TAP CHANGER SELECTING MANUAL

TECHNICAL DATA

HM0.154.000

SHANGHAI HUAMING POWER EQUIPMENT CO., LTD.

General

1. General requirement for tap changer selecting

To ensure correct tap changer selecting and its safe operation, according to the stipulations of IEC60214-1-2003, this manual gives guideline suggestions for tap changer type selecting and highlights the special points for due attentions. Furthermore, it proposes the necessary technical data which should be provided by transformer manufacturers when inquiring about or ordering tap changer. In case of special applications which are not covered in this manual, please contact us technical department for assistance.

1.1. Insulation level

The following listed insulation strength data on all the tap positions must be checked with the permissible voltage duty provided by tap changer manufacturer. According to Article 5.2.6.4 of IEC60214-1-2003, these voltages are:

1) The highest voltage for tap changer during operation;
2) Rated separate source AC withstand voltage on the tap changer during transformer test;
3)Rate lightning Impulse withstand voltage on the tap changer during transformer test.

Due to the difference of voltage regulation mode and specifications of tap changer, the above insulation requirement is not all the same. Each insulation distance and its relations with transformer winding voltages are stipulated for each model of tap changer. Transformer designers shall be responsible to select correct insulation levels to meet the requirement.

1.2. Current and step voltage

The current and step voltage requirement below shall be followed when selecting tap changer.

1.2.1. Rated through-current (Iu)
The current flowing through an tap changer toward the external circuit, which can be transferring from one tap to the other at the relevant rated step voltage and which can be carried continuously while meeting the requirement of the standard.

According to article 4.1 of IEC60076-1, tap changer rated through-current shall not be less than the maximum tap current of transformer winding under rated capacity. Rated through-current correlates with continuous load. If transformer has different apparent capacity in different environment (for example in different cooling modes), then the bigger capacity shall be taken as the rated capacity. Therefore, it is also the reference value of the rated through-current of the tap changer.

1.2.2. Overload current
Tap changer in compliance with article 5.2.1 of IEC60214-1-2003 shall meet the overload requirement of IEC 60354.

Number of tap changes during accidental overload shall be limited to number of operations from one end position to the other.

In case transformer overload exceeds the limit stipulated by IEC 60354 for special application, please consult tap changer manufacturer to recommend a tap changer with suitable rated value.

1.2.3. Rated step voltage (Ui)
For each value of rated through current, the highest permissible voltage between terminals which are intended to be connected to successive taps of the transformer.

Tap changer rated step voltage shall not be less than the maximum step voltage of the tap winding. As long as the voltage imposed on the transformer does not exceed the limit stipulated in Article 4.4 of IEC60076-1, tap changer should be able to make the switching operation.

In case tap changer is required to make frequent switching under higher imposed voltage of transformer, rated step voltage of tap changer shall be increased accordingly.

Tap changer transition resistor is designed in accordance with the actual value of transformer maximum step voltage Ust and rated through-current Iu. Hence, to use tap changer which is ordered with certain step voltage and rated through-current of a transformer in another different transformer other than the original one, please consult us to verify whether the transition resistor needs to be replaced. Even if the new rated value is less than the original maximum step voltage Ust and rated through-current Iu, such verification still needs to be done. Because matching of the transition resistor will not only affect the contact switching capacity, but also the evenness of contact wear.

1.3. Breaking capacity

If the biggest tapping current and each step voltage is within the tap changer nominal rated through-current and its relevant rated step voltage, then the breaking capacity of such tap changer meets the requirement.

Please consult tap changer manufacturer in case the value exceeds the nominal value.

When tap changer is to be used in the transformer with variable current and step voltage, the design of the transition impedance shall ensure the switching current and recovery voltage does not exceed such values in the product type test.

In case of abnormal voltage and current variation, tap changer manufacturer shall explain its influence on the breaking capacity upon customer request.

1.4. Short circuit current

There are three parameters of permissible short circuit current of tap changer.

1) Rated short duration withstand current: represented by the effective value of short circuit current
2) Rated withstand peak value: represented by the maximum peak value of the short circuit current
3) Short circuit current duration: represented by the permissible short circuit continuous period for short circuit current test.

According to article 5.2.3 of IEC60214-1:2003, tap changer short circuit current shall not be less than the transformer current limit. Such current limit value is calculated as per article 3.2 of IEC60076-5. For the permissible short circuit duration under short circuit current test less than rated value, or for the permissible short circuit current value with longer withstand duration, both can be calculated as per following equation:

$I_x^2 \cdot t_x = I_k^2 \cdot t_k$

Where: I_k: rated short duration withstand current; t_k rated short circuit duration,

I_x Permissible short duration current for duration; t_x Permissible short circuit duration under short circuit current I_x

It rarely happens that transformer is impacted by short circuit current during service. For transformers more frequently impacted by short circuit current, (such as industrial transformer, testing transformer, low impedance transformer etc.), tap changer with better short circuit withstand ability shall be selected according to short circuit strength and frequency.

1.5. Tap positions

Tap changer inherent position has been standardized by tap changer manufacturer. Transformer designer shall select tap position within standard series.

With more tap range, the voltage regulation range also increases. Therefore, necessary measures must be taken to limit over voltage when the tap position is on the minimum effective turns. This situation is very common in furnace transformer or rectification transformer with big tap range. Besides, tap changer is in constant potential winding, where the core flux variation range is very big.

1.6. Recovery voltage of change-over selector

For transformers with high voltage rating and big regulation range, during the operation of the change-over selector, the tap winding is disconnected momentarily from the main winding and in a so-called "suspension" status. At that moment, the tap winding takes a new potential which is determined together by the coupling capacitance to ground Ce and coupling capacitance to the adjacent winding Cw. (refer details to Fig. 2). Usually this potential is different from the previous potential of the tap winding before the operation. The difference between the two is called bias voltage. This bias voltage turns out to be the recovery voltage Uw on the gap of the change-over selector. When the bias voltage exceeds a certain critical value, the change-over selector would discharge electricity and produce considerable amount of gas. This current is called breaking current Is. Different tap changer is with different recovery voltage Uw and permissible breaking current Is. The permissible breaking strength is shown in Fig. 3.

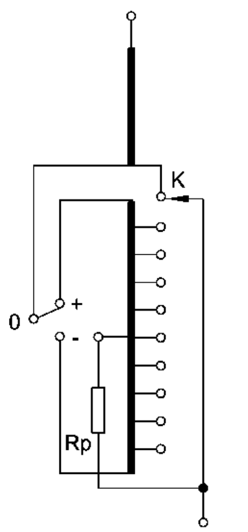


Fig.1 Permanent Connection of the Tie-in Resistor

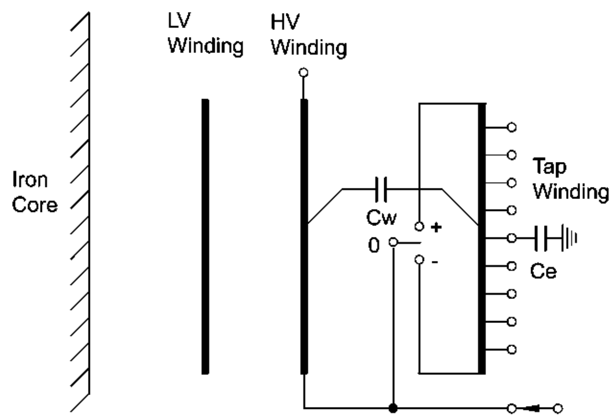


Fig 2 Winding Arrangement of Reversing Regulation of Double Winding Transformer

Therefore, when selecting tap changer, the breaking strength of coarse/fine and reversing change-over selector must be verified. If the result exceeds the permissible value shown in Fig 3, tap winding must be connected to a fixed potential during switching (As in fig.1) to avoid discharge of the change-over selector. But whether tie-in resistor is connected or not, the transformer winding design must not exceeds the nominal switching values provided by tap changer manufacturer.

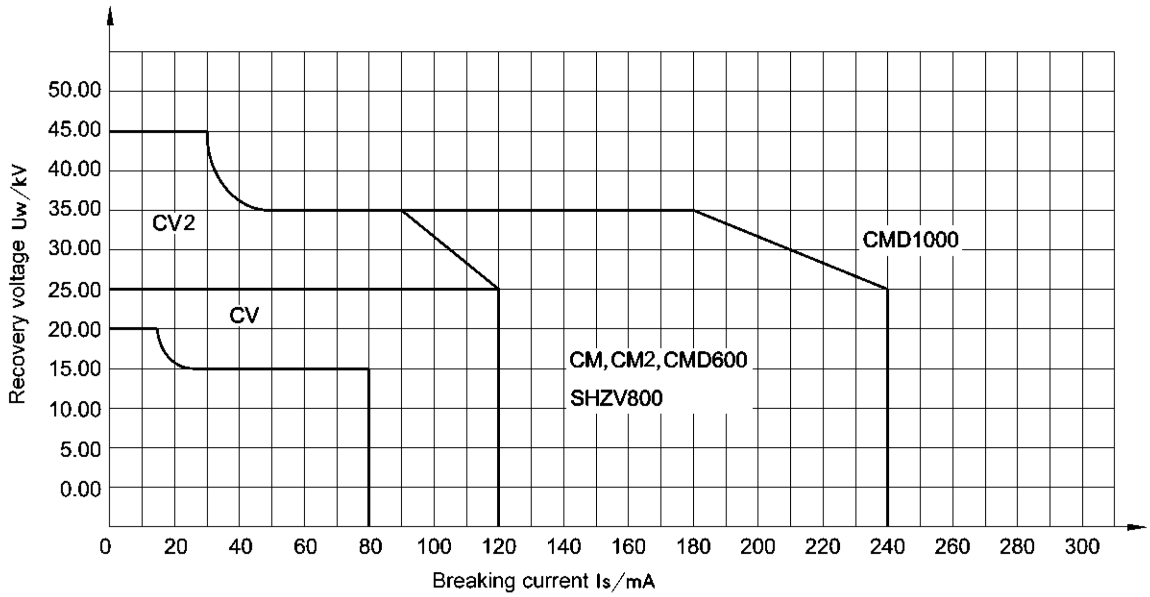


Fig.3 Breaking strength of change-over selector without tie-in resistor

Because of the connection of tie-in resistor, the recovery voltage between the change-over selector contacts is reduced. But the breaking currents is increased due to the extra current going through the tie-in resistor. Fig 4 shows the permissible breaking strength value with tie-in resistor for different types of tap changer. Fig.6 shows the breaking strength calculation method of change-over selector contacts for different voltage regulation arrangements. Transformer designer can follow the formulas to calculate when selecting tap changer. Please consult us if the breaking strength exceeds the permissible value. We can calculate the breaking strength and tie-in resistor value if the user/transformer designer provide the following data:

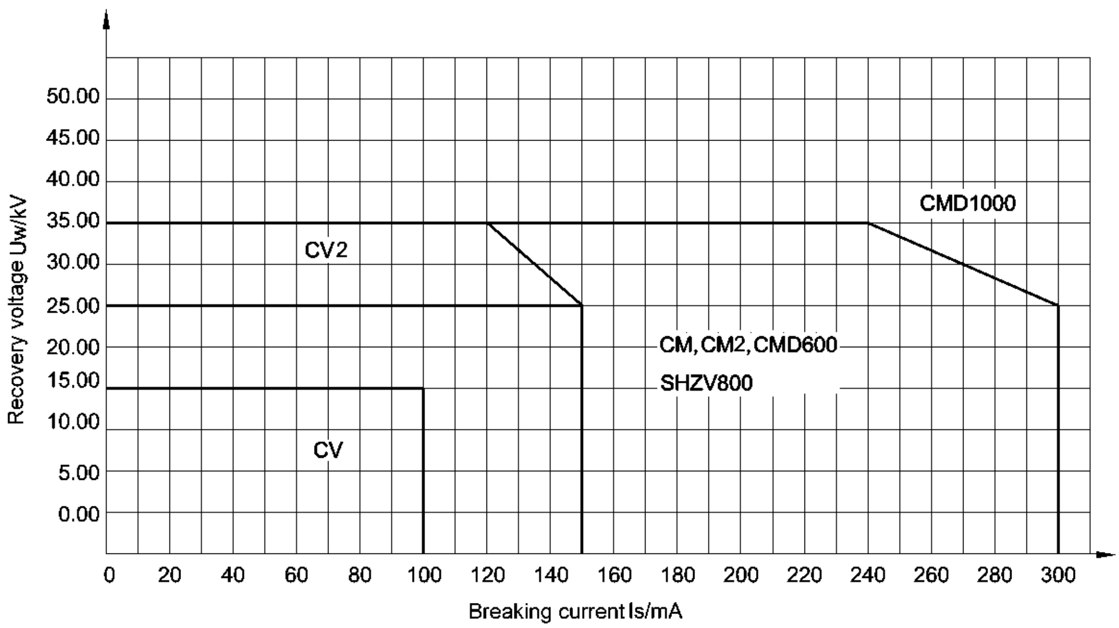


Fig. 4 Breaking strength of change-over selector with tie-in resistor

1) Complete transformer parameter: rated capacity, rated voltage, voltage regulating range, winding connection model, insulation level and so on
2) Arrangement of the windings, i.e. the relative position of the tap winding to the adjacent coil or winding parts
3) Operating A.C. voltage across windings or layers of windings adjacent to the tap windings
4) Capacitance of the tap winding to adjacent windings (C_w)
5) Capacitance of the tap winding to ground or grounded adjacent windings (if exist) (C_e)
6) Voltage stress across half the tap winding at lightning impulse voltage test
7) A.C. voltage across half the tap winding under operation and test conditions.(is normally derived from order specification sheet for tap changer)

The tie-in resistor can either be permanently connected or connected by potential switch. For permanent connection (As in Fig.1), the tie-in resistor is permanently connected between the mid position of tap winding and current take-off terminal. Voltage on both ends of tie-in resistor changes between zero and half of tap winding voltage along with different tap positions. Because of permanent connection, the permissible heat load strength is low. The other tie-in resistor connection is by potential switch (as in Fig. 5). The potential switch is serially connected with tie-in resistor. During the switching of change-over selector, the potential switch makes or breaks the connection of tie-in resistor. By this connection, the permissible heat load value can be increased, meanwhile the no-load loss of transformer is avoided compared with permanent connection.

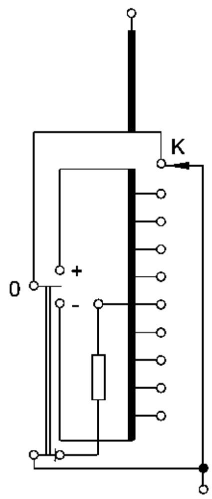


Fig.5 Tie-in resistor connection by potential switch

Example of recovery voltage calculation
Transformer is star connected and regulated at neutral point.
Rated capacity: P_N=325MVA
HV winding: 240kV (1±10×1.25%)
Winding capacitance: C_1=1950pF (between main winding and tap winding)
C_2=450pF (between tap winding and earth)
Assume winding capacitance C1 and C2 is concentrated on mid of winding, by above data:
U_1=240kV; U_T=240×12.5%=30kV

$$|U_{r+}|=\frac{U_1}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)+\frac{U_T}{2\sqrt{3}}=(240/2\sqrt{3})\times[1950/(1950)+450)]+30/2\sqrt{3}=64.95\text{kV}$$

$$|U_{r-}|=\frac{U_1}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_T}{2\sqrt{3}}=(240/2\sqrt{3})\times[1950/(1950+450)]-30/2\sqrt{3}=47.63\text{kV}$$

$$I_{s+}=2\pi\times50[240\times1950/2\sqrt{3}+(30/2\sqrt{3})\times(1950+450)]=48.97\text{mA}$$

$$I_{s-}=2\pi\times50[240\times1950/2\sqrt{3}-(30/2\sqrt{3})\times(1950+450)]=35.91\text{mA}$$

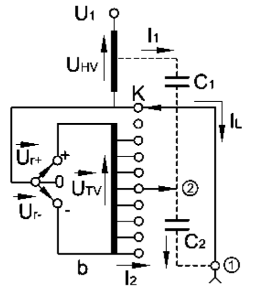
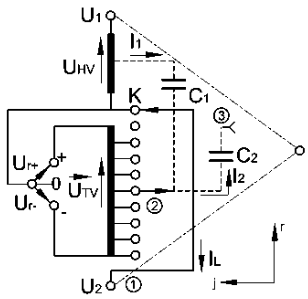
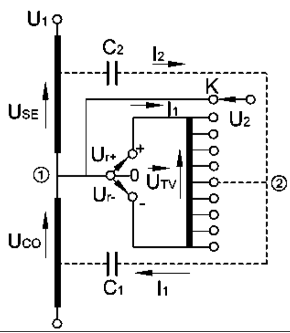
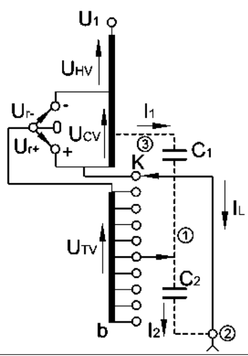
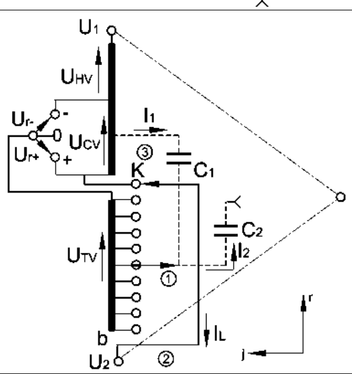
Regulation mode		Regulation circuit	Breaking strength of change-over selector contacts (recovery voltage Uw and breaking current Is)
Reversing Regulation	Neutral point of Y connection		$\lvert U_{r+}\rvert=\frac{U_1}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)+\frac{U_T}{2\sqrt{3}}$ $\lvert U_{r-}\rvert=\frac{U_1}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_T}{2\sqrt{3}}$ $\lvert I_{s+}\rvert=\omega\left[\frac{U_1}{2\sqrt{3}}C_1+\frac{U_T}{2\sqrt{3}}(C_1+C_2)\right]$ $\lvert I_{s-}\rvert=\omega\left[\frac{U_1}{2\sqrt{3}}C_1-\frac{U_T}{2\sqrt{3}}(C_1+C_2)\right]$
	Delta connection		$U_{r+/-}=\frac{U_1}{2}\pm\frac{U_T}{2}-j\frac{U_1}{2\sqrt{3}}\cdot\frac{C_2}{C_1+C_2}$ $\lvert U_{r+/-}\rvert=\sqrt{\left(\frac{U_1}{2}\pm\frac{U_T}{2}\right)^2+\left(\frac{U_1}{2\sqrt{3}}\cdot\frac{C_2}{C_1+C_2}\right)^2}$ $\lvert I_{s+/-}\rvert=\omega\sqrt{\left(\frac{U_1}{2\sqrt{3}}C_2\right)^2+\left[\left(\frac{U_1\pm U_T}{2}\right)(C_1+C_2)\right]^2}$
	Mid position regulation of auto transformer		$\lvert U_{r+/-}\rvert=-\frac{U_2}{2\sqrt{3}}+\frac{U_1}{2\sqrt{3}}\left(\frac{C_2}{C_1+C_2}\right)\mp\frac{U_T}{2\sqrt{3}}$ $\lvert I_{s+/-}\rvert=\omega\left[\frac{U_1}{2\sqrt{3}}C_2\mp\frac{U_T}{2\sqrt{3}}(C_1+C_2)-\frac{U_2}{2\sqrt{3}}(C_1+C_2)\right]$
Coarse/fine regulation	Neutral point of Y connection		$\lvert U_{r+}\rvert=-\frac{U_C}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_T}{2\sqrt{3}}$ $\lvert U_{r-}\rvert=-\frac{U_C}{2\sqrt{3}}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_T}{2\sqrt{3}}+\frac{U_C}{\sqrt{3}}$ $\lvert I_{s+}\rvert=\omega\left[\frac{U_T}{2\sqrt{3}}(C_1+C_2)+\frac{U_C}{2\sqrt{3}}C_1\right]$ $\lvert I_{s-}\rvert=\omega\left[\frac{U_T}{2\sqrt{3}}(C_1+C_2)+\frac{U_C}{2\sqrt{3}}C_1-\frac{U_C}{\sqrt{3}}(C_1+C_2)\right]$
	Delta connection		$\lvert U_{r+}\rvert=\sqrt{\left[\frac{U_1}{2}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_1+U_C+U_T}{2}\right]^2+\left[\frac{U_1+U_C}{2\sqrt{3}}\left(1-\frac{C_2}{C_1+C_2}\right)\right]^2}$ $\lvert U_{r-}\rvert=\sqrt{\left[\frac{U_1}{2}\left(\frac{C_1}{C_1+C_2}\right)-\frac{U_1+U_C+U_T}{2}+U_C\right]^2+\left[\frac{U_1+U_C}{2\sqrt{3}}\left(1-\frac{C_1}{C_1+C_2}\right)\right]^2}$ $\lvert I_{s+}\rvert=\omega\sqrt{\left[\frac{U_1+U_C}{2\sqrt{3}}C_2\right]^2+\left[\frac{U_T+U_C}{2}C_1+\frac{U_T+U_1+U_C}{2}C_2\right]^2}$ $\lvert I_{s-}\rvert=\omega\sqrt{\left[\frac{U_1+U_C}{2\sqrt{3}}C_2\right]^2+\left[\frac{U_T+U_C}{2}C_1+\frac{U_T+U_1+U_C}{2}C_2-U_C(C_1+C_2)\right]^2}$

Fig.6 Breaking strength calculation of change-over selector contacts for different regulation modes

1.7. Switching of magnetic flux leakage induction

For resistive tap changer, when it changes from the end of fine tap winding to the end of coarse tap winding, under reversing serial connection of two windings, there will be considerable magnetic flux leakage induction produced in tap changer switching circuit (as in fig. 7). This flux leakage induction becomes the internal impedance of this serial connection, which causes switching current and recovery voltage phase displacement of diverter switch or tap selector. Consequently, the arcing extinguishing time is extended. But for service positions other than the above, there is only one step voltage flux leakage induction impedance, which can be neglected compared with transition resistor value.

In certain cases, this flux leakage induction could be a critical factor when selecting tap changer. Therefore, transformer designer should ensure not to exceed any leakage induction level or switching parameters provided by tap changer manufacturer.

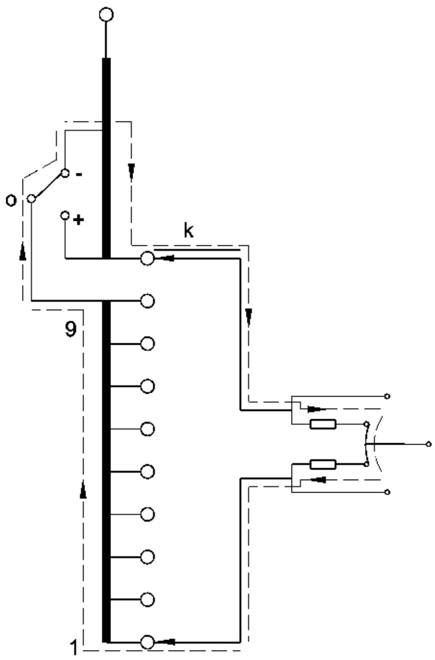


Fig. 7 Schematic diagram of flux leakage induction for coarse/fine regulation

1.8. Out-of-step status between transformers and phases

When two (or more) transformers work in parallel, there could be a short time out-of -step situation between phases because of the operation time difference of tap changers.

This will lead to transformer and tap changer load difference. Different impedance voltage causes different load. Besides, different voltage will cause circulating current between transformers. This circulating current will be limited by the circuit impedance. These circulating current will jointly contribute to the load current and affect the breaking strength of tap changer. When evaluating switching condition, do not consider the current only in absolute value, but also take into account the phase displacement on the diverter switch contacts.

When selecting single phase on-load tap changer in delta and star connection, there is possibility of out-of-step. Even if tap changer is driven by one motor drive unit, or by three motor drive units with one command signal, it can't prevent the diverter switch or tap selector from out-of-step. If the tap winding is delta connected, voltage difference will cause circulating current. Therefore, when designing transformer winding and selecting tap changer rated current value, this extra current should be taken into consideration.

1.9. Forced current division

For big current single phase tap changer, if the current needs to be divided forcedly for special model or special application, then several current branches can be connected in parallel. Transformer design shall consider two more parallel winding branches, and require forced divided structure both for tap winding and main winding. The impedance of parallel windings must be at least two or three times higher than the actual transition resistor of the diverter switch, in order to ensure forced current even when the tap changer is in switching process and limit the circulating current. Any extra circulating current must not cause the tap changer to switch beyond the nominal switching parameter between parallel branches. In forced current division structure, the parallel contacts must not be short connected.

Please consult us for this application and provide complete winding arrangement drawing of the parallel winding.

1.10. Tap changer used in non sine current special transformer

If tap changer used in special transformers with high-order harmonic through-current, transformer designer must define such non sine current. These non sine through-current has big impact on tap changer breaking strength, which must be controlled by diverter switch. For resistive tap changer working by pennant cycle or multi-resistor circulation, the increase of recovery voltage on main shunt contacts means the through current causes voltage drop on ends of the transition resistor. Hence, recovery voltage is also a non-sine curve.

Transformer designer shall provide curve and overload details to us.

1.11. Tap changer used in variant step voltage

The maximum possible step voltage must be considered when tap changer is used in variable step voltage transformers, such variable flux regulation, different turn voltage of tap winding, phase shifters where step voltage changes with load and tap position and wide range voltage fluctuation, etc.

When actual required step voltage and relevant through-current is variable, the biggest step voltage and maximum through-current combination must be considered within the permissible switching capacity range. Tap changer selecting must assume both the maximum step voltage and maximum through-current will occur at the same time. If this value exceeds the permissible nominal switching capacity provided by tap changer technical data, please consult us.

1.12. On-Load tap changer used in furnace transformer

The load character of furnace transformer is relatively special. Its overload can be 2.5 times rated load during service. The matching OLTC must endure the same overload, too. When selecting tap changer, the rated value must be adjusted based on actual overload situation. When at rated through-current, the permissible step voltage must be reduced to 80% of the nominal technical data.

When designing a furnace transformer, transformer designer shall provide us with transformer connection diagram and transformer nameplate for the design and production of tap changer.

1.13. Contact life

Service duty test has set a bottom line for the operation life of OLTC at maximum current and relevant step voltage. The nominal contact life provided in each OLTC technical is defined on the same basis. For example, current value, voltage level, power factor and tap change range etc. OLTC technical data also gives contact life under different load current. However, it shall be specially treated when tap changer is used for unusually frequent operation, such as electrolysis transformer, furnace transformer, etc. To use a higher rating tap changer for achieving intended contact life for such application, please pay attention to the impact of circulating current, by which the transition contact wear may not be even.

1.14. Tap changer operating in low temperature

If the tap changer is to be used in oil below -25℃ , please specify it when placing the order for the provision of temperature control and protection devices.

2. Attention for tap changer mounting

Tap changer shall be vertically mounted into transformer, vertical inclination of OLTC should not be over 2% when it is mounted onto the transformer. The mounting method of each tap changer is subject to transformer structure design.

3. Oil drainage pipe

3.1. Oil drainage pipe

Tap changer is usually equipped with an oil drainage pipe. When designing the height of oil drainage pipe, please refer to Fig. 8.

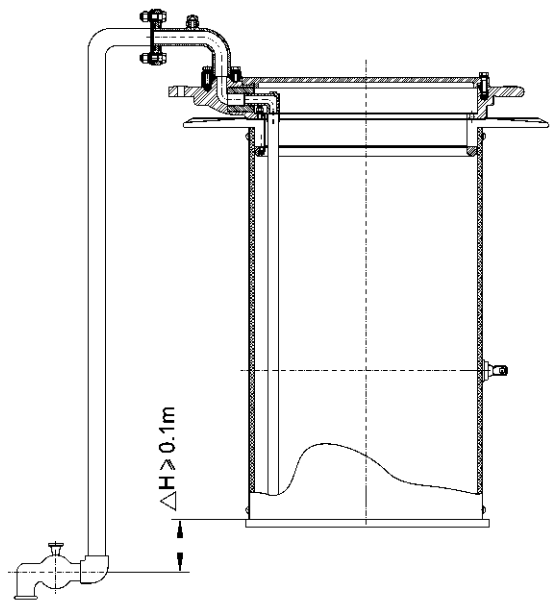


Fig.8 Height of tap changer oil drainage pipe

3.2. Protectiva relay

Protective relay is the one of protective devices for oil-immersed on-load tap changer, when OLTC interior failure produces gas and oil surge, the protective relay contact acts, produces signal, or switches on to the tripping circuit of the transformer circuit breaker, the transformer will be cut off at once.

Protective relay is installed in the pipe which connects the OLTC head oil elbow pipe and oil conservator. The "Arrow" mark shall be directed to the side of the oil conservator when being installed. We provide four models of protective relay, namely QJ4-25, QJ4G-25, QJ6-25 and QJ4-25A. Different tap changer matches with different models of protective relay. OLTC with arc extinguishing in oil matches with QJ4G-25 (1 pair of trip contact) or QJ6-25(2 pairs of trip contact). OLTC with arc extinguishing in vacuum interrupter matches with QJ4-25 or QJ4-25A,both have gas signal and trip signal, please refer to appendix for details.

3.3. Pressure relief device

Pressure relief valve and rupture disc are safety protection devices of oil-immersed on-load tap changer. In case tap changer has an internal failure, which decomposes the oil in the compartment and produces large amount gas, the internal pressure inside the oil compartment will increase dramatically. If this pressure couldn't be released, tap changer will be deformed or even explode. Therefore, pressure relief devices can avoid the upgrade of the failure.

Pressure relief valve is a self-sealing relief valve. It opens the cover in case of over pressure and re-closes after the pressure is released, which can be used repeatedly and minimize the liquid loss during the operation.

The rupture disc is a weak point on the top cover of tap changer. Once the pressure in the oil compartment exceeds the set value, the disc will explode to release the over pressure of the compartment, as a result the oil compartment will be prevented from damage.

Pressure relief valve is a low-energy failure protection device. The rupture disc is a high-energy protection device. Tap changer failure usually tends to be high-energy failure. Hence, pressure relief valve is not recommended for tap changer, or use it as an assistant protection besides the rupture disc. Therefore, pressure relief valve is an optional accessory of tap changer for customer to select when ordering the tap changer.

3.4. Driving shaft

Driving shaft is the transmission device between motor drive unit and tap changer. For mounting and connection arrangement, please refer to appendix.

3.5. Bevel gearbox

Bevel gearbox is used for the inter-connection of tap changer horizontal shaft and motor drive unit vertical shaft, in order to transfer the motor drive unit driving torque to the tap changer. Different tap changer matches with gearboxes of different transmission ratio. Its overall dimension is shown in Appendix 3-1& 3-2.

3.6. On line oil filter plant

On-line oil filter is used to filter the transformer oil inside tap changer in circulation. This device can effectively filter carbon and metallic particles from the oil inside tap changer, and reduce its moisture. As a result, tap changer operation reliability is increased and maintenance interval is extended. For tap changer under frequent operations, such as furnace transformer, rectification transformer etc, the on-line oil filter plant is recommended. Meanwhile, for high rating voltage regulating transformer, on-line oil filter is also recommended.

3.7. Motor drive unit

On load tap changer is driven by motor drive unit SHM-III, CMA7 and CMA9. For different OLTC and technical requirement, customer may choose suitable motor drive unit. Their technical data is below in Table 1.

3.8. Tap changer operation controller

3.8.1 HMK8 controller

HMK8 controller is the device for remote control of SHM-III motor drive unit; it realizes OLTC switching operation through SHM-III. HMK8 can display the OLTC switching operation status and tap positions.

HMK8 has BCD code position signal output (contact capacity:AC250V/5A or DC30V/5A) and remote control signal input (non potential contact), it can also communicate with host computer via RS485 interface to realize remote supervising of OLTC position.

HMK8 main technical data is as below, refer to HMK8 manual for more details.
Working voltage: 380V, 3AC/N
Power frequency: 50Hz/60Hz
Maximum operation positions: 35
Environment temperature: -10℃ to 40℃ Indoor

3.8.2 HMC-3C OLTC tap position indicator
HMC-3C OLTC tap position indicator can be connected with CMA7 and CMA9 motor drive unit for remote indication. It has the operation function of "1→ N" "Stop" "N→ 1" and remote control indicating lamp.
HMC-3C technical data
Service voltage: 220V AC
Working frequency: 50Hz
Maximum indication number of tap position: 107
Service temperature: -10℃ ~ + 40℃
Note: For power supply other than the above, please specify when ordering

3.8.3 ET-SZ6 automatic voltage regulator
ET-SZ6 automatic voltage regulator is applicable to CMA7, CMA9 motor drive unit or SHM-III MDU through HMK8 controller, to realize manual or automatic operation for the on-load tap changer, its feature is as below:
1. tap position display
2. "1-N" , "N-1" and "stop" manual operation and automatic voltage regulating
3. remote operation command input
4. BCD position signal output (contact capacity: AC220V/5A)
5. RS485 interface
6. 4-20mA analog position signal output
7. parallel control up to 3 transformers
8. overvoltage warning and under voltage blocking

Table 1 Technical Data of Motor Drive Unit

Motor drive unit		SHM-III		CMA7		CMA9
Motor	Rated power (W)	750	1100	750	1100	370
	Rated voltage (V)	380,3AC/N		380/3AC		380/3AC
	Rated current (A)	2.1	2.8	2.0	2.8	1.1
	Rate frequency(Hz)	50 or 60		50 or 60		50 or 60
	Rotate speed (r.p.m.)	1400		1400		1400
Rated torque on drive shaft (Nm)		45	66	18	26	40
Revolution of the drive shaft per switching operation		33		33		2
Revolution of the hand crank per switching operation		33		33		30
Running time per switching operation (S)		5.6		About 5		About 4
Max. operation positions		35		107		27
Voltage for control circuit and heater circuit (V)		220/AC		220/AC		220/AC
Heater power (W)		50		50		30
A.C. voltage test to ground (kV/50Hz, 1min)		2		2		2
Approx. weight (kg)		73		90		70
Protective degree		IP66		IP56		IP56
Mechanical endurance (operations)		Not less than 2,000,000		Not less than 800,000		

ET-SZ6 main technical data is as below:
Working voltage: 220V/AC
Power frequency: 50Hz
Maximum operation positions: 35
Ambient air temperature: -20°C to 40°C Indoor

3.8.4 HMK-2A automatic voltage regulator
HMK-2A automatic voltage regulator is applicable to CAM7, CMA9 motor drive unit or SHM-III MDU through HMK8 controller, to realize manual and automatic operation for the on-load tap changer. HMK-2A has following main function:
1. tap position indicating
2. "1-N" , "N-1" and "stop" manual operation and automatic voltage regulating
3. remote operation command input
4. BCD position signal output (contact capacity: DC28V/1A)
5. overvoltage warning and under voltage blocking

HMK-2A main technical data is as below:
Working voltage: 220V/AC
Power frequency: 50Hz
Maximum operation positions: 35
Ambient air temperature: -20°C to 40°C Indoor

4. Tap changer selecting

4.1. Selecting principle and selecting procedure

Tap changer selecting principle is to meet the actual transformer operation and testing conditions. In normal conditions, power transformers do not have to consider safety margin of tap changer parameters and just choose the most cost-effective solutions. But for industrial transformers, the safety margin must be considered.

When selecting tap changer, the transformer designer must provide detailed technical parameters related to tap changer.

Main transformer parameter includes:
1) Rated capacity P_N
2) Connection of transformer winding (Neutral end of star connection, Delta connection, single phase)
3) Rated voltage and regulation range U_N (1±X%)
4) Steps, tap winding connection diagram
5) Rated insulation level
6) Voltage gradient on tap winding during impulse test and AC induction test

Based on the above data, basic tap changer parameters can be defined for selecting tap changer Firstly, calculate switching parameter of tap changer
1) Maximum through-current Imax: by item 1, 2 and 3.
2) Step voltage U_{st}: by item 3 and 4
3) Switching capacity: $P_{st}=U_{st} \times I_{max}$

Secondly, based on the above, select basic tap changer model:
1) Tap changer type
2) Number of phases
3) Maximum rated through-current

Thirdly, define tap changer insulation level and tap selector (or selector switch) specification:
1) Define tap changer main insulation level
2) Define tap changer internal insulation level
3) Basic connection diagram

Fourthly, verify the following parameter:
1) Switching capacity of diverter switch
2) Short duration overload
3) Permissible short circuit test current
4) Contact life of diverter switch.

4.2. Tap changer selecting example

4.2.1. Example

4.2.1.1. Power transformer technical specification
a) Rated capacity: P_N=50MVA
b) Transformer winding connection: Neutral end of star connection
c) Rated voltage and regulation range: 110 (1±10%)kV
d) Steps: ±8 steps, with change-over selector.
Tap winding connection is shown in Fig. 9.
e) Rated insulation level: HV winding PF: 230kV 50Hz, 1 min
BIL: 550kV 1.2/50μs
f) Voltage gradient on tap winding during impulse test and AC induction test

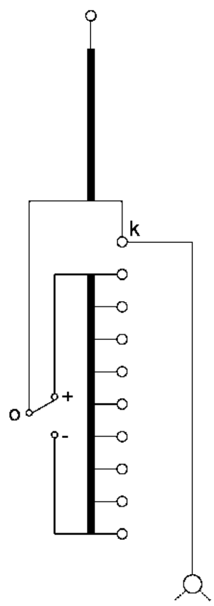


Fig.9 Transformer Connection Diagram

4.2.1.2. Calculate the switching data of tap changer
a) Maximum rated through-current I_{max}
$I_{max}=50\times 10^3/[110\times(1-10\%)\times\sqrt{3}]A=291.6A$
b) Step voltage U_{st}
$Ust= 110\times 10^3\times 10\%/[8\times\sqrt{3}]=793.9V$
c) Switching capacity:
$P_{st}= I_{max}\times U_{st}= 291.6\times 793.9\times 10^{-3}kVA=231.5kVA$

4.2.1.3. Define tap changer basic type with the above data
a) OLTC model: CM type
b) Number of phases: 3-phase
c) Maximum rated through-current: 500A

4.2.1.4. Define tap changer insulation and tap selector size
a) Define tap changer insulation to earth
According to the regulation schematic diagram, this transformer is to regulate voltage on the neutral point. The tap changer insulation to earth can select tap changer highest equipment voltage U_{max}=72.5kV, PF: 140kV 50Hz, 1min, BIL: 350kV 1.2/50μs.

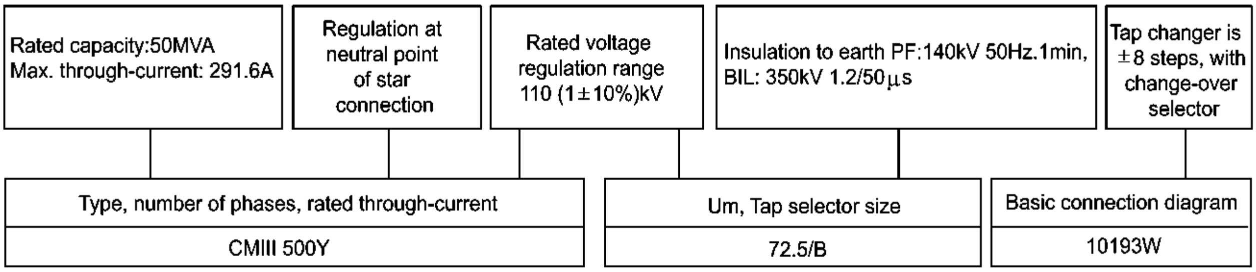
b) Define tap changer internal insulation level For insulation "a" across tap winding and "b" between any taps of different phases, the maximum impulse load can be calculated by voltage gradient K. Select K=3.5, then $U_{max}=3.5\times 10\%\times 550kV=192.5kV$.

AC working voltage load on insulation distance "a" and "b" ΣUi=793.9V¡Á8=6351V. Then, Rated separte source AC withstand voltage is 2~3 times AC working voltage, i.e. 6351V×3= 19053V. Hence, 20kV 50Hz, 1min is selected.

According to the above data, tap selector size B shall be selected.

c) Basic connection diagram
Based on the provided data, the tap selector should be 10193W.

4.2.1.5. Define tap changer model
After verification, the selected tap changer is CMIII500Y/72.5B-10193W.



4.2.2. Example 2

4.2.2.1. Power transformer technical specification
a) Rated capacity: PN=600MVA
b) Transformer winding connection: star connection
c) Rated voltage and regulation range: 220 (1±10%)kV
d) Steps: ±8 steps, with change-over selector. Tap winding connection is shown in Fig. 10.
e) Rated insulation level: HV winding PF: 230kV 50Hz, 1 min
BIL: 550kV 1.2/50μs
f) Voltage gradient on tap winding during impulse test and AC induction test

4.2.2.2. Calculate the switching data of tap changer
a) Maximum rated through-current I_{max}
$I_{max}=600\times10^{3}/[220\times(1-10\%)\times\sqrt{3}]A=1750A$
b) Step voltage U_{st}
$U_{st}=220\times10^{3}\times10\%/[8\times\sqrt{3}]=1587.7V$
c) Switching capacity:
$P_{st}=I_{max}\times U_{st}=1750\times1587.7\times10^{-3}kVA=2778.5kVA$

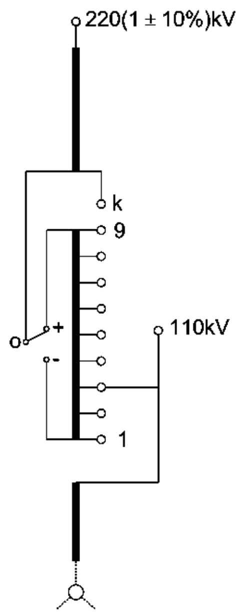


Fig.10 Transformer Connection Diagram

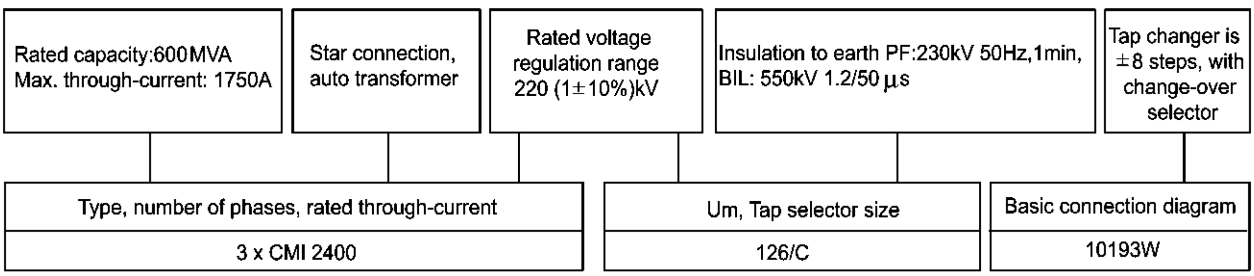
4.2.2.3. Define tap changer basic type with the above data
a) OLTC model: CMD type
b) Number of phases: I phase
c) Maximum rated through-current: 2400A

4.2.2.4. Define tap changer insulation and tap selector
a) Define tap changer insulation to earth
According to the regulation schematic diagram, this auto transformer is to regulate voltage in the middle of winding. The tap changer insulation to earth can select tap changer highest equipment voltage U_{max}=126kV, PF: 230kV 50Hz, 1min, BIL: 550kV 1.2/50μs.
b) Define tap changer internal insulation level
For insulation "a" across tap winding and "b" between any taps of different phases, the maximum impulse load can be calculated by voltage gradient K. Select K=5, then Umax=5×10%×550kV=275kV.

AC working voltage load on insulation distance "a" and "b" ΣUi=1587.7V×8=12701.6V. Then, Rate separate source A.C. withstand voltage is 2~3 times AC working voltage, i.e. 12701.6V×3= 38kV. Hence, 50kV 50Hz, 1min is selected. According to the above data, tap selector size C shall be selected.

c)Basic connection diagram
Based on the provided data, the tap selector should be 10193W.

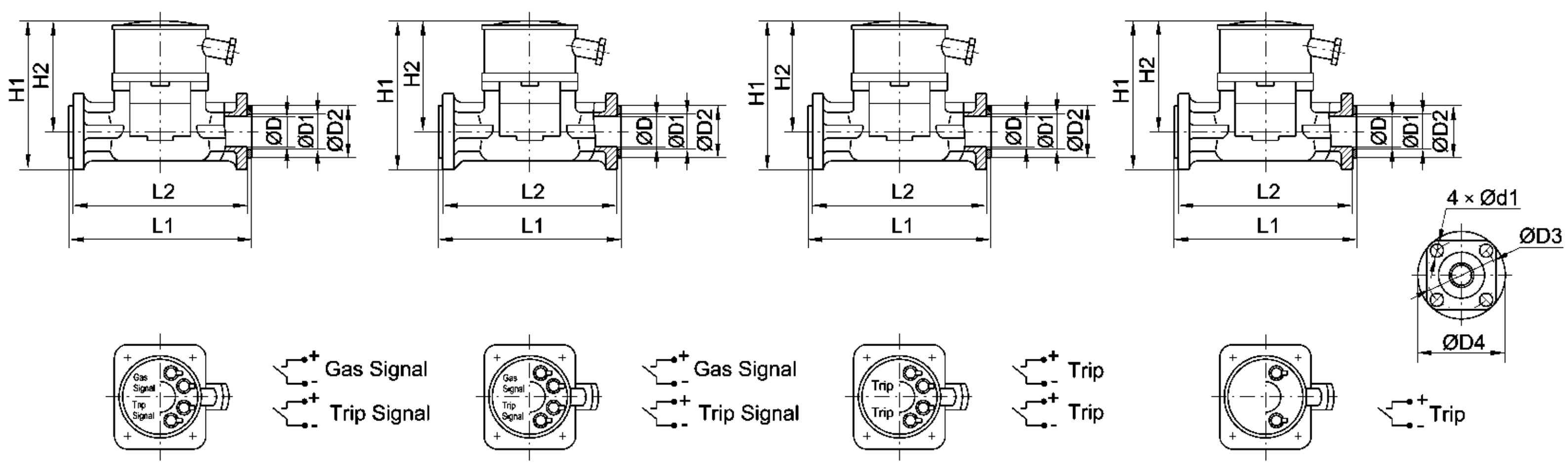
4.2.2.5. Define tap changer model After verification, the selected tap changer is 3×CMDI 2400/126C-10193W.



5. Appendices

Appendix 1 Overall dimension of protective relay

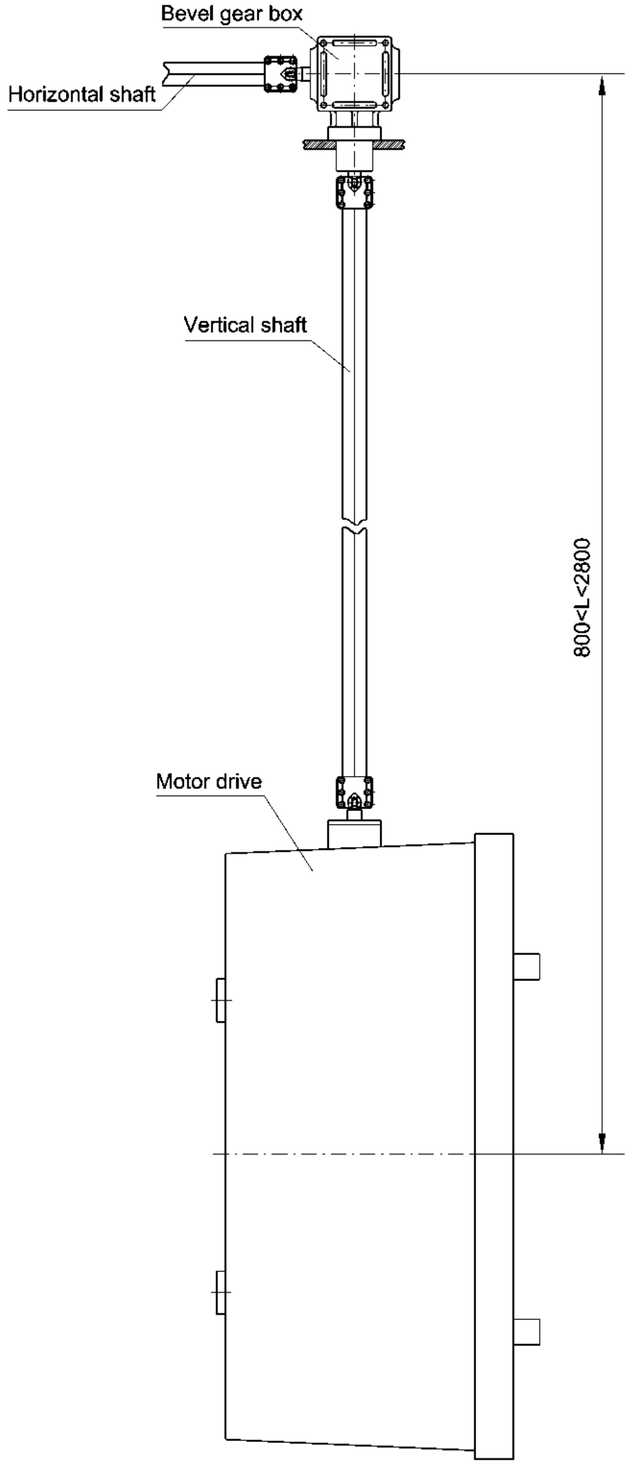
Type QJ4-25A protective relay   Type QJ4-25 protective relay   Type QJ6-25 protective relay   Type QJ4G-25 protective relay



Model	D	D1	D2	D3	D4	d1	H1	H2	L1	L2	Note
QJ4-25A	25	35	65	85	115	14	215	153	208	200	1 pair of gas signal and 1 pair of trip signal, gas release device connected to man position
QJ4-25	25	35	65	85	115	14	215	153	208	200	1 pair of gas signal and 1 pair of trip signal
QJ4G-25	25	35	65	85	115	14	195	133	208	200	With one pair of trip signal
QJ6-25	25	35	65	85	115	14	215	153	208	200	With two pairs of trip signals

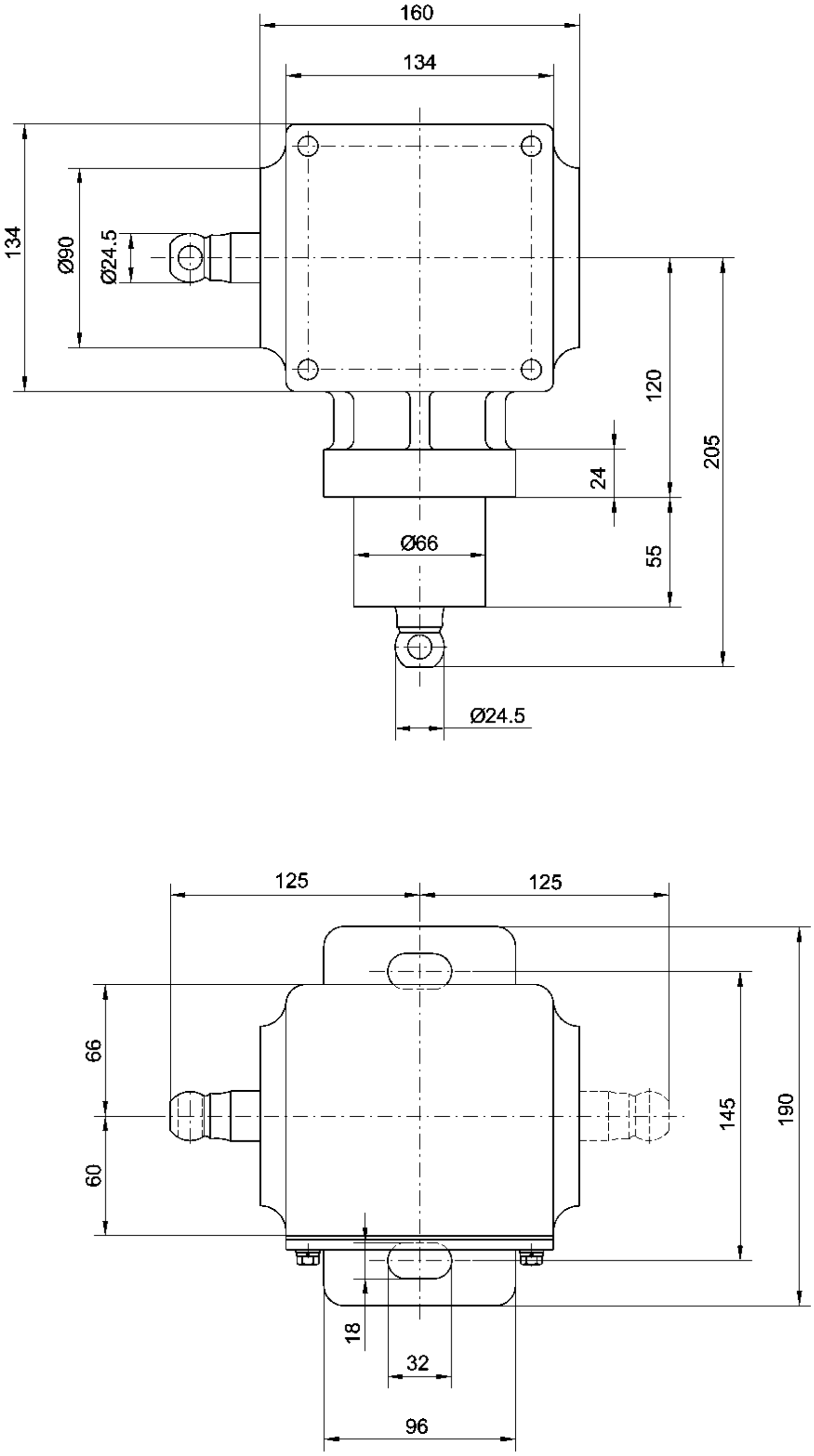
Unit: mm

Appendix 2 Mounting diagram of driving shaft



Unit: mm

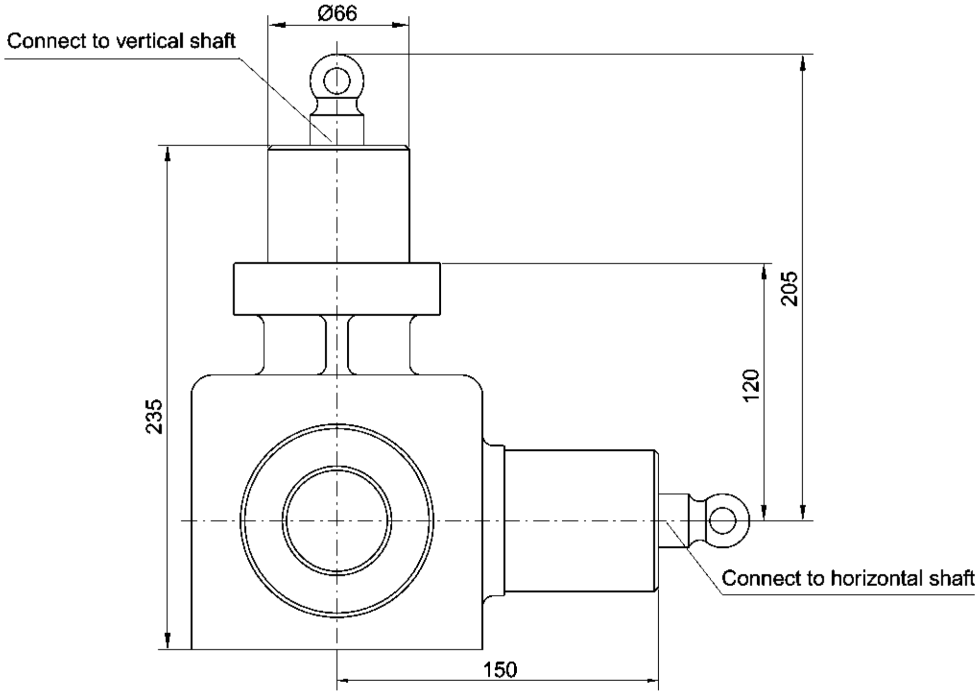
Appendix 3-1 Overall dimension of bevel gearbox

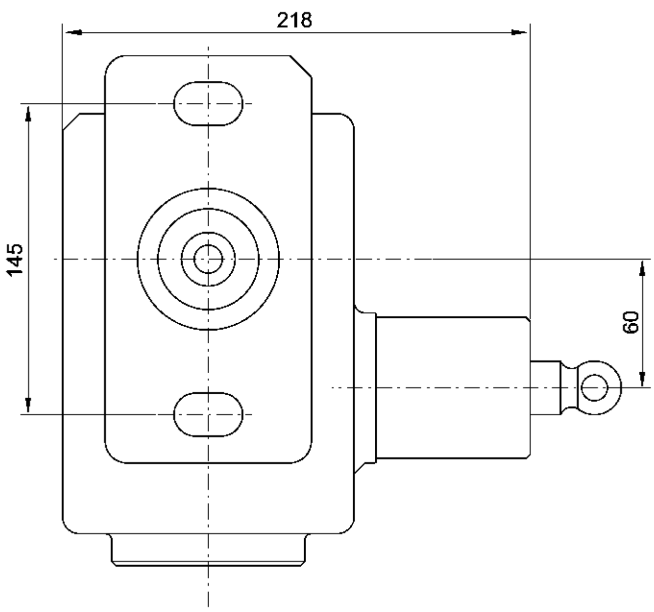


Remark: Please refer to technical data for suitable bevel gearbox of the tap changer

Unit: mm

Appendix 3-2 Overall dimension of bevel gearbox

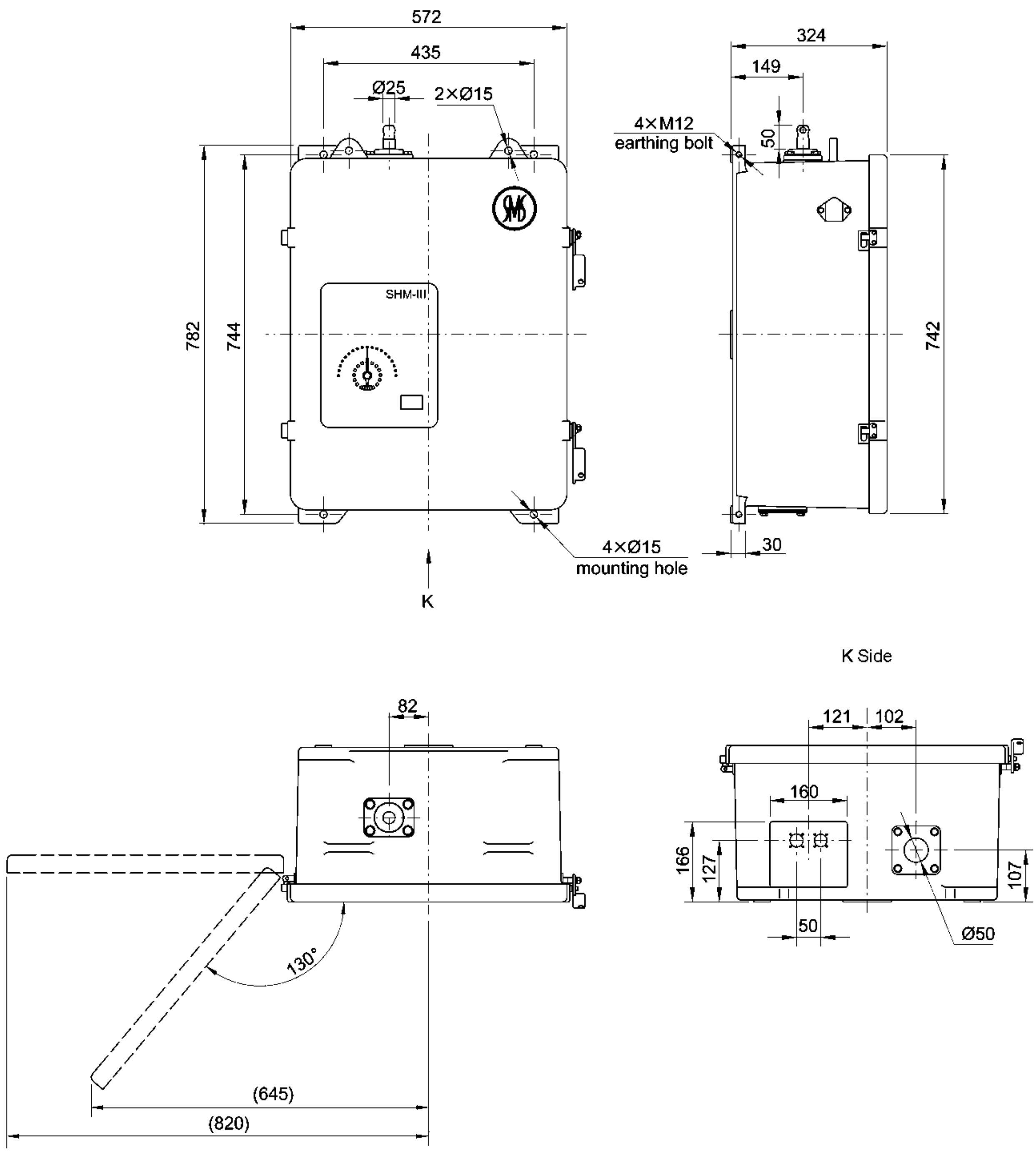




Remark: Please refer to technical data for suitable bevel gearbox of the tap changer

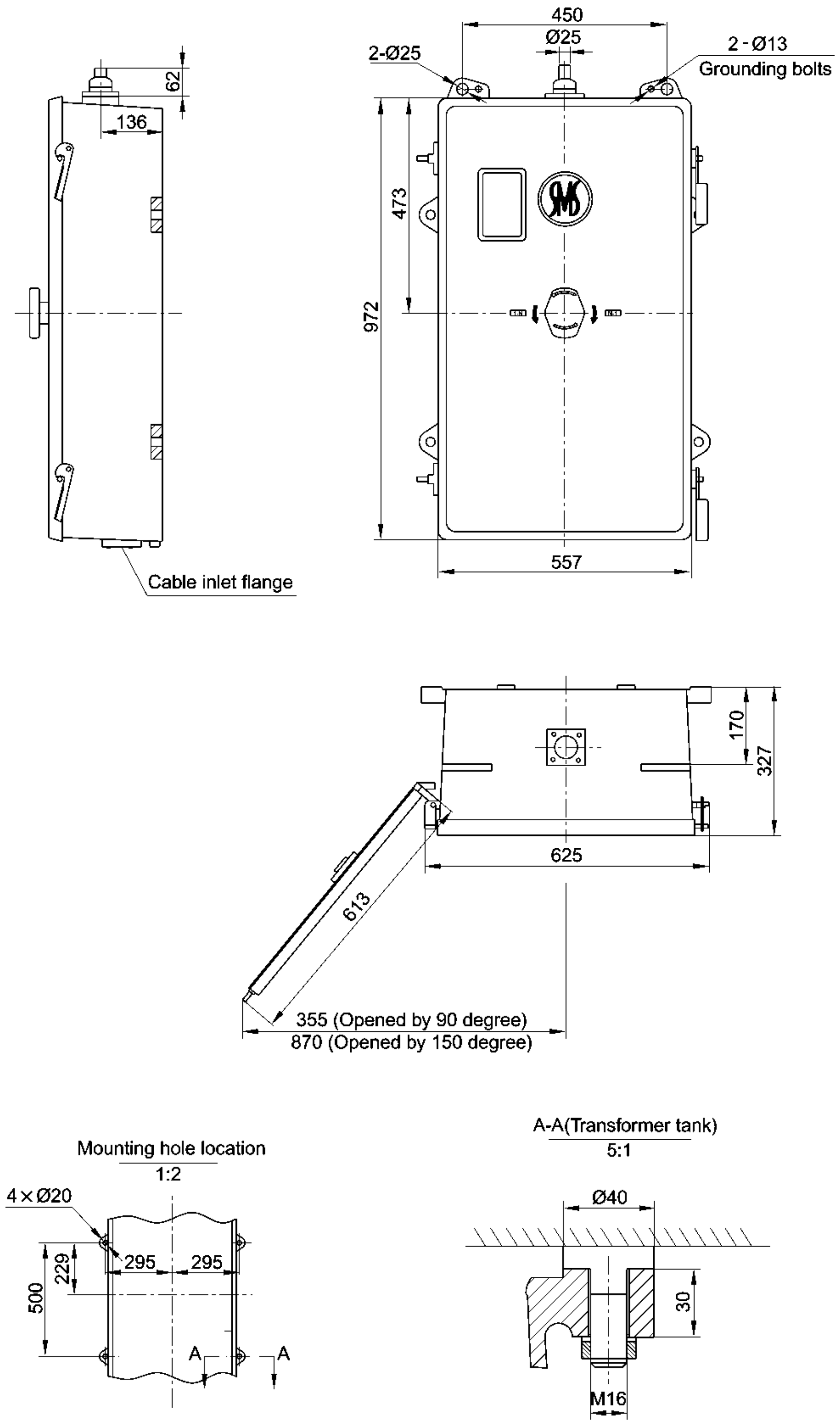
Unit: mm

Appendix 4 Overall dimension of SHM-III motor drive unit



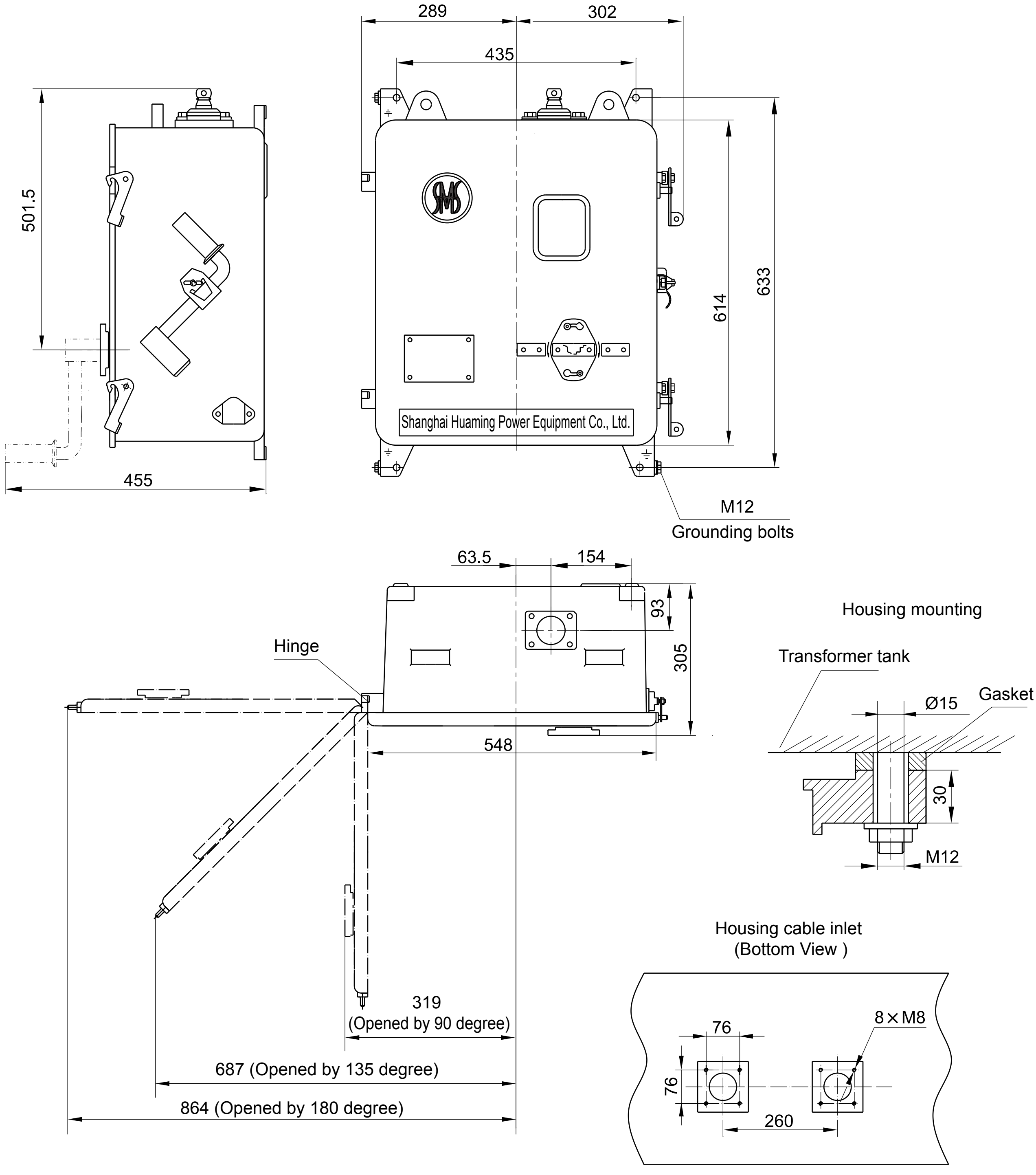
Unit: mm

Appendix 5 Overall dimension of CMA7 motor drive unit



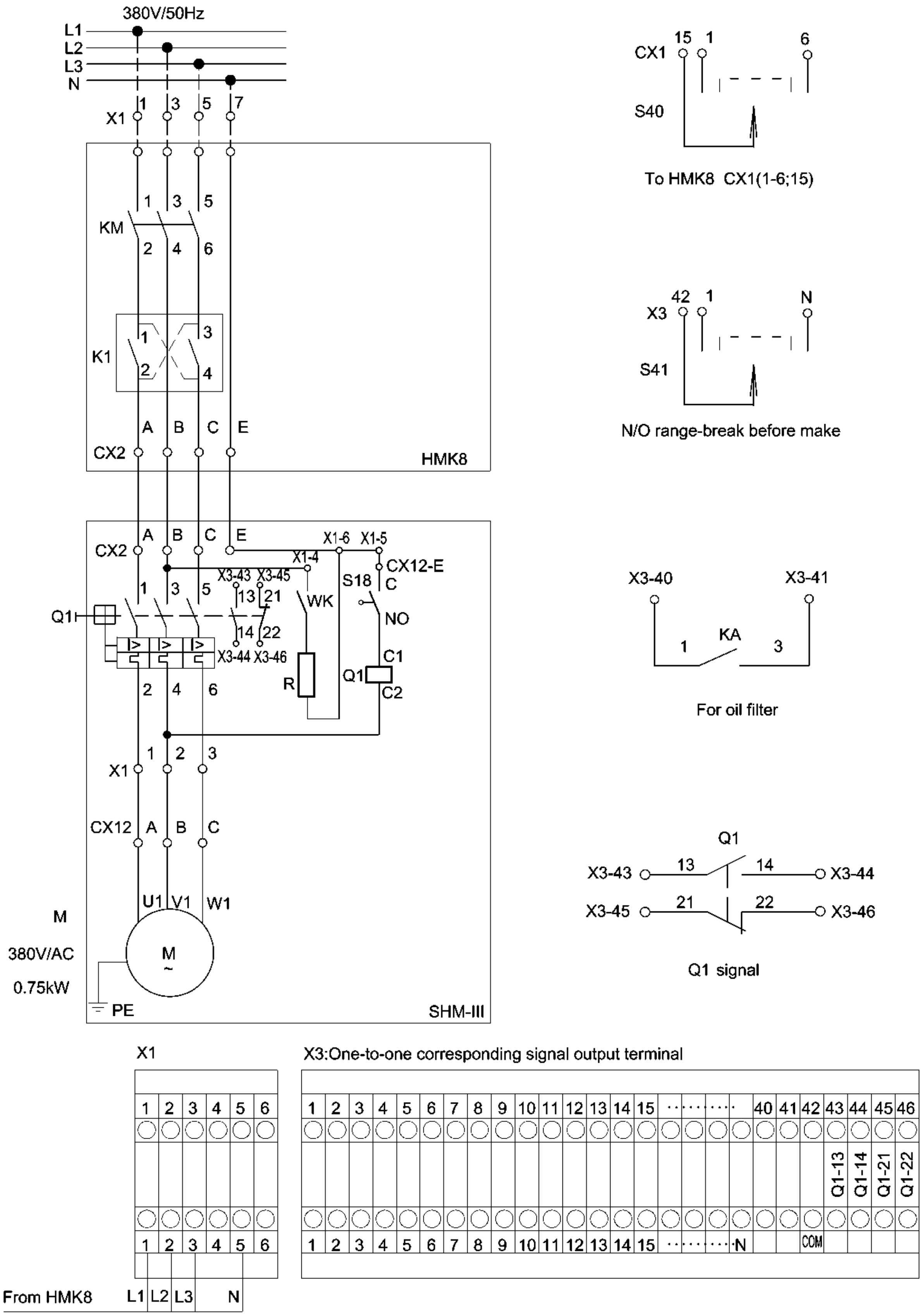
Unit: mm

Appendix 6 Overall dimension of CMA9 motor drive unit

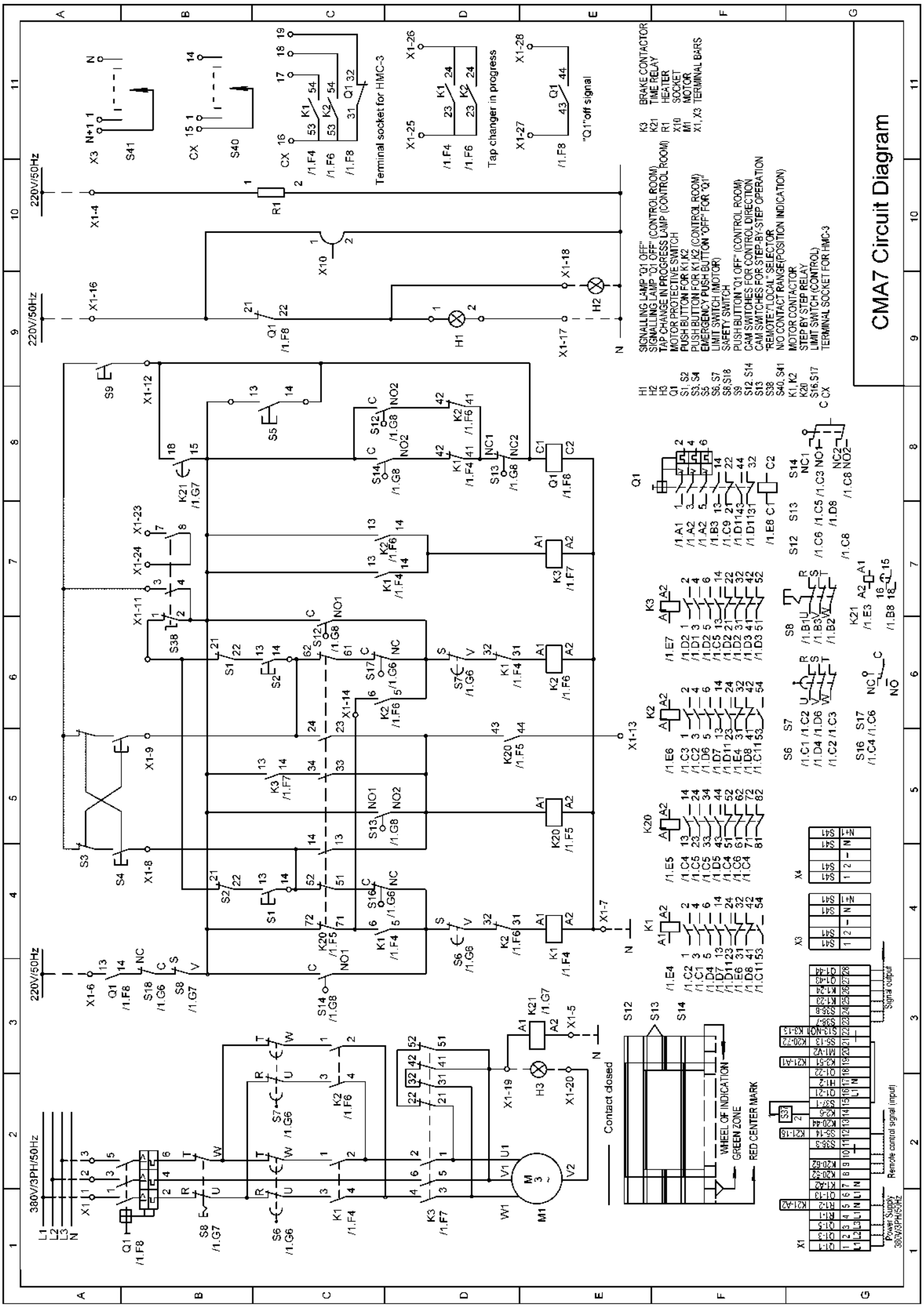


Unit: mm

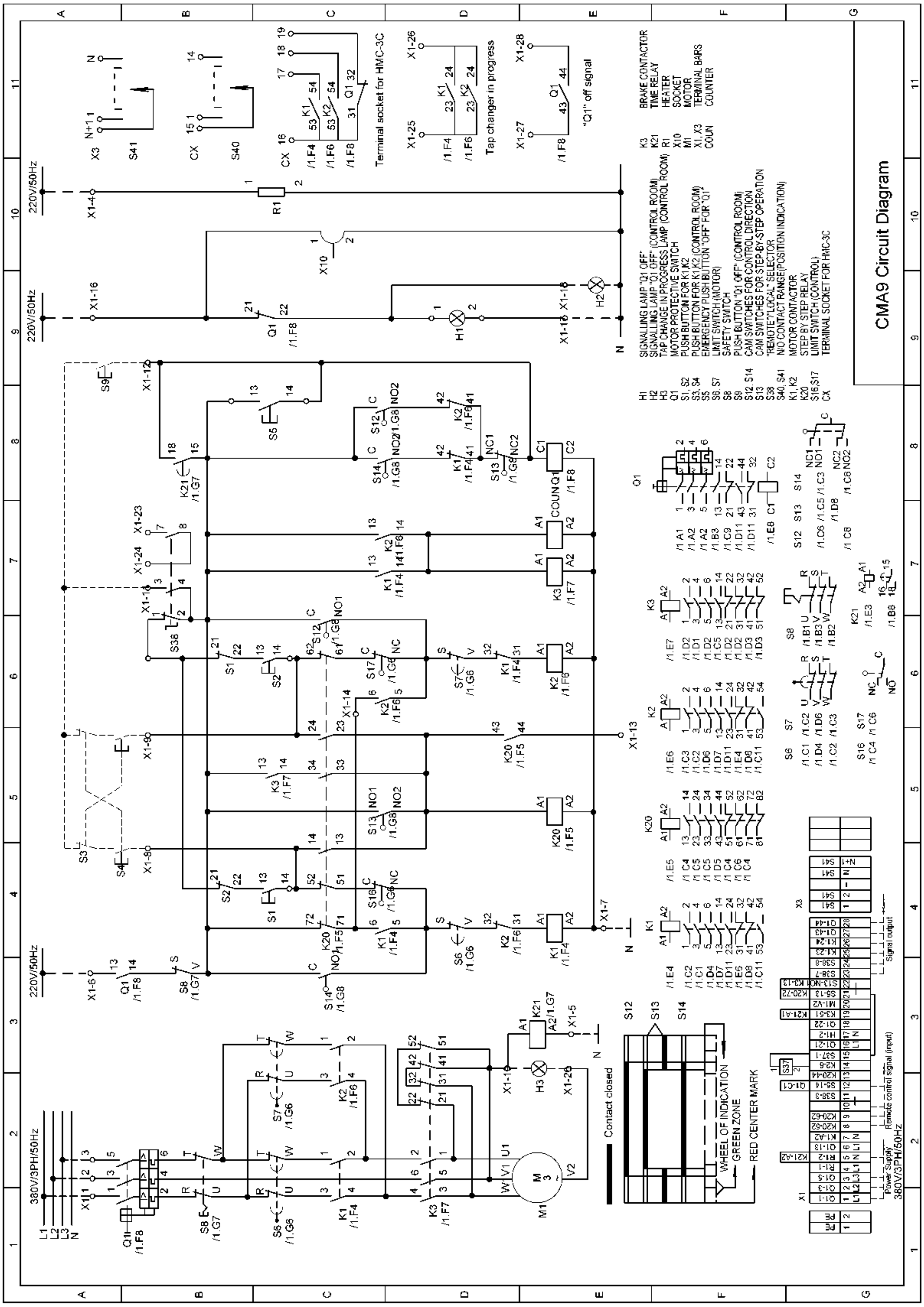
Appendix 7 Circuit diagram of SHM-III motor drive unit



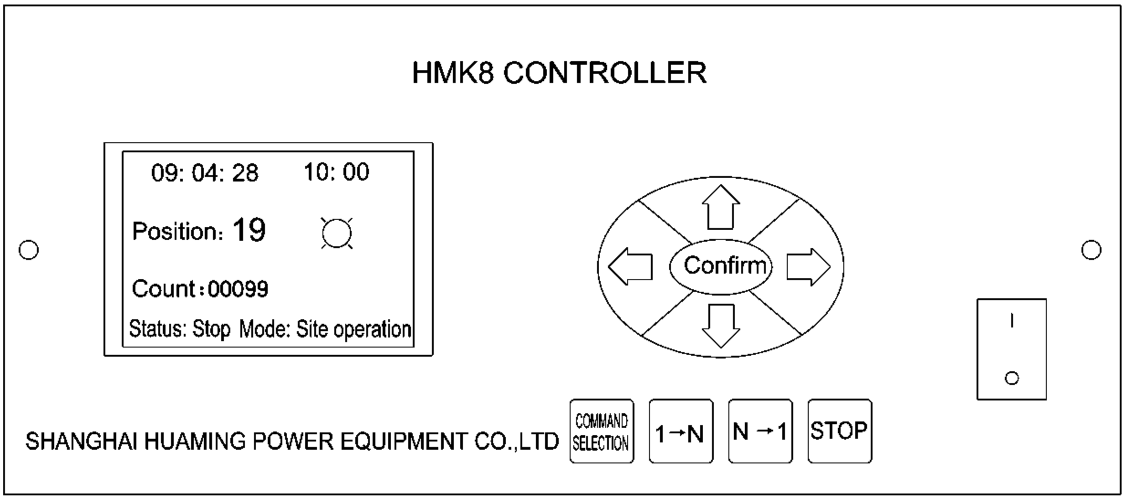
Appendix 8 Circuit diagram of CMA7 motor drive unit

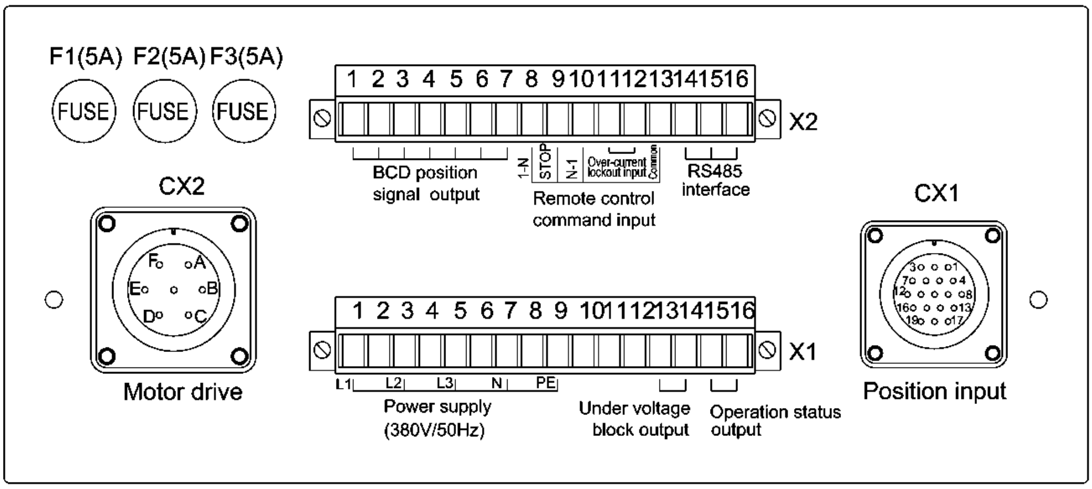


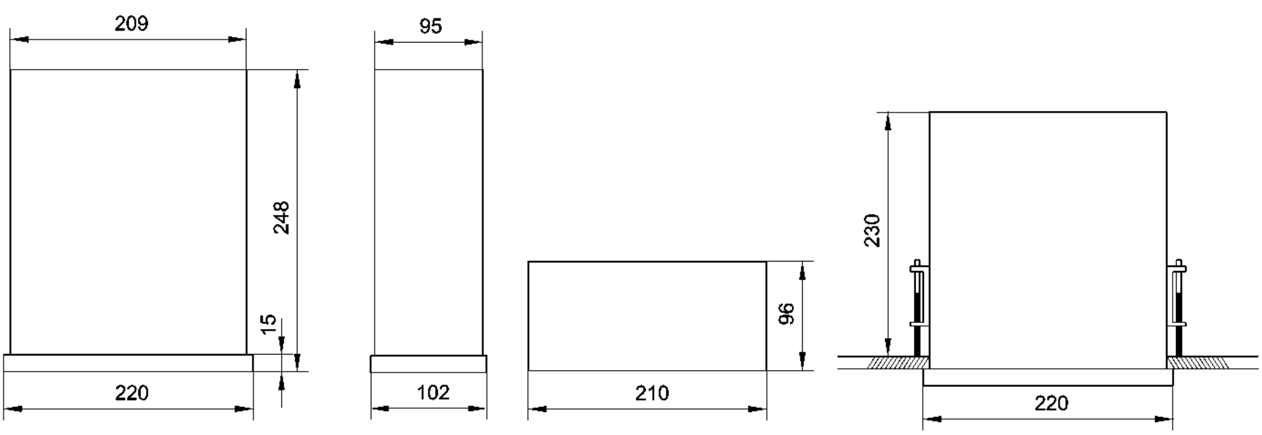
Appendix 9 Circuit diagram of CMA9 motor drive unit



Appendix 10 Schematic drawing and dimension of HMK8 controller





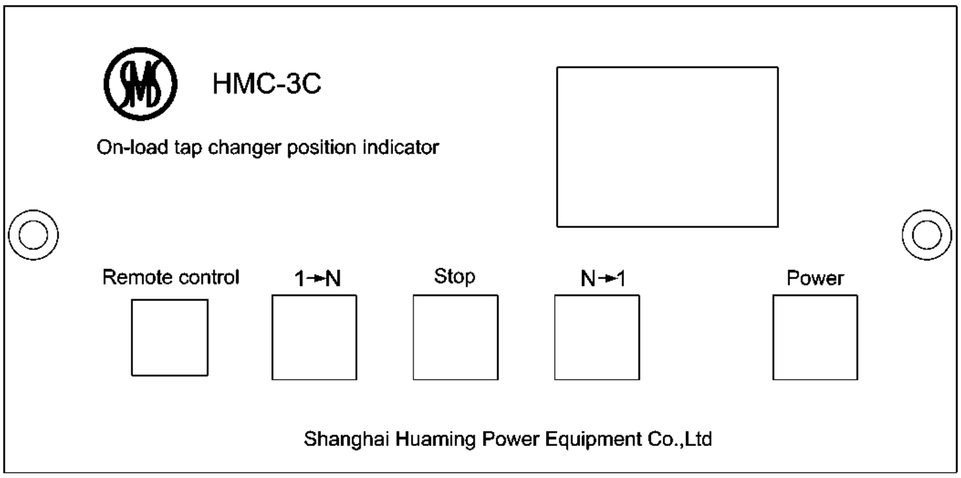


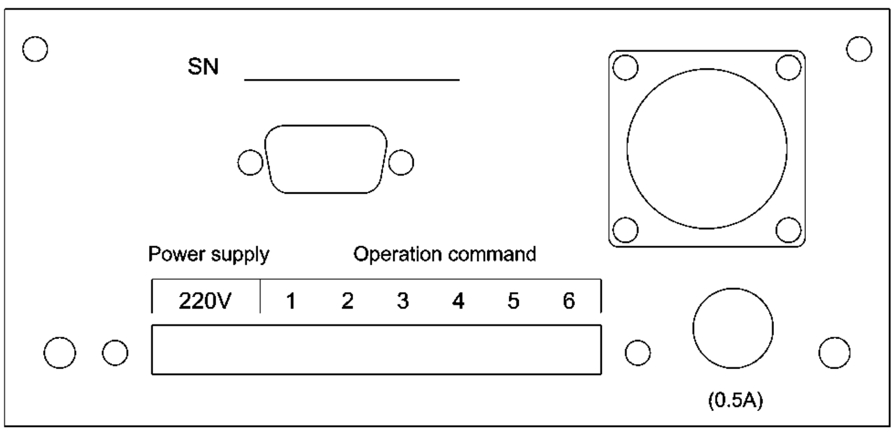
overall dimension

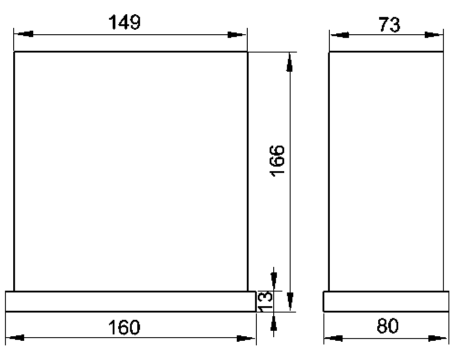
Opening size and mounting schematic drawing

Unit: mm

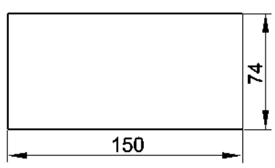
Appendix 11 Schematic drawing and dimension of HMC-3C position indicator



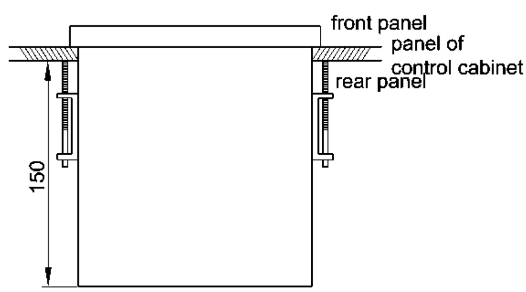




overall dimension



Opening size

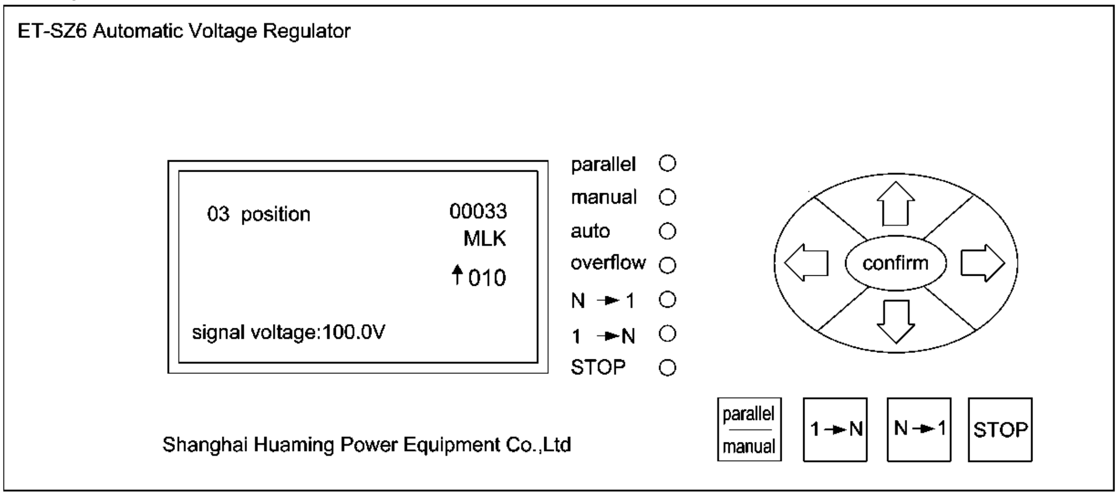


Mounting schematic drawing

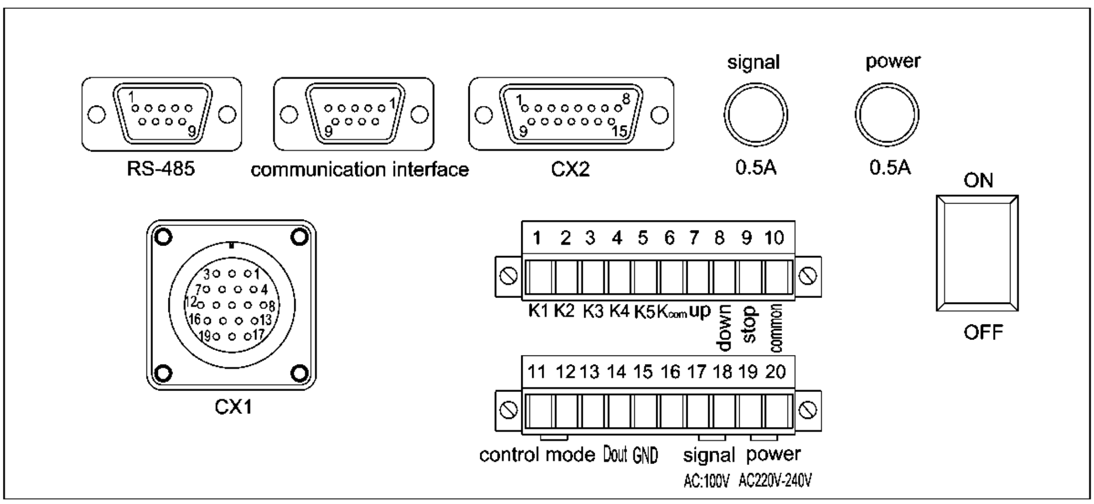
Unit: mm

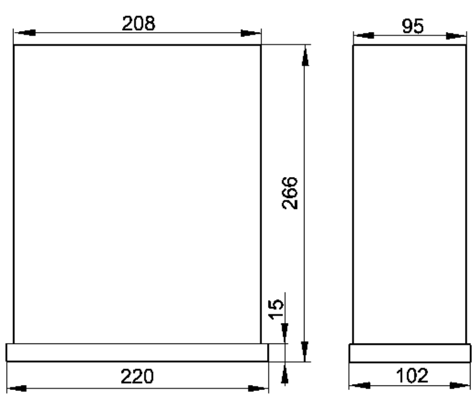
Appendix 12 Schematic drawing and dimension of ET-SZ6 automatic voltage regulato

Front panel

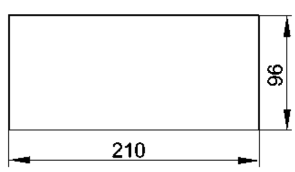


Rear panel

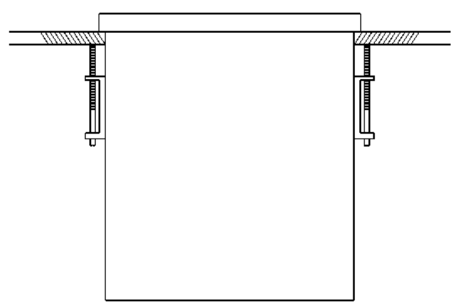




overall dimension



Opening size

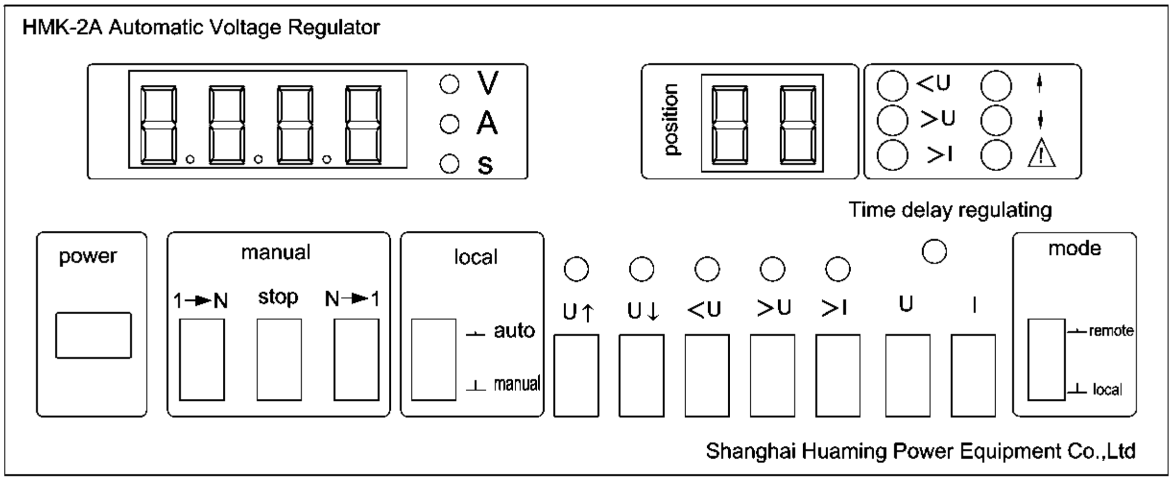


Mounting schematic drawing

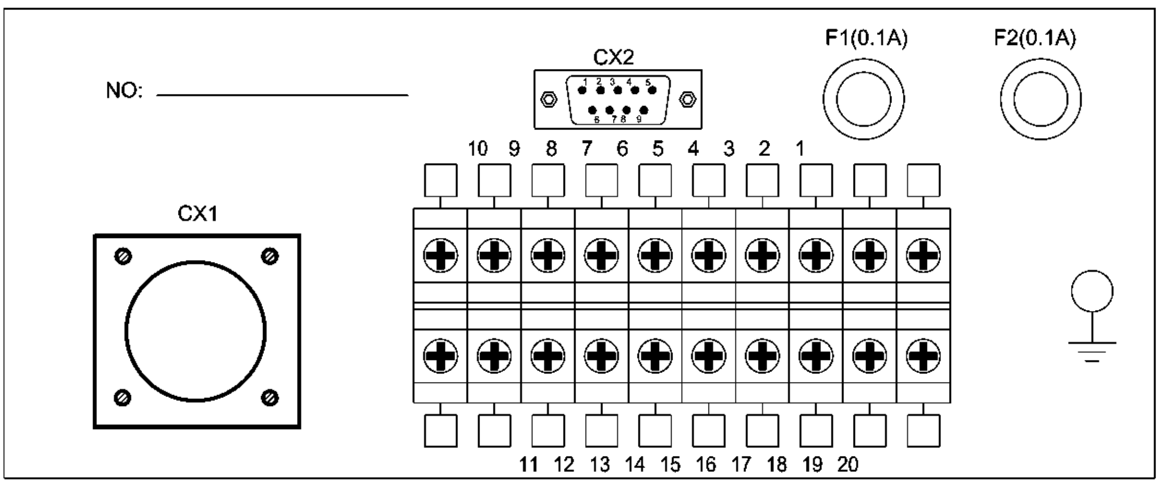
Unit: mm

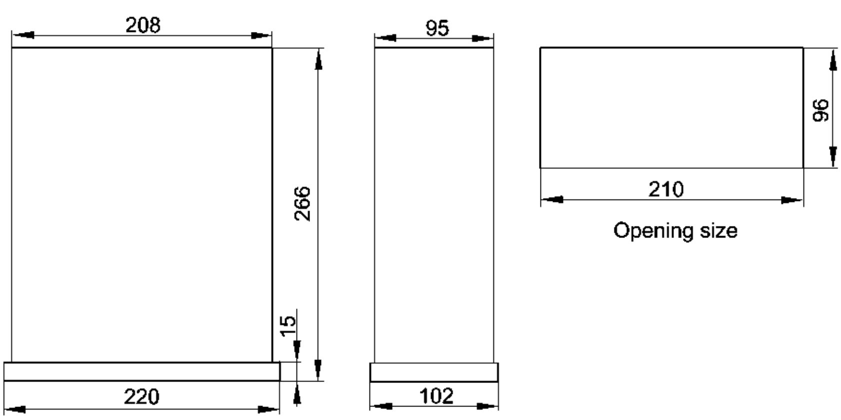
Appendix 13 Schematic drawing and dimension of HMK-2A automatic voltage regulator

Front panel



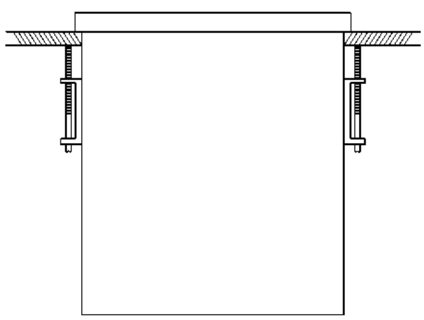
Rear panel





overall dimension

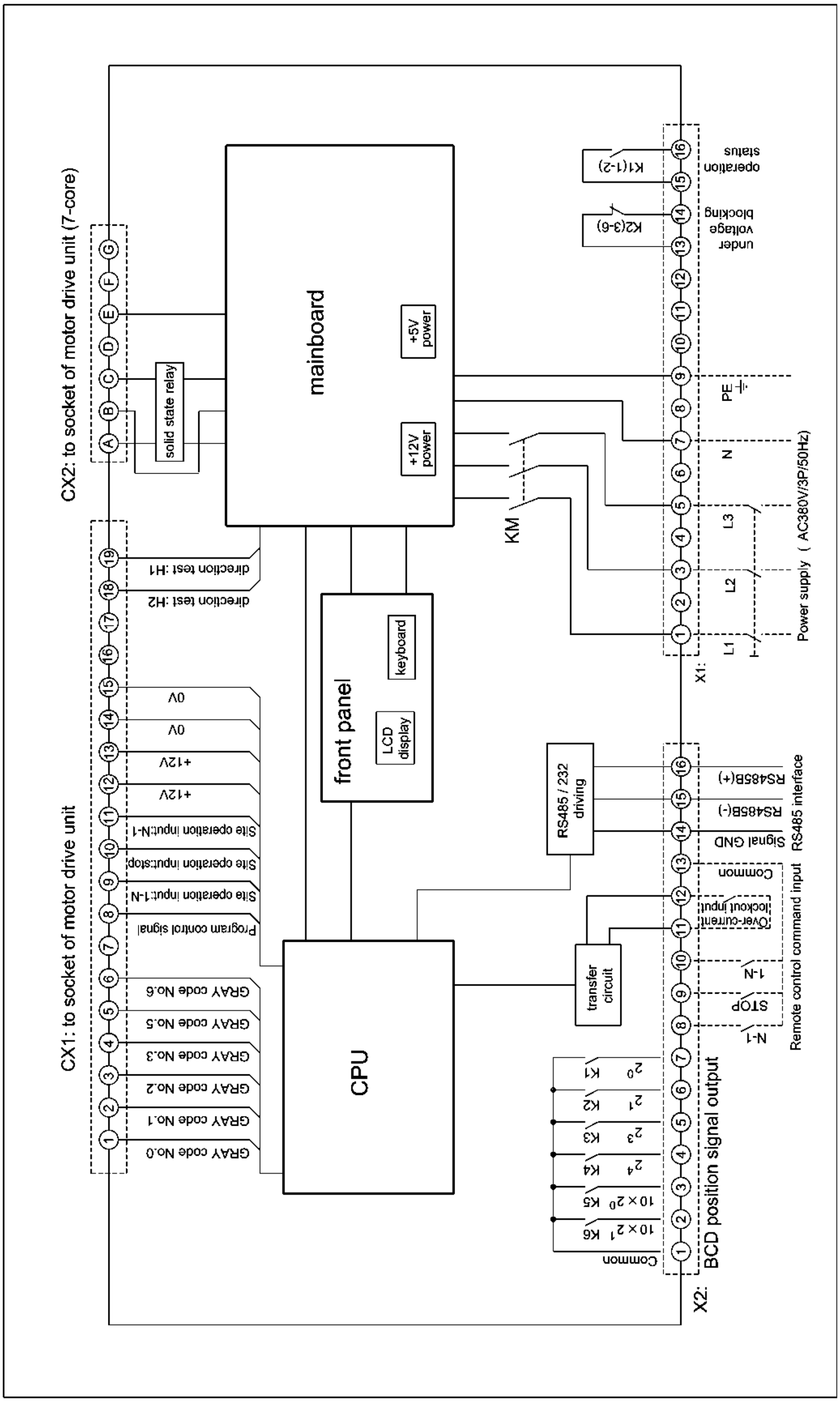
Opening size



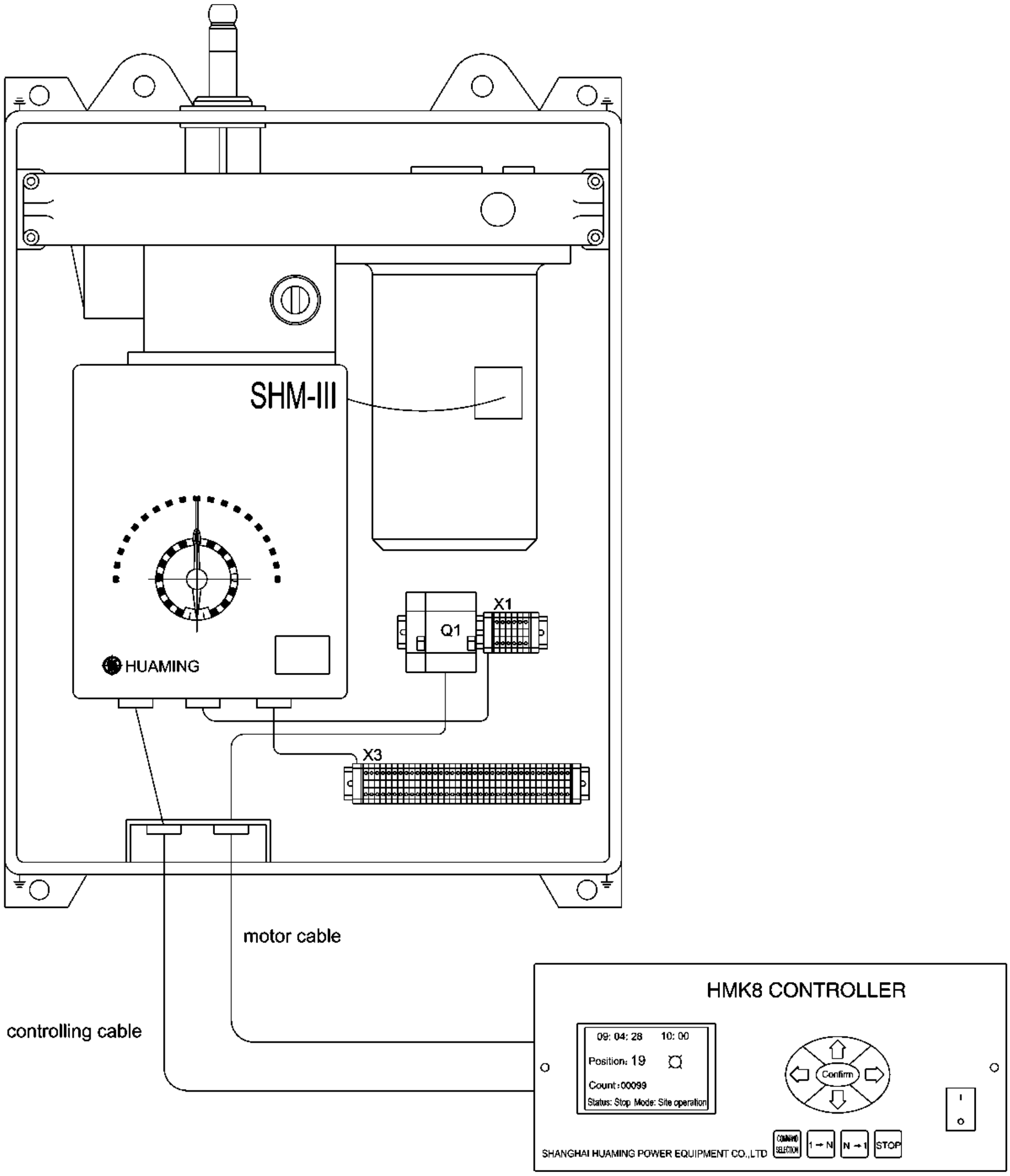
Mounting schematic drawing

Unit: mm

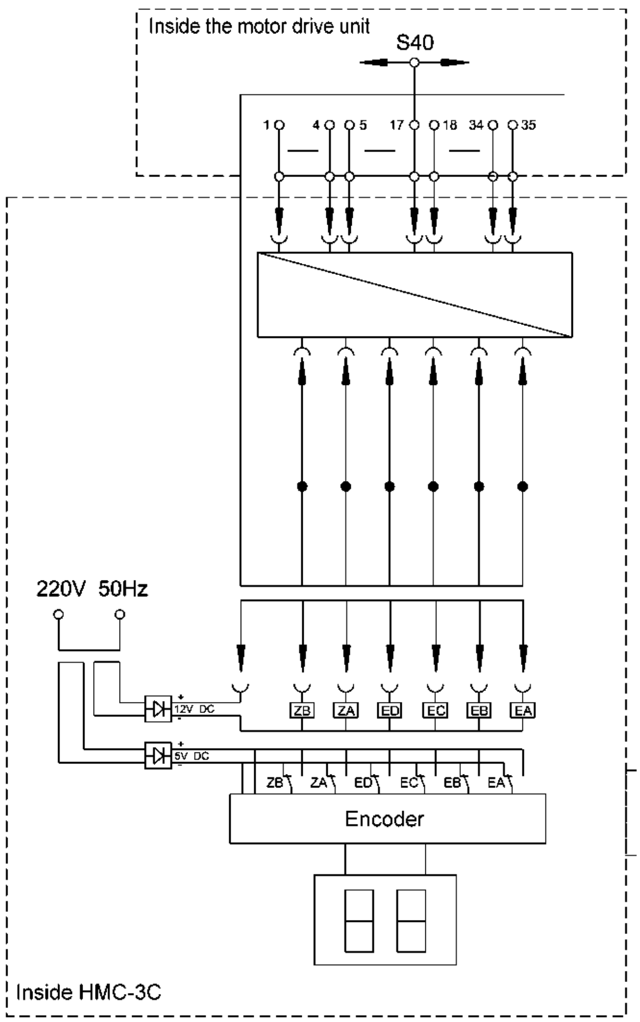
Appendix 14 Circuit diagram of HMK8 controller



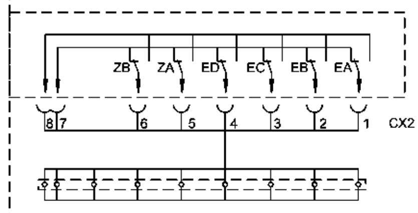
Appendix 15 Connection schematic drawing of SHM-III MDU and HMK8 controller



Appendix 16 Circuit diagram of HMC-3C position indicator



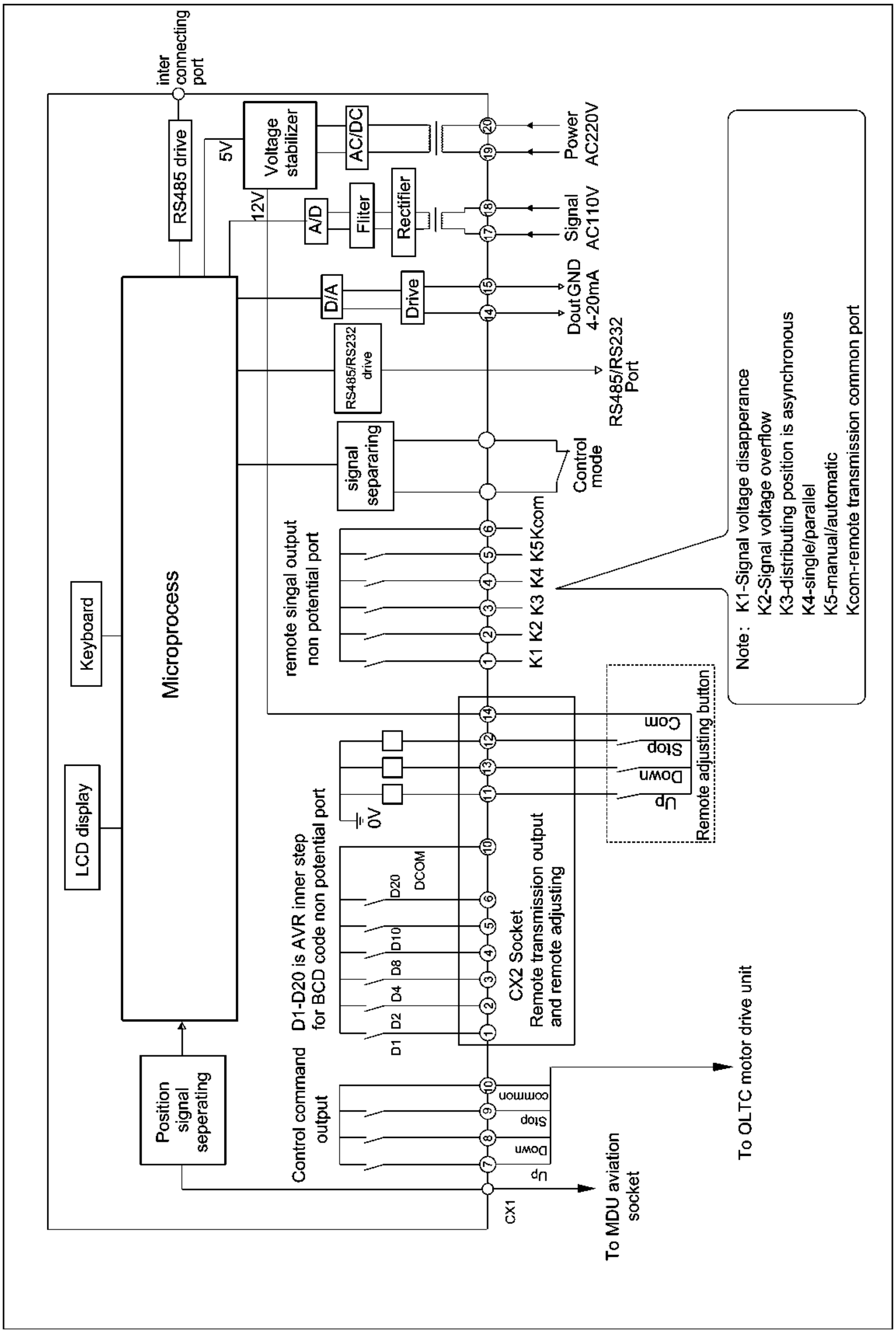
Position No.	Position No.						Digit display
	Tens digit		Units digit				
	ZB	ZA	ED	EC	EB	EA	
1						X	01
2					X		02
3					X	X	03
4				X			04
5				X		X	05
6				X	X		06
7				X	X	X	07
8			X				08
9			X			X	09
10		X					10
11		X				X	11
12		X			X		12
13		X			X	X	13
14		X		X			14
15		X		X		X	15
16		X		X	X		16
17		X		X	X	X	17
18		X	X				18
19		X	X			X	19
20	X						20
21	X					X	21
22	X				X		22
23	X				X	X	23
24	X			X			24
25	X			X		X	25
26	X			X	X		26
27	X			X	X	X	27
28	X		X				28
29	X		X			X	29
30	X	X					30
31	X	X				X	31
32	X	X			X		32
33	X	X			X	X	33
34	X	X		X			34
35	X	X		X		X	35



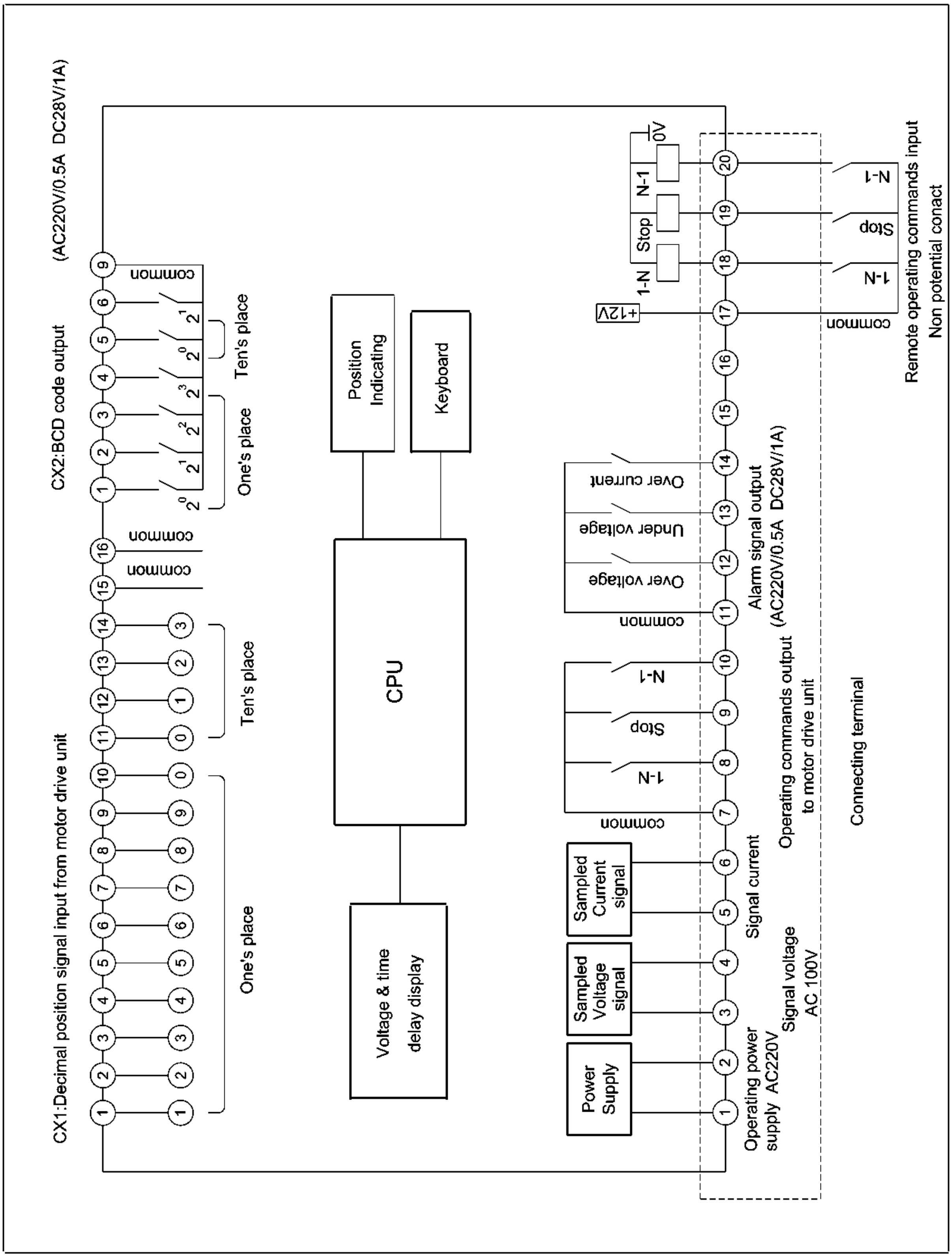
☒ Relay energized

☐ Relay de-energized

Appendix 17 Circuit diagram of ET-SZ6 automatic voltage regulator



Appendix 18 Circuit diagram of HMK-2A automatic voltage regulator



Appendix 19 ET-SZ6 AVR and HMK8 controller connection table

ET-SZ6 AVR		HMK8 Controller	Explanation
Terminal	7	X1-19	1-N command
	9	X1-20	Stop command
	8	X1-21	N-1 command
	10	X1-18	Command common terminal
Aviation socket	CX1-1	X1-28	BCD position signal one's 2^0
	CX1-2	X1-27	BCD position signal one's 2^1
	CX1-4	X1-26	BCD position signal one's 2^2
	CX1-8	X1-25	BCD position signal one's 2^3
	CX1-12	X1-24	BCD position signal ten's 2^0
	CX1-13	X1-23	BCD position signal ten's 2^1
	CX1-15	X1-22	BCD position signal common terminal

Appendix 20 ET-SZ6 AVR and CMA7/CMA9 MDU connection table

ET-SZ6 AVR		CMA7/CMA9 MDU	Explanation
Terminal	7	X1-8	1-N command
	9	X1-12	Stop command
	8	X1-9	N-1 command
	10	X1-11	Command common terminal
Aviation socket	CX1-1	CX-1	Position signal single digital 1
	CX1-2	CX-2	Position signal single digital 2
	CX1-3	CX-3	Position signal single digital 3
	CX1-4	CX-4	Position signal single digital 4
	CX1-5	CX-5	Position signal single digital 5
	CX1-6	CX-6	Position signal single digital 6
	CX1-7	CX-7	Position signal single digital 7
	CX1-8	CX-8	Position signal single digital 8
	CX1-9	CX-9	Position signal single digital 9
	CX1-10	CX-10	spare terminal
	CX1-11	CX-11	spare terminal
	CX1-12	CX-12	Position signal decimal digital 1
	CX1-13	CX-13	Position signal decimal digital 2
	CX1-14	CX-14	Position signal decimal digital 3
	CX1-15	CX-15	Position signal common terminal
	CX1-16	CX-16	Operation lamp common terminal
	CX1-17	CX-17	1-N display
	CX1-18	CX-18	N-1 display
	CX1-19	CX-19	Stop display

Appendix 21 HMK-2A AVR and HMK8 controller connection table

HMK-2A AVR		HMK8 Controller	Explanation
Terminal	8	X1-19	1-N command
	9	X1-20	Stop command
	10	X1-21	N-1 command
	7	X1-18	Command common terminal
Aviation socket	CX1-1	X1-28	BCD position signal one's 2^0
	CX1-2	X1-27	BCD position signal one's 2^1
	CX1-4	X1-26	BCD position signal one's 2^2
	CX1-8	X1-25	BCD position signal one's 2^3
	CX1-12	X1-24	BCD position signal ten's 2^0
	CX1-13	X1-23	BCD position signal ten's 2^1
	CX1-15	X1-22	BCD position signal common terminal

Appendix 22 HMK-2A AVR and CMA7/CMA9 MDU connection table

HMK-2A AVR		CMA7/CMA9 MDU	Explanation
Terminal	8	X1-8	1-N command
	9	X1-12	Stop command
	10	X1-9	N-1command
	7	X1-11	Command common terminal
Aviation socket	CX1-1	CX-1	Position signal single digital 1
	CX1-2	CX-2	Position signal single digital 2
	CX1-3	CX-3	Position signal single digital 3
	CX1-4	CX-4	Position signal single digital 4
	CX1-5	CX-5	Position signal single digital 5
	CX1-6	CX-6	Position signal single digital 6
	CX1-7	CX-7	Position signal single digital 7
	CX1-8	CX-8	Position signal single digital 8
	CX1-9	CX-9	Position signal single digital 9
	CX1-10	CX-10	spare terminal
	CX1-11	CX-11	spare terminal
	CX1-12	CX-12	Position signal decimal digital 1
	CX1-13	CX-13	Position signal decimal digital 2
	CX1-14	CX-14	Position signal decimal digital 3
	CX1-15	CX-15	Position signal common terminal
	CX1-16	CX-16	spare terminal
	CX1-17	CX-17	spare terminal
	CX1-18	CX-18	spare terminal
	CX1-19	CX-19	spare terminal

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