RADE KONČAR KONTAKTORI I RELEI D.O.O.

CNNK CNKM

CAPACITOR CONTACTORS
CNNK / CNKM

Special contactors for switching capacitors for power factor correction

I. GENERAL

I.1. What is reactive energy?

Reactive energy is a part of the consumed power, which is not converted into useful work.

All individual loads have to contain magnetic field to be able to work. Such loads are:

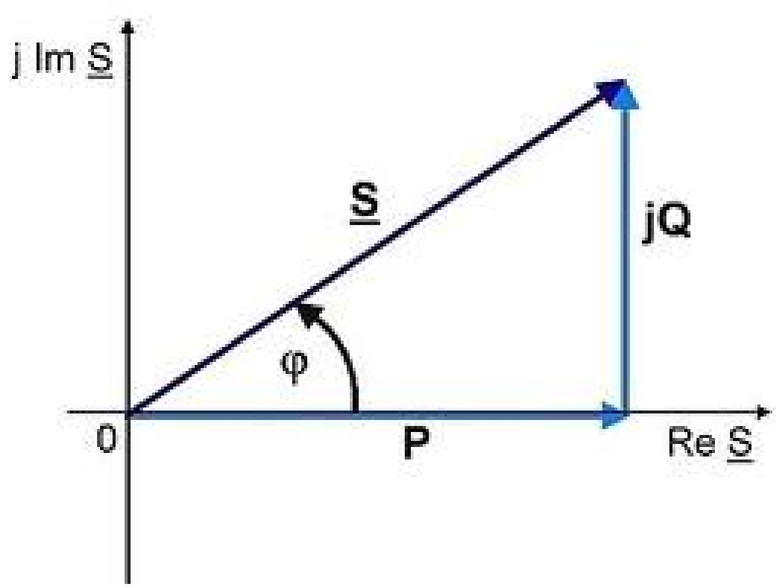
- electro motors
- transformers
- fluorescent and street light
- inductive electro thermal devices etc.

To generate magnetic field energy is consumed, which is in general supplied from the distributive net. The reactive energy, although necessary for these devices to be able to work, does not produce useful work. Electrical energy that is used by inductive loads consists:

- P is active electrical power, which practically converts electrical power into some kind of useful work. This power is measured in kWh
- Q is reactive power, which generates magnetic field what is a base for working of the inductive electro motors. This power is measured in kVArh

According the above these consumers use active and reactive power, and the only part of the power that is used is – the active.

Total energy (active and reactive), which the load overtakes from the net is called complex power S. Complex power S is vector sum of the active and reactive electrical energy. This power is measured in kVAh.



Drw.1 - Vector diagram of a power

I.2 Power Factor cosφ

The ratio between active and reactive power is called power factor and is marked **cosφ:**

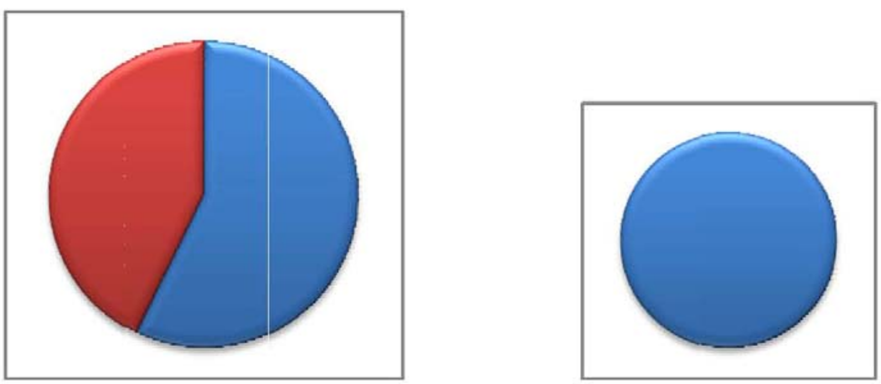
$$\cos\varphi = \frac{\text{Active power}}{\text{Reactive power}} = \frac{P}{S} = \frac{kW}{kVA}$$

Power factor is different for each device and usually it may be from 0.4 to 1. As much as the power factor is closer to zero, that much the usage of the active energy is lower. The best case is when the power factor is 1, because in such case the total consumed energy is transferred into useful work, in other words than P=S, which is ideal case and in practice is hardly possible.

Through the power factor value it can be seen with how high quality the used electrical energy has been converted into "real useful work. Let's take an example of electro motor with power 10kW that typically has cosφ= 0.8. This means that the electro motor uses each hour 10kW active energy (P) and 7.5 kVArh reactive energy. The active energy of 10kW converts into useful work, while 7.5 kVArh reactive energy are spent for magnetizing of the poles of the electro motor, while the final consumer does not have any direct benefit of this energy, while the same has to be paid for.

On the other hand, the reactive energy must be transported from the place where produced (generator, transformer) to the consumer, it occupies part of the capacity of the cable.

For electro motor of P=10kW (from the above mentioned example), the current that flows because of the active component is 25A, and because of the reactive component 18.75A. Through the cable flows total 43.75A, which directly causes increase of the general loses in the cable (heating of the cable). As consequence of the heating of the cable, which causes increase of the resistance, the increased voltage fall is generated that rises with the length of the cable.



a) cos φ = 0.8　　　　b) cos φ = 1

Drw.2 - Occupation of cable capacity

From drawing 2a can be seen that existence of the reactive component occupies about 40% of the necessary capacity for cosφ= 0.8. On the drawing 2b is shown the cross section of the cable if the load is completely compensated - cosφ= 1.

I.3. Why is it necessary to compensate the reactive energy?

The compensation of reactive energy generates more benefits:

➢ <u>Benefit for the end-user</u>

End-users of electrical energy, who in their invoice have got an item for reactive energy, have direct financial benefit because after the compensation of reactive energy, the item for reactive energy is eliminated from the total invoice or it lowers to negligible amount. Because of this the invested financial amount in the equipment for compensation of reactive energy are returned 10 to 30 times during the exploitation period of the equipment.

➢ <u>Electro energetic system benefit</u>

By compensation of reactive energy:

- The total amount of current in the net is reduced for the amount of reactive energy component in the current, which reduces the load in the electrical cables for transmitting of electrical energy.
- Reduces the load of the power plants and transformers which prolongs their working life period.
- There are smaller voltage drops, increased stability of the EE network and higher security in providing the end-users with electrical energy.
- The technical loses of the active energy are reduced in the whole energetic system.

II. REACTIVE ENERGY COMPENSATION

II.1 Introduction

For the loads using alternative current, for their functioning, current and voltage with changeable value and sinusoidal form is necessary. For the resistive loads, the current and the voltage are in phase, which means that they are passing through zero value at the same time. In this case supplied power (S) from the main is completely converted in useful work (S=P). For the functioning of electro motors and transformers there has to be magnetic field. For this devices, for their functioning, there has to be current that contains active (working) and reactive (barren) component. In this case one part of the consumed electrical energy is converted in active – working power (P), and the other part that produces the magnetic field is converted into reactive – barren power (Q).

The active component of the current $\mathbf{I_r}$ is in phase with the voltage and takes part in creation of the working power (P). The reactive component of the current $\mathbf{I_L}$ is delayed after the voltage, it is translated by phase for π/2 (90º), and takes part in creation of the magnetic field. The phase delay of π/2 is result of the inductive resistance in the coils of the electrical devices.

Illusory current **I** is geometrical sum of the active current $\mathbf{I_r}$ and reactive current $\mathbf{I_L}$ and is translated by phase (delayed) for an angel φ related to the supply voltage (U). As bigger the number of the inductive loads connected to the net is, that much the undesirable phase translation is bigger.

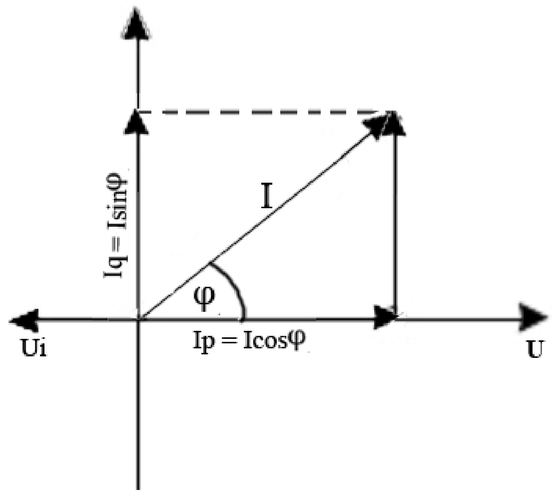
Generally the consumed power from the electrical supply net is a multiple result from the voltage U and current I. The following formulas exist in the three phase systems for the active, reactive and barren power:

$$P = \sqrt{3} \cdot U \cdot I_r = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \quad [kW]$$

$$Q = \sqrt{3} \cdot U \cdot I_L = \sqrt{3} \cdot U \cdot I \cdot \sin\varphi \quad [kVAr]$$

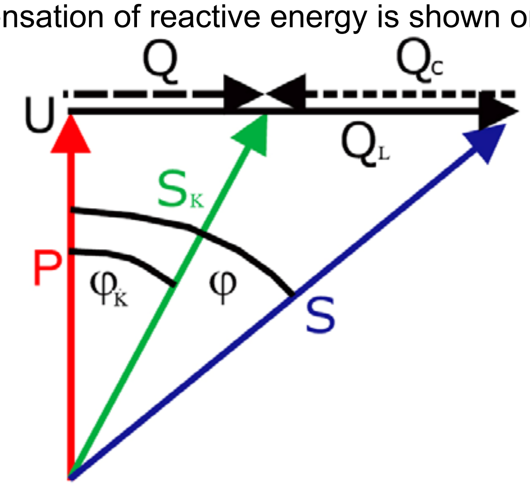
$$S = \sqrt{3} \cdot U \cdot I \quad [kVA]$$

that results from the bellow presented vector diagram for the currents and the voltage:



Drw.3

For the transmission of electrical energy, the un-useful reactive part Q should be as small as possible. The reactive energy that is necessary for functioning of the inductive loads should be gained the other way, not through the distributive net. The reactive power that is necessary for functioning of the devices working with alternative current is supplied by the capacitors connected in parallel, which at the same time are relaxing the transmission and production of the electrical energy. While this fact that capacitors as a capacitive load have reactive power (reactive component of the current) that surpasses the voltage for π/2 (90º) is helping. Physically, the capacitor connected in parallel is using the created energy when the magnetic field decreases for excitation of its electrostatic field (filling up the dielectric. Right after that, in the rhythm of the alternative current, during the decreasing of the electrostatic field, the created energy is used for excitation of the electromagnetic field practically without loses (empting the dielectric). By this way the portions of energy of the electrical fields of capacitors and magnetic fields of the inductors (loads) are equalized. This procedure is called compensation of reactive energy. The vector diagram for compensation of reactive energy is shown on drawing 4.



Drw.4

Where:

φ – Phase angel
S - uncompensated barren energy
Sk - compensated barren energy
P - active energy
Q - reactive energy
Ql - inductive reactive energy
Qc – capacitive reactive energy

From the above diagram the following formula are created:

$$S = \sqrt{P^2 + Q^2} \quad \textbf{[kVA]}$$

$$Q = \sqrt{S^2 - P^2} \quad \textbf{[kVAr]}$$

$$P = \sqrt{S^2 - Q^2} \quad \textbf{[kW]}$$

II.2 Power factor

With cosφ is marked the ratio of the active and barren energy:

cosφ = P/S

and is called p**ower factor.**

According the vector diagram on Drw.4 capacitor with power Qc = Ql will compensate the reactive energy completely and the power factor will be ideal (cosφ=1). In the practice with compensation of reactive energy the power factor is between cosφ=0.95 to cosφ=0.99.

With compensation of reactive energy close to the load the electro power net is relaxed because the reactive energy is not received through the electric net and it is created by the capacitors. The benefit of the power factor correction is presented in the following table:

Decrease of the current and thermal losses of the current for the power factor correction

cos ϕ uncompensated	cos $ϕ_K$ compensated	Reducing current and apparent power u %	Losses reduction (I^2/R) u %
0.5	0.9	44%	69%
0.5	1.0	50%	75%
0.6	0.9	33%	55%
0.6	1.0	40%	64%
0.7	0.9	22%	39%
0.7	1.0	30%	51%
0.8	1.0	20%	36%

From the table above can be viewed the benefit of the power factor correction.
With ideal compensation the relaxation of the supply cable is made and the voltage drop is decreased for a significant value.

II.3 Higher harmonics - general

When correcting the power factor it is necessary to be careful about the excessive compensation, which can make technical problems, and under certain circumstances to cause remarkable damages. This is especially valid for loads where are present high harmonics.

High harmonics in the electrical network are caused by the not linear consumers such as rectifiers, frequent regulators, saturated transformers etc. These electrical devices can be found in all the factories with electromotor drives, electrolysis, chemical factories, city and intercity transport, which at the same time are the main consumers of the reactive energy that causes the necessity for compensation of the same. Due to the existence of higher harmonics, during this process there is possibility of overloading the capacitors and appearance of the resonance.

With purpose of avoiding such phenomenon, filter inductance calculated to limit the influence of the most expressed high harmonic, is build in series to the capacitors. It is the most common to filtrate high harmonics of the following resonant frequencies:

$$f_r = 189 \text{ Hz}$$
$$f_r = 213 \text{ Hz}$$

Building in of the filter inductance has two advantages:

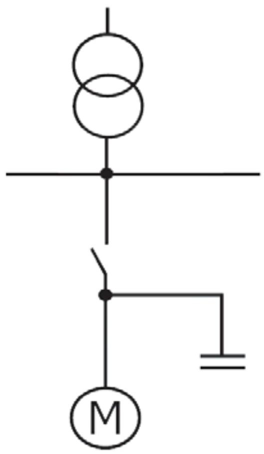
1. The filter circuits are unloading the network from the unwanted high harmonics. The problems while operating nonlinear loads are suspended, especially in parallel work. In the same time the conditions for appearance of the resonance are prevented and because of it the overloading of the capacitor device is avoided.
2. The capacitors in the filtering circuit are compensating the reactive energy of the basic harmonic and this is decreasing the expenses for payment of the electrical energy.

II.4. Compensation types

We recognize three different types of compensation:

- Single compensation (steady compensation)
- Group compensation
- Central compensation

II.4.1. Single compensation



Sl.5

Single compensation is typical for the plants with single asynchronous motors, transformers, welding devices, lights with chokes etc. It is especially interesting for the big motors that are steady in working mode, such as in pumps and compressors. The load can be very good compensated with cosφ = 0.95.

With single compensation inductive reactive energy is compensated on the same place where it is generated.

The advantages of the single compensation are:

- Feeding terminal cables are unloaded of the reactive energy
- Additional switching devices are normaly not necessary, because the switching of the electric motor and the capacitor is done with the same switcing device.

The single compensation is economical for loads with power bigger than 20 kW (P > 20kW).

The power of the capacitor connected in parallel with the electromotor is calculated by the formula:

$$Qc = \sqrt{3} \cdot 0.9 \cdot Imag \cdot Un \quad [kVAr]$$

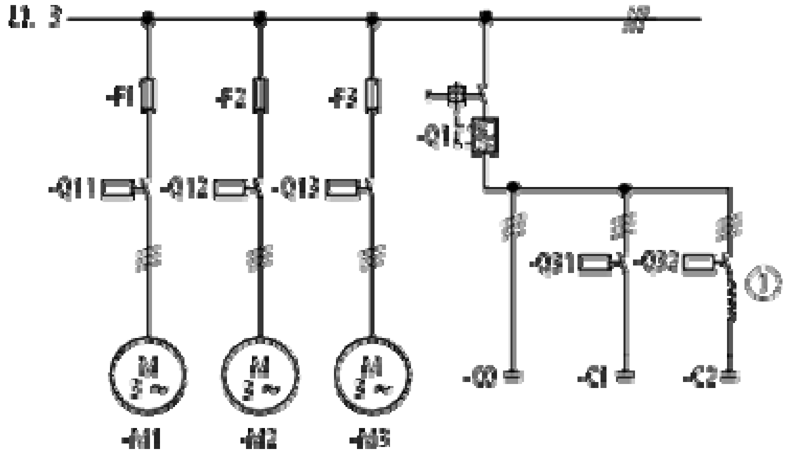
Where is:

Un – nominal voltage of the electromotor (V)
Imag – magnetizing current (A)
Qc – capacitor nominal power (kVar)

For single compensation the following must be taken care about:

1. For motors that are switched on with delta-star combination the direct connection of the capacitor is not allowed, because with transferring (from one combination to other) the capacitor is switched off for a moment, but instantaneous switch on of the capacitor is not allowed. In such case harmful voltage overloads and current shocks are possible.
2. For the current overload bimetal protection of the motor the reduction of the current must be considered.
3. For the motors with big rotation moment must to be careful not to come to self initiating that happens when fast unloading of big electro-motors is done.

II.4.2. Group compensation



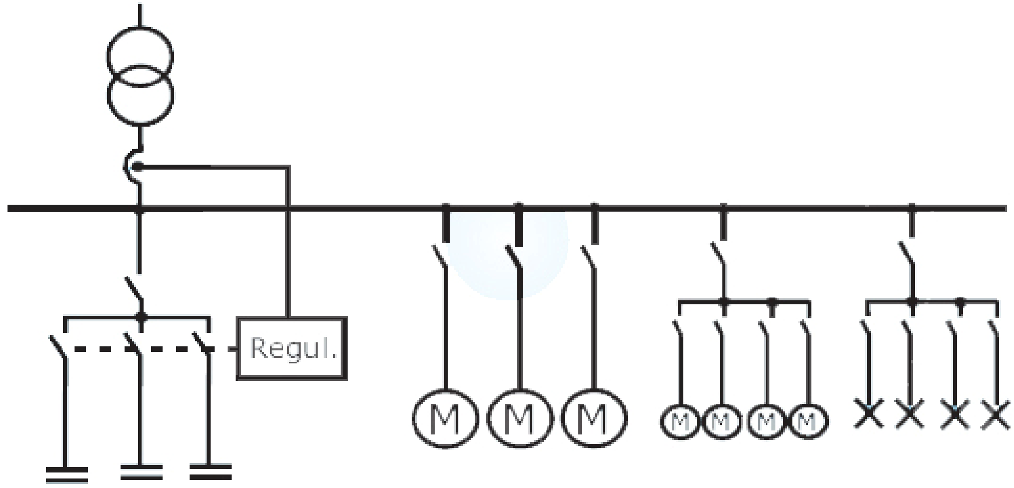
Sl.6

For group compensation several smaller inductive loads are compensated. The compensation can be done with one capacitor battery or with capacitor plant.

This way of compensation is especially suitable for a group of electro-motors. Normally these loads are switched on one by one, because of what there is changeable consumption of reactive energy. For these reasons the capacitor plant is divided into smaller units and must contain switching elements (capacitor contactors). The capacitors through the contactors for capacitors are switched on only when all the inductive loads are switched-on, or a regulator is installed that makes single switching–on of the capacitors. To make right dimensioning of the capacitor units is necessary to have daily working diagram for the inductive loads.

For group compensation the reactive energy and the losses are reduced only in the bus-bars, and not in the wires between the bus-bars and the loads.

II.4.3 Central Compensation



Sl.7

The plants with variable needs of reactive energy do not allow the firm compensation to be used because of uneconomical under-compensation or dangerous overcompensation. The needed power of the compensation units must be adapted to the variable needs of reactive energy and in that case should be used only the central compensation. For central compensation, should be used only the regulated compensation units and they must be connected directly to the substations, bus-bars and sub-bus-bars.

The regulated compensation plants contain: capacitors, contactors for capacitors and regulators of reactive energy for measuring of reactive energy. When appears the difference between the measured and preset power factor ($\cos\varphi k - \cos\varphi l = \pm \Delta \cos\varphi$) , the regulator appropriately switch on and switch off the capacitors step by step . With central automatic regulation compensation system can be achieved high level of the power factor ($\cos\varphi \geq 0.95 - 0.99$) and therfore there is no need of educated personal to follow the changes of the reactive energy and to switch on and off the separate units.

- **Determination of the power of the compensation plant**

The power of the compensation plant is determined by the amount of reactive energy that is the number of kVAr that have to be compensated every hour.

Normally there are monthly calculations of the consumed electric energy. According the valid tariff system the allowed free of charge consumption of reactive energy is on the level of 32.9% from the active energy ($\cos\varphi = 0.95$). The excessive reactive energy that we should pay for, can be calculated and compensated in following way:

Monthly calculation (Invoice) for the consumed electrical energy contains:

- Pv – active energy – high tariff
- Pn – active energy – low tariff
- Qv - reactive energy – high tariff
- Qn – reactive energy – low tariff

The needed power of the compansation plant is:

$$Qc = Psr\,(tg\varphi - tg\varphi_k)$$

Where :

- For preset $\cos\varphi_k \geq 0.95 - 0.99$ the value of $tg\varphi_k$ is determined from the mathematic table
- $tg\varphi = (Qv + Qn) / (Pv + Pn)$
- $Psr = (Pv + Pn) / T$
- T – number of working hours per month

- **The advantages of the central compensation**

  - The power of the capacitors automatically is adapted to the needed reactive power
  - It is relatively simple to be mounted additional modular units for enlarging of the compensation system for reactive energy.
  - Very easy supervision of the functioning of compensation system for reactive energy.

When choosing the type of compensation, it is necessary to overview the technical and economical factors. Considering every day bigger presence of high harmonics in electric net , the automatic regulated plant with appropriate construction supposed to be **the best choise.**

III. Contactors for controlling of three phase capacitor banks

► Capacitor contactors ◄

Wile switching on and switching off the capacitor banks under load , a short-circuit overloads appears equal to the value of short-circuit current. Therefore, in order to protect staff and electrical installation it is necessary to be used contactors for controlling of capacitor banks. The use of standard contactors are jeopardizing personnel and complete electrical installation.

Wile switching on the capacitor in the AC system, a resonant current circuit appears, which in damping in greater or lesser extent. The already bruised capacitors cause inrush current of 200 times the nominal current.

The great value of the involvement current can lead to melting of the main contacts of the contactor what is in the same time very detrimental for capacitors. The value of the involvement current depends on the type of compensation and that is displayed on the following figures:

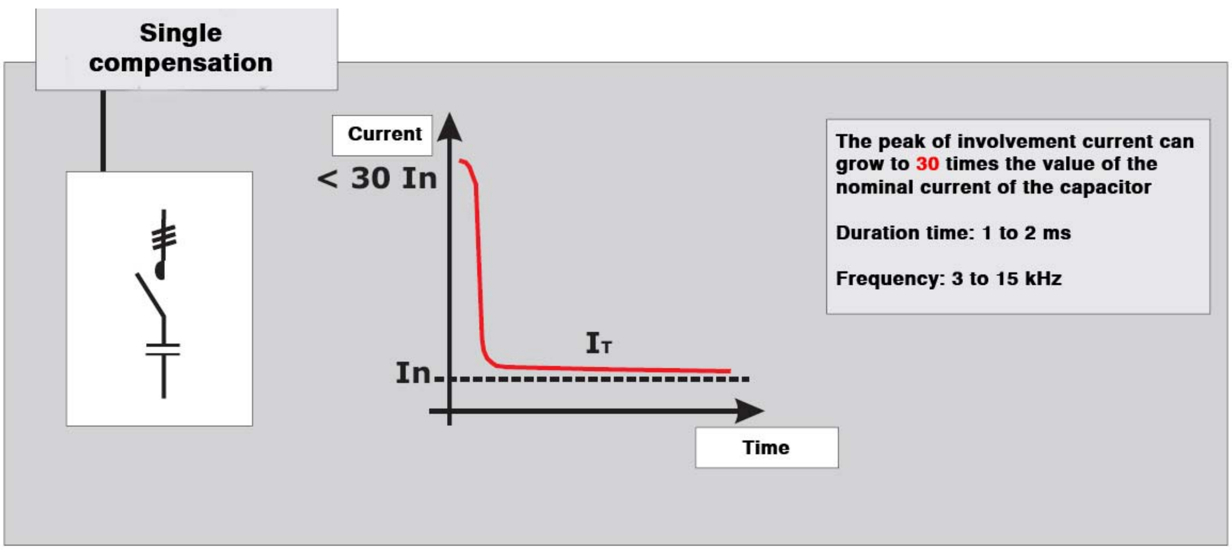


Fig. 8

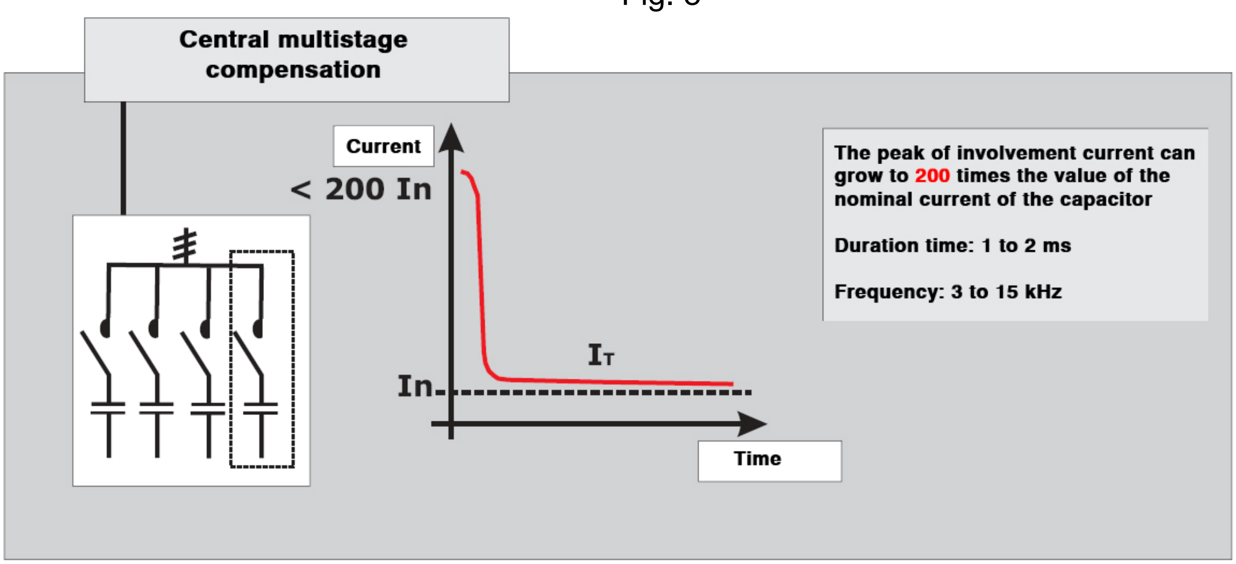


Fig. 9

In the automatic compensation systems have to be used contactors who throttle the involvement current. With throttling of the involvement current drop voltage and transients current are also avoided .

In these capacitor contactors pre-contacts are used to limit involvement current. Each pre-contact is connected in series with a resistor to limit the involvement current (current charge) of the capacitors. Pre-contacts closed before the main contacts, and open when they are surely closed. Such construction of capacitor contactors ensure effective functioning in their working time. The functioning of capacitor contactor is shown in Figure 10.

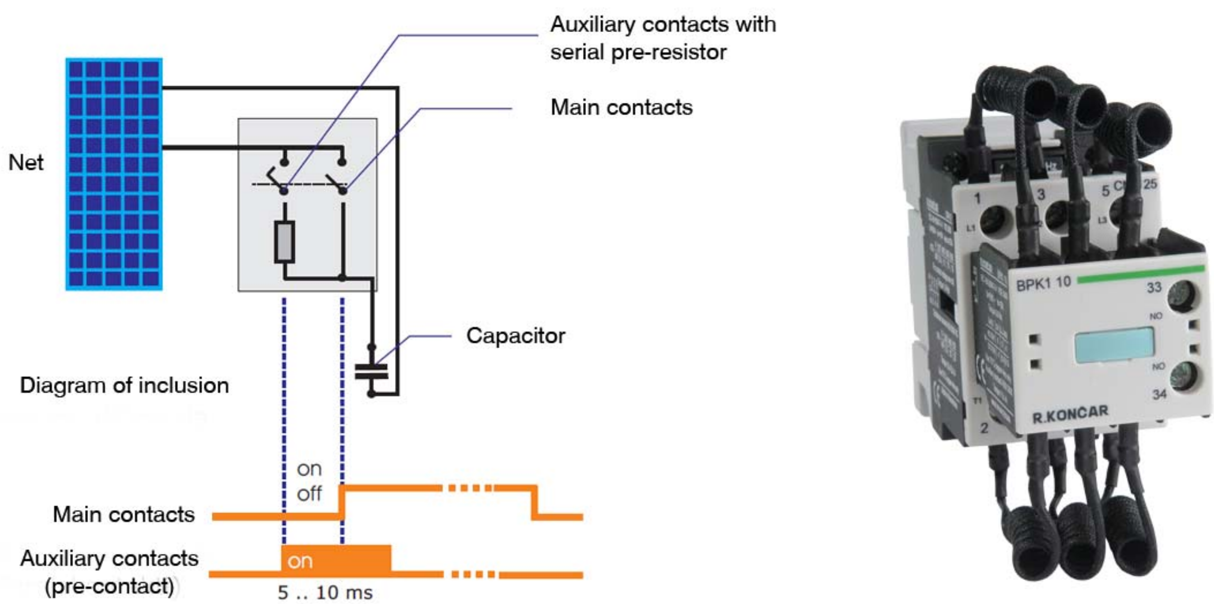


Fig. 10

Efficient operation of the capacitor contactors can be vividly seen from the comparison diagrams for involvement current of capacitor contactor without pre-contacts and with pre-contacts.

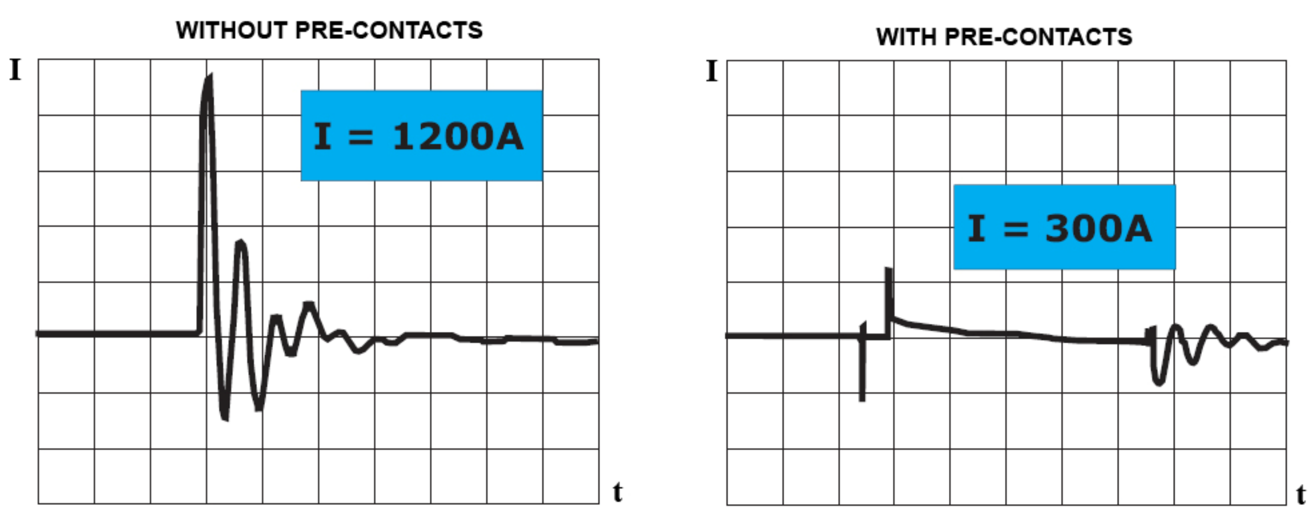


Fig. 11

Diagram of the current involvement for 12.5 kVar capacitor (In = 18A; Un = 400V)

Scale: I: 250A / unit; t: 0.5ms / unit

The capacitor contactors of "Rade Koncar – Kontaktori i relei" doo – Skopje, series CNNK10 - CNNK30 and CNKM 40 – CNKM 60 have modern design with top constructive solutions fully complied with IEC requirements. They are suitable for controlling of capacitors with order without reactors. Because of the pre-contacts and resistors , the involvement current is <70 times In.

The fusses type gl(gG) should be dimensione 1.6 to 1.8 times In .

Features of contactors series CNNK10 -CNNK30 and CNKM40–CNKM60:

- ❖ pre-switching on:
  - the greatest value of switching current is limites by wire resistors
  - all contactors are equipped with pre-contacts for fast switching operation
  - pre-contacts open after the main contacts closed
- ❖ switching on:
  - no loss of power in the resistors because resistors are disconnected from thr current circuit
- ❖ switching off:
  - while main contacts switch off, pre-contacts remain stand-by

Capacitor contactors series CNNK and CNKM can be used in other cases where high involvement current exist.

► Advantages of capacitor contactors from "Rade Koncar – Kontaktori i relei" doo – Skopje, series CNNK10 - CNNK30 and CNKM 40 – CNKM 60:

- power range of the contactors 10 kVAr do 60kVAr
- resistant to the growth of voltage caused by the over merger of reactors
- do not require changing the contactor in post-installed reactors
- greatest possible safety in operation, which is achieved using a single controlled pre-contacts
- reducing of involvement current of the capacitor
- lowered losses during operation
- standardized features
- compact design with small dimensions
- standards: IEC / EN 60947 and VDE 0660
- the width of the contactors up to 30 kVar is only 45mm
- suitable terminal contacts for connecting cables with bigger cross section
- box terminal contacts for all contactors with power bigger than 25 kVar
- resistible to temperatures up to +55 ° C without reducing the nominal value
- possible installation on DIN rail for all contactors from series CNNK
- all moving parts of the contactor are covered, so the manipulation with the operating mode indicator (ON / OFF) is prevented


BPK2 10
33
34
R.KONČAR


1 L1
3 L2
5 L3
CNKM 50
R.KONČAR


1 L1
3 L2
5 L3
CNKM 60
R.KONČAR
2 T1
4 T2
6 T3

Selection of Capacitor contactor

Capacitor contactors series CNNK and CNKM are selected according to the power of the capacitor. For groups and central compensation, when three phase reactor is not used, it's recommended selection of contactor with a higher degree of nominal value for the appropriate capacitor value.

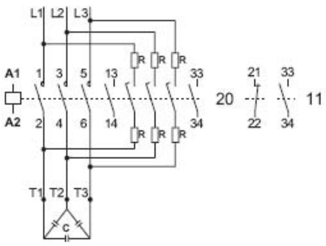
Type designation	**CNNK 10 20** **CNNK 10 11**	**CNNK 12 20** **CNNK 12 11**	**CNNK 15 20** **CNNK 15 11**	**CNNK 20 10**	**CNNK 25 10**	**CNNK 30 10**	**CNKM 40 00** **CNKM 40 22**	**CNKM 50 00** **CNKM 50 22**	**CNKM 60 22**
Capacitor rating at 230V kvar	5	6.7	8,5	11	14	20	25	29	34
400V kvar	**10**	**12.5**	**15**	**20**	**25**	**30**	**40**	**50**	**60**
Rated operational current Ie/AC6b et 400 V A	**14**	**18**	**22**	**29**	**36**	**44**	**58**	**72**	**87**
Insulation rating V	690						750		1000
Permissible ambient temperature °C	- 25 to + 55								
Coil voltage tolerances	0,85 - 1,1 Un								
Maximum permissible fuse ratings main circuit gL/gG A auxilliary circuit A	25 16	35 16	50 16	50 16	63 16	80 16	100 16	125 16	160 16
Frequency of switching operations s/h	240			120			100		
Electrical endurance	200.000			150.000	100.000				
Sizes of connecting conductors main circuit multi-wire conductor mm^2 multi-wire conductor with cable shoe mm^2	1.5-6	1.5-6	1.5-6	2.5-10	6-25	6-25	16-35	16-35	50-70
Terminal screw	M4	M4	M4	M4	M5	M5	M8	M8	M8
Screw head	PZ2	PZ2	PZ2	PZ2	Hexagon socket				
Tightening torque Nm	1,2	1,2	1,2	1,4	2	2	4	4	3,5

Accessories for assembling of CNNK

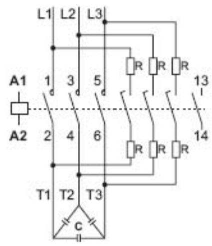
For optimizing stock of contactors, we offer Capacitor blocks for transforming the three pole contactors CNN type in CNNK type. The table below presents Capacitor blocks that should be purchased depending on available standard contactors in stock.

TYPE of CONTACTOR	TYPE of CAPACITOR BLOCK	TYPE of CAPACITOR CONTACTOR
CNN 9	BPK1	CNNK 10
CNN 12	BPK1	CNNK 12
CNN 18	BPK1	CNNK 15
CNN 25	BPK1	CNNK 20

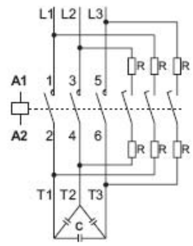
Electric connection of the contactor



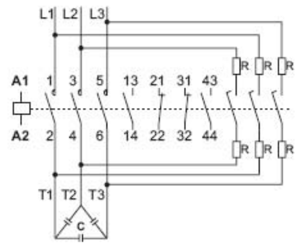
CNNK 10; CNNK 12; CNNK 15



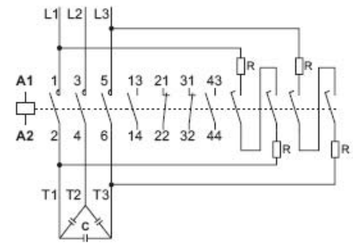
CNNK 20 10, CNNK 25 10
CNNK 30 10,



CNKM 40 00;
CNKM 50 00



CNKM 40 22, CNKM 50 22



CNKM 60 22

Ordering Capacitor contactors

Type

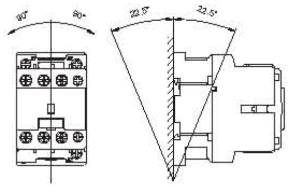
Version
- Number of NO contacts
- Number of NC contacts

Standard control voltages AC 220/230,380/400 V

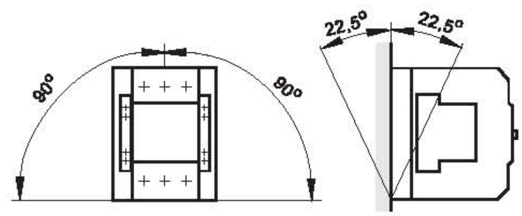
Example: Capacitor contactor type CNKM 50 with two NO and two NC auxiliary contacts, control voltage 220 V, 50 Hz

CNKM 50	2	2	220 V	50 Hz.

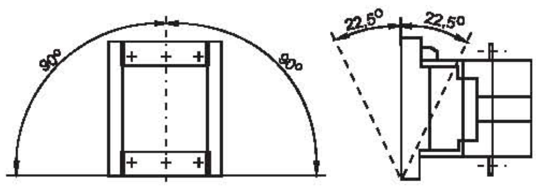
Possible instalation position



CNNK 10, CNNK 12, CNNK 15,
CNNK 20, CNNK 25, CNNK 30

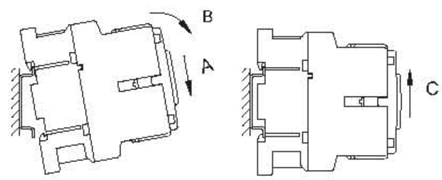


CNKM 40; CNKM 50

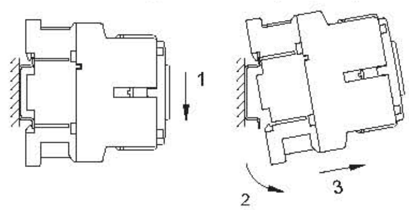


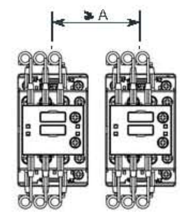
CNKM 60

Mounting of a contactors, steps: A, B and C



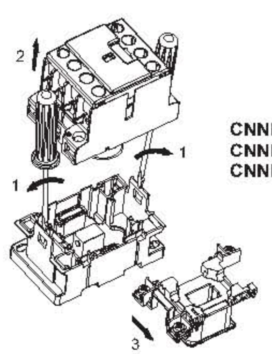
Unmounting of a contactor, steps: 1, 2 and 3



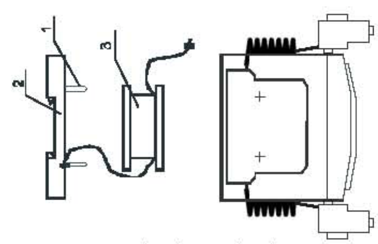


A= 60 - CNNK 10, CNNK 12,
CNNK 15, CNNK 20,
CNNK 25, CNNK 30
A=100 - CNKM 40 00, CNKM 50 00
A=124 - CNKM 40 22, CNKM 50 22
A=145 - CNKM 60

REPLACEMENT OF THE COIL

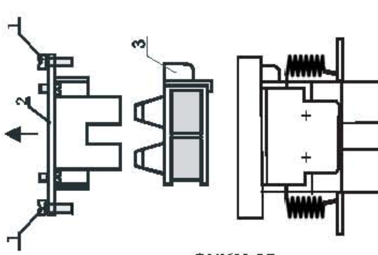


CNNK 10; CNNK 12;
CNNK 15; CNNK 20;
CNNK 25; CNNK 30



Unscrew pos.1
Lift the upper part pos.2
Replace the coil pos.3

CNKM 40; CNKM 50

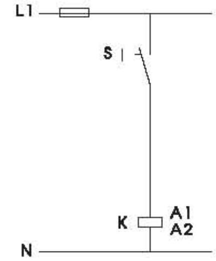


Undo the screws pos.1
lift the plate pos.2
replace the coil pos.3

CNKM 65

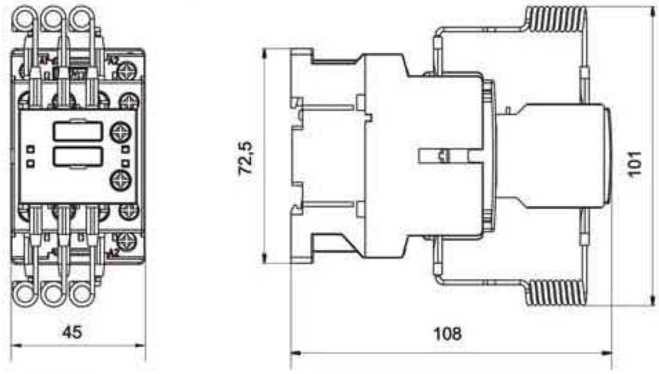
CONTROL DIAGRAM

With permanent button "TK"

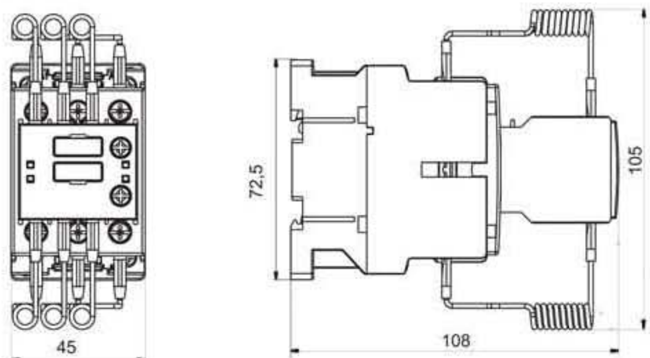


DIMENSION DRAWINGS (mm)

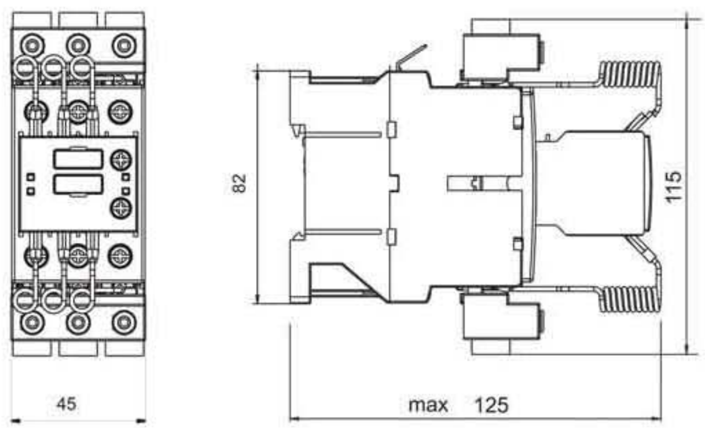
CNNK 10; CNNK 12; CNNK 15



CNNK 20

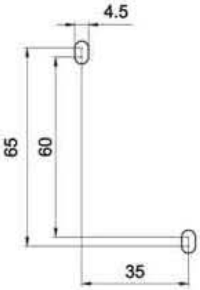


CNNK 25; CNNK 30

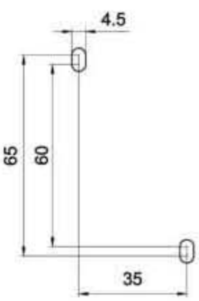


Driling plan (mm)

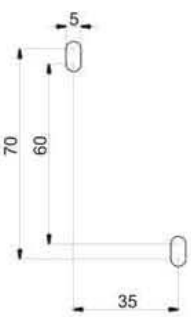
CNNK 10; CNNK 12; CNNK 15



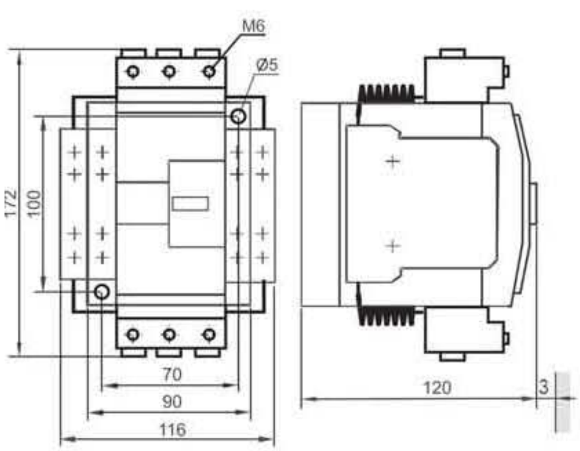
CNNK 20



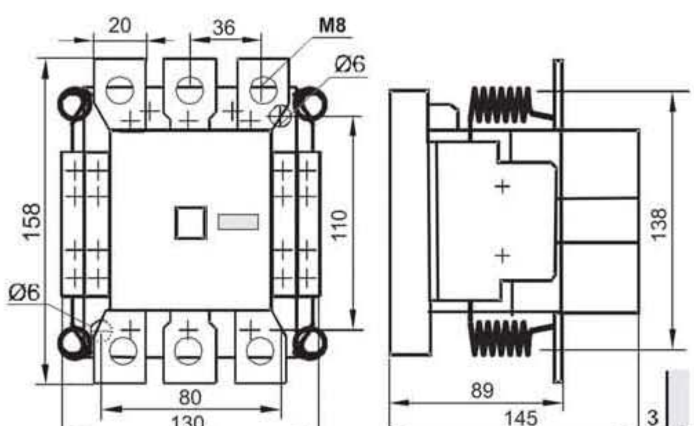
CNNK 25; CNNK 30

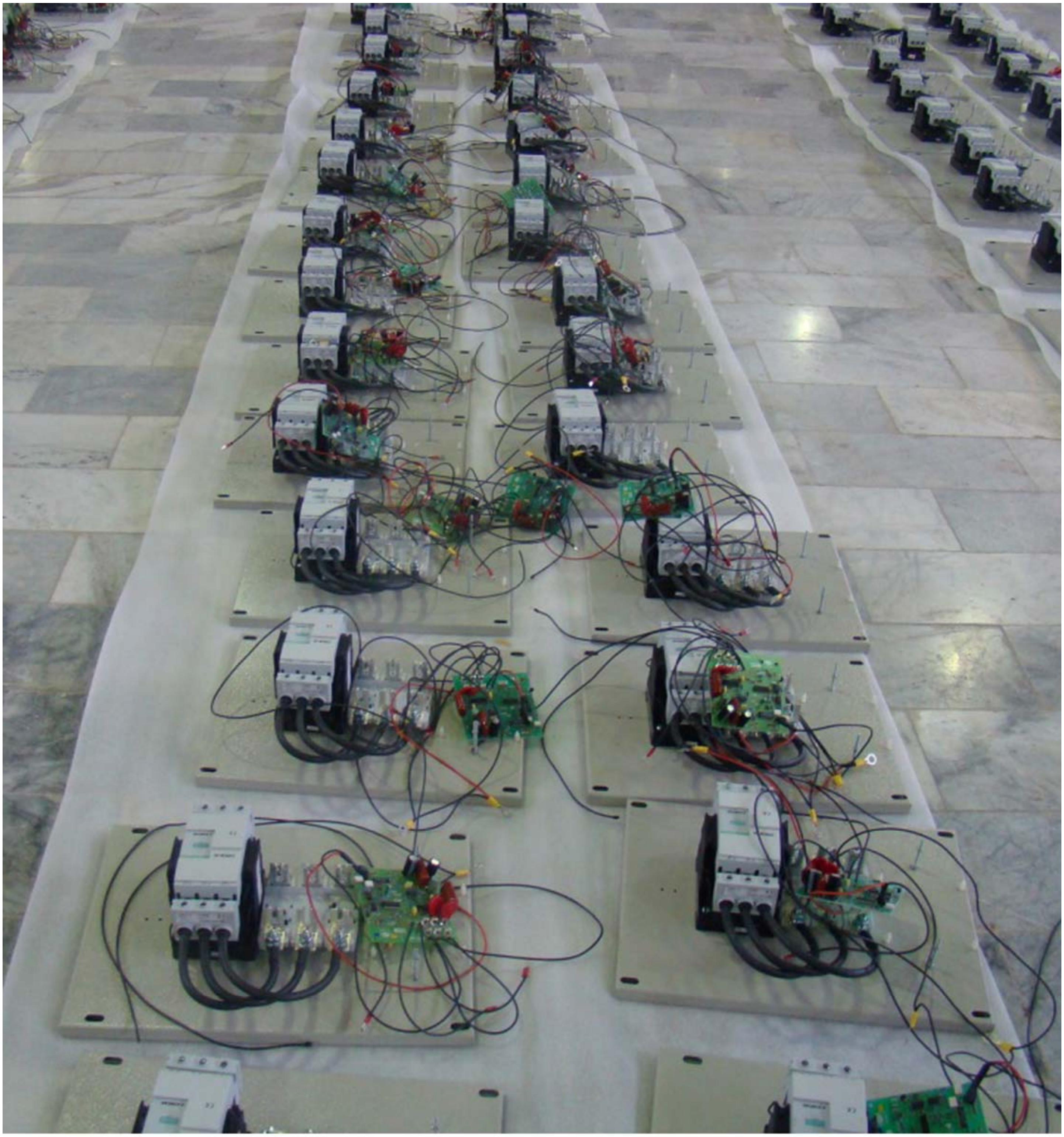


CNKM 40, CNKM 50



CNKM 60





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