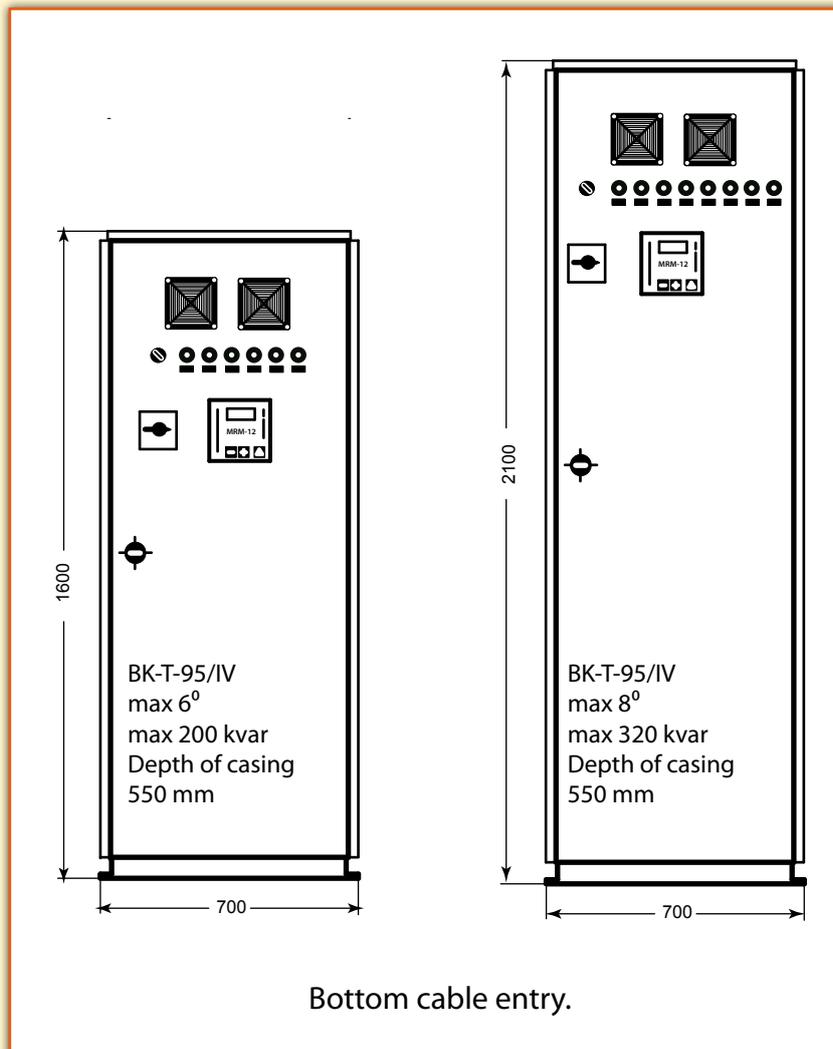


Fig.2. Dimensional drawing of BK-T-95 capacitor bank, IV series.

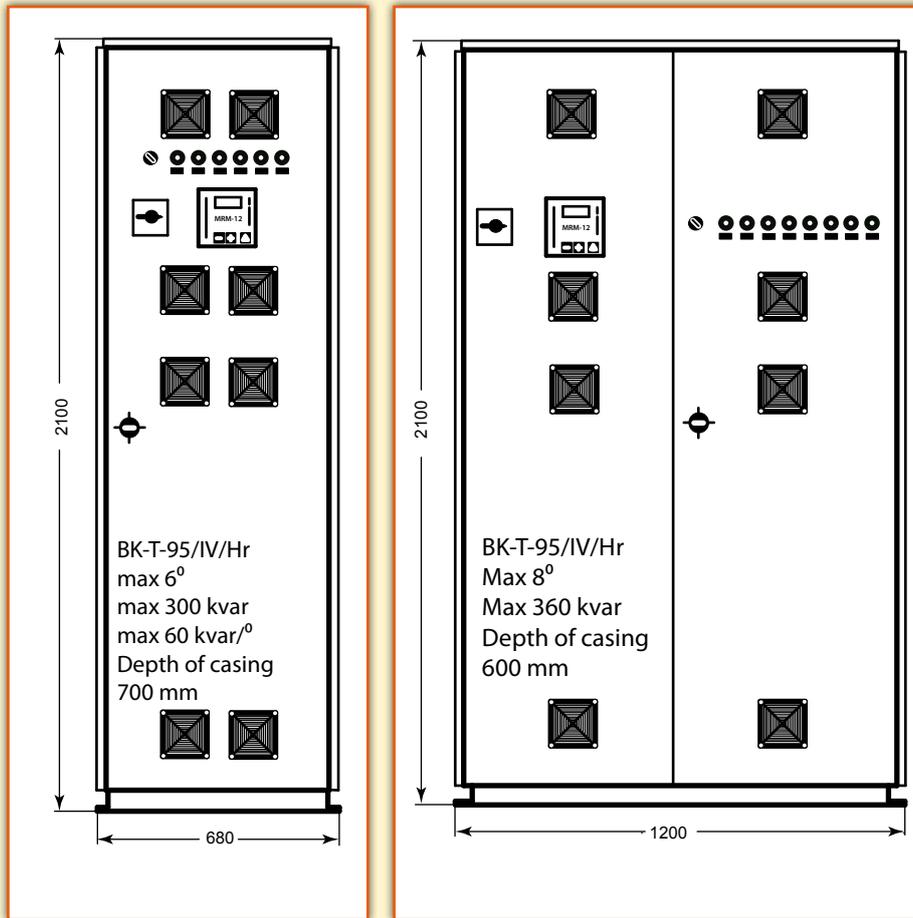


Fig.3. Dimensional drawing of BK-T-95/Hr capacitor bank, IV series.

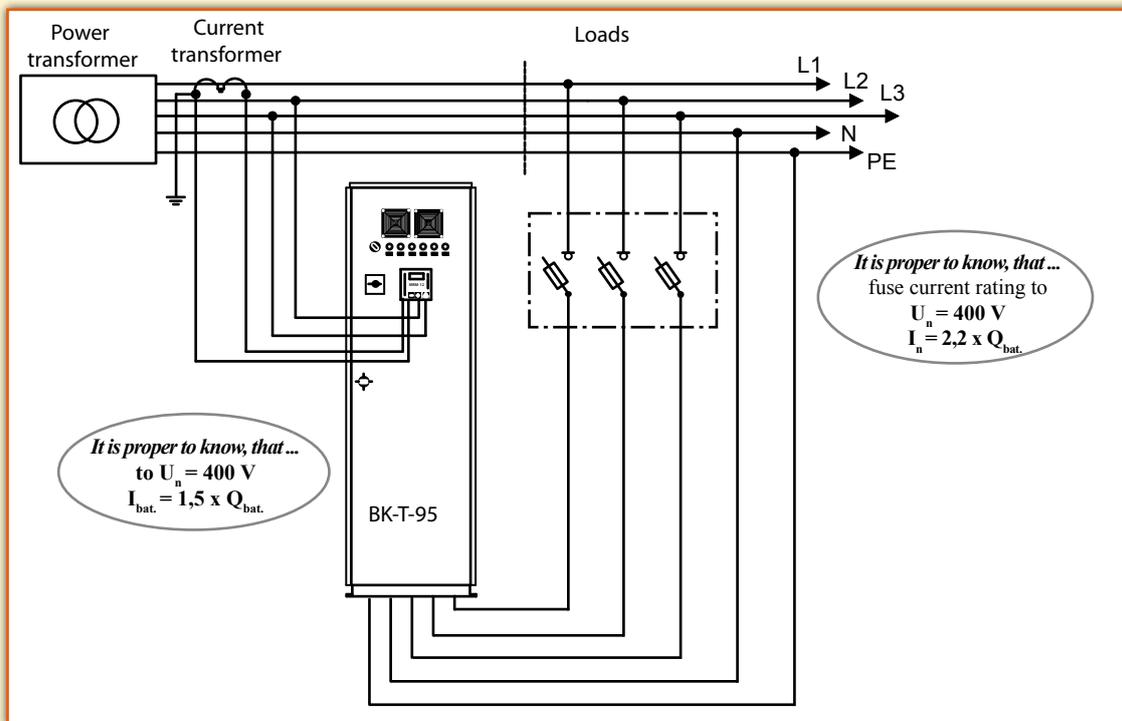


Fig.4. Connection diagram of BK - T - 95 unit.

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