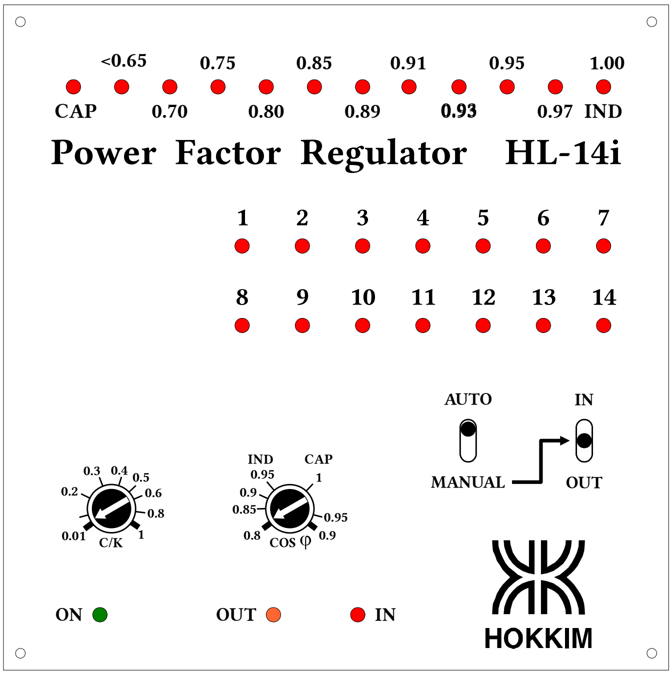
HOKKIM Control & Protection Relays
Giving You Control

Model : HL-14i
Description : 14-STEP BINARY WITH P.F INDICATOR POWER FACTOR REGULATOR.

Utilization: Power Factor Regulator
- LEDs to indicate power on, capacitive or inductive load and connected steps
- Switching speed increases with greater inductive load
- Step less adjustment for C/K and Cos



FUNCTION

The Hokkim Power Factor Regulator is a device which controls the connection and the disconnection of capacitors in relation to the capacitive power required.

MODELS

The Hokkim Regulator is available in sixteen models:

HL-7	HL-7i	HL-7c	HL-7ci
HL-14	HL-14i	HL-14c	HL-14ci
HL-20	HL-20c	HL-24	HL-24c
HL-26	HL-26c	HL-30	HL-30c

OPERATION

When the power factor is inductive and below the preset value and this difference persists for a certain period of time, the first or subsequent step is connected.
This interval or delay between a step and the next varies automatically, from 20 to 40 seconds, according to the capacitive power required. If the compensation requirement increases, the interval decreases and vice-versa.
For models HL-7, HL-14, HL-7i and HL-14i which operates on the binary system; the connection and/or disconnection of the steps always begin at the lowest step: 1... 2... 3... (connection) and 1... 2... 3... (disconnection).
For models HL-7c, HL-14c, HL-7ci and HL-14ci which operates on the cyclic system; the connection and/or disconnection of the steps are cycled through all banks in turn.

CONTACTORS AND CAPACITORS

The seven step HL-7, HL-7c, HL-7i and HL-7ci require seven contactors for connecting seven capacitor banks; and the HL-14, HL-14c, HL-14i and HL-14ci requires fourteen. For binary models, each capacitor bank after the first must have a capacitive rating that is at least equal to but never greater than double the value of the previous one of the sequence. For example, the ratio of the capacitor banks may be as follows, Table 1:

1 : 1 : 1 : 1 : 1 : 1 :...	1 : 2 : 2 : 2 : 2 : 2 :...	1 : 2 : 2 : 4 : 8 : 16 :...	1 : 2 : 4 : 8 : 16 : 32 :...

For cyclic models, all capacitor banks must have the same value.

ADJUSTMENTS AND CONTROLS

The following parameters can be adjusted from the regulator front:

- Power Factor from 0.8 inductive to 0.9 capacitive
- Minimum Operational Current C/K from 0.01 to 1 (ratio between the first capacitor bank and the current transformer ratio of the system).
- Switch to select Auto or Manual operation
- Switch to manually connect or disconnect the capacitors
- Automatic adjustment to suit 1:1:1... or 1:2:2... capacitor bank ratios for binary models

A correct setting of the C/K value can eliminate hunting and connect the first bank (minor capacity) when the system requires 70% of the capacitive power of this bank or disconnect it when the required power falls to 40%.
A selector switch AUTO-MANUAL is for the selection of automatic or manual operation. When set to MANUAL, the IN-OFF-OUT switch is used to manually connect (IN) or disconnect (OUT) the capacitor banks.

LED INDICATIONS

There is an LED each to indicate Power On (Green), Inductive Load “IN” (Red), Capacitive Load “OUT” (Amber) and each connected step. Models with the letter ‘i’ in their designation comes with a row of LEDs to indicate power factor.

CASING

Flush mounting in heat resistant durable plastic. Overall dimension: 144x144x161mm. Wire connection at the rear by screw-on removable plug-in type terminals. Refer to Casing Dimension below.

MOUNTING

Cut an opening 138x138mm in the front panel of the switchboard. Insert the Regulator through the opening from the front. Hooked the brackets through the twin holes on either side of the Regulator. Adjust the bracket screws until they pressed against the back surface of the panel; thus locking the unit in place.

SETTING

Normally **COS φ** is set to 0.95. The C/K setting depends on the value of the first capacitor bank and the current transformer ratio. Set according to the value from the C/K Selection Table on the side of the Regulator.

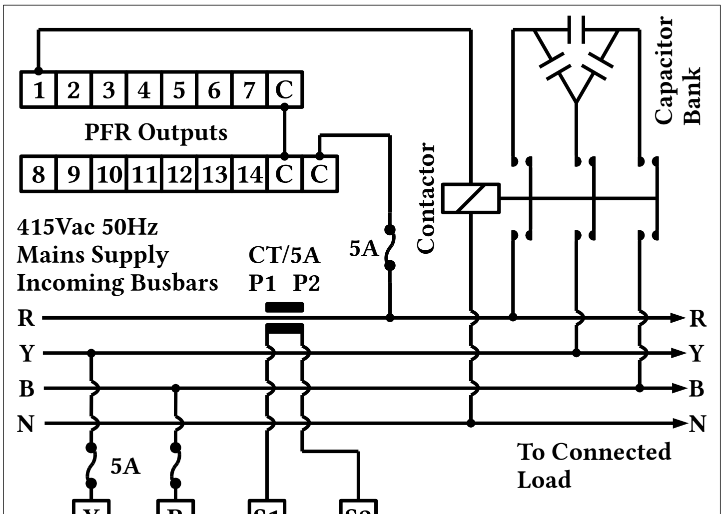
		C/K SELECTION TABLE										
415V		**Rating of 1st Capacitor Bank (kVAR)**										
		2.5	5	10	15	20	25	30	40	50	60	100
C/K SELECTION TABLE	**30/5**	0.39	0.77									
	60/5	0.19	0.39	0.77								
	75/5	0.15	0.31	0.62	0.93							
	100/5	0.12	0.23	0.46	0.70	0.93						
	125/5	0.09	0.19	0.37	0.56	0.74	0.93					
	150/5	0.08	0.15	0.31	0.46	0.62	0.77	0.93				
	200/5	0.06	0.12	0.23	0.35	0.46	0.58	0.70	0.93			
	250/5	0.05	0.09	0.19	0.28	0.37	0.46	0.56	0.74	0.93		
	300/5	0.04	0.08	0.15	0.23	0.31	0.39	0.46	0.62	0.77	0.93	
	400/5	0.03	0.06	0.12	0.17	0.23	0.29	0.35	0.46	0.58	0.70	
	600/5	0.02	0.04	0.08	0.12	0.15	0.19	0.23	0.31	0.39	0.46	0.77
	800/5	0.01	0.03	0.06	0.09	0.12	0.14	0.17	0.23	0.29	0.35	0.58
	1000/5	0.01	0.02	0.05	0.07	0.09	0.12	0.14	0.19	0.23	0.28	0.46
	1200/5	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.15	0.19	0.23	0.39
	1400/5	0.01	0.02	0.03	0.05	0.07	0.08	0.10	0.13	0.17	0.20	0.33
	1600/5	0.01	0.01	0.03	0.04	0.06	0.07	0.09	0.12	0.14	0.17	0.29
	2000/5	0.01	0.01	0.02	0.03	0.05	0.06	0.07	0.09	0.12	0.14	0.23
	2500/5		0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.11	0.19
	3000/5		0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.15

EXAMPLE OF C/K SELECTION
Rating of 1st Capacitor Bank = 10kvar at 415V
C.T. Ratio = 250/5
From the table, C/K Setting = 0.19
Refer to C/K Selection Table as shown above.

By setting the C/K value according to the table, the connection of the first capacitor bank is made when the system requires 70% of the capacitive power of this bank.
Conversely, the disconnection takes place when the power required by the system falls to 40% of the first bank rating.
In these conditions, the C/K value is intentionally preset at a value lower than the one indicated in the table since the capacitive current required for compensation varies in relation to the preset power factor.
Too low C/K value causes hunting of the first bank with consequence of contactor and capacitor wear. On the other hand, too high C/K value reduces the regulator sensitivity with consequence of under compensation.

WIRING

Mount the current transformer on the red phase and connect to the terminals on the back of the Regulator marked S1-S2. This current transformer must not be shared with the ammeter or used for any other purpose. It must be installed between incoming supply switchgear and outgoing connected load. Connect the yellow and blue phases to the terminals marked "Y" and "B" respectively. It is important not to cross these two connections. For contactors with 240V coils; connect any phase to the terminal marked "C"; then connect the contactors' coils to the terminals marked "1", "2", "3", etc, and the neutral line.
See PFR Connection Diagram on this page.



PFR Connection Diagram

TECHNICAL CHARACTERISTICS

Supply Voltage	415V 50HZ
Current Transformer Input	5A
Range of Target P.F	0.8 Inductive to 0.9 Capacitive
Range of Response Current	0.05A to 1A
Initial Power Consuption	6.3 VA
Additional Power Consuption	0.25 VA (For Each Connected Step)
Consumption in Current Circuit	1VA
Output Contacts Rating	5A 250V AC
Mechanical Life	10^7 Operations
Electrical Life	10^5 Operations AC1
Switching Time	5-40 Seconds (Load Dependent)
Operational Temperature	0^o to 50^oC
No-Volt Release	Yes
Manual Operation	Yes
Dimensions	144mm x 144mm x 161mm

BINARY & CYCLIC POWER FACTOR REGULATOR

Basic Facts

Power factor can be defined as the ratio of true power consumed to the apparent power, that is the ratio of watts to volt-amperes. If voltage and current are sinusoidal; then, power factor is equal to cos f where f is the phase angle between voltage and current.

Most a.c. motors and numerous other electrical equipment are inductive. The current drawn by these equipment consists of an active and a reactive component. For the same power (watt), the magnitude of the current to these equipment is inversely proportional to the power factor. Thus a low power factor and resultant higher current will be a wasteful strain on the electricity grid.

Consequently, the Electricity Board will impose additional charges on consumers with low load power factor. Consumers are encouraged to maintain load power factor of 0.9 to unity.

To bring the power factor towards unity, power capacitors can be connected in parallel to the inductive loads. It is not practical to connect capacitors of constant value to the supply lines because most installations have varying loads operating at different times. Thus it is usual to maintain a series of capacitors which are connected to the supply lines as and when required to compensate the inductive loads.

Power Factor Regulator

The power factor regulator is a device which detects the phase difference between the current and voltage of the supply lines and automatically connects or disconnects capacitor banks to the supply to achieve the required power factor.

Power factor regulators come in various steps to control the varying numbers of capacitor banks in different installations. For example, you will have a 7-step power factor regulator to control an installation with seven capacitor banks.

Irregardless of the number of steps, power factor regulators can be divided into two types depending on their mode of operation— binary and cyclic.

Binary Type (First In, First Out). Table 2

In binary power factor regulators, the connection or disconnection of capacitor banks always start with the first bank. When inductive working loads like motors are switched on and capacitive load is required for compensation, the first capacitor bank is connected, followed by the second bank, then the third and so on until the required capacitive load is achieved. When the inductive working loads are subsequently reduced and thus less capacitive load is required for compensation, the first capacitor bank is disconnected, followed by the second bank, then the third and so on until the required capacitive load is again achieved.

With this mode of operation, the values of the capacitor banks need not be the same.
However, for consistent switching of the banks, each bank must be equal to or double the bank in front. Thus the configuration of capacitor banks for binary operation is as shown above in Table 1.

The sensitivity of binary type power factor regulation, with correct configuration of the banks, is dependent only on the kvar of the first bank. For example, if the first bank is 10kvar, then the capacitive compensation can be connected in incremental steps of 10kvar. And if the first capacitor bank is 5kvar, the capacitive load can be connected to the nearest 5kvar

Cyclic Type (Rotational). Table 3

For cyclic power factor regulators, when there is a change in inductive loads, the first step to be connected or disconnected is cycled through the available capacitor banks. In this way, the first bank connected, when then is an increase in inductive load, will be the first available bank that has not been connected before or the bank that has been disconnected the longest period of time. And the first bank disconnected, when there is a decrease in inductive load, will be the bank that has been connected the longest period of time. With the cyclic mode of operation, the values of all the capacitor banks must be the same and the sensitivity of the power factor regulation is dependent on that value. For example, if the capacitor banks are all 15kvar, then the capacitive compensation can of course be connected in steps of 15kvar only.

Advantage of Binary Power Factor Regulator

Binary power factor regulation can provide for a very large total compensatory capacitive load and at the same time connect the load in a very small incremental step. In this way, it is suitable for installations with large loads and yet can be sensitive to small variations in the loads.
Consider an installation with the following 7-step capacitor bank configuration: 1:2:4:8:16:32:64.

With a first bank of 10kvar, this installation can provide a total capacitive load of 1270kvar and this can be connected in incremental steps of 10kvar. For a 7-step cyclic power factor regulator, having a sensitivity of 10kvar gives a total load of 70kvar only. Or, conversely, to achieve a total load of 1270kvar, a minimum incremental step of more than 180kvar is required. This will make it totally insensitive to small load changes.

Disadvantage of Binary Power Factor Regulator

Owing to its mode of operation, binary power factor regulators will usually take more switching steps to arrive at the proper capacitive load. See Table 1 which shows the operation of a 7-step binary power factor regulator under varying capacitive load requirements. Moreover, during operation, the first few capacitor banks are constantly being switched on and off when inductive load changes. This will shorten the lives of those capacitors.
In order to protect the capacitors, the switching time can be lengthened but this will make the regulator unresponsive to quickly changing loads.

Advantage of Cyclic Power Factor Regulator

In the cyclic mode, the capacitor bank that is connected or disconnected, when the inductive load is increased or decreased, is cycled through all the available capacitor banks. See Table 2 which shows the operation of a 14-step cyclic power factor regulator under varying capacitive load requirements. In this way there is the longest possible time delay between the switching on and off of any capacitor bank. It also spreads the wear and tear equally among all the banks. This will prolong the lives of the capacitor banks.

As a result, cyclic power factor regulators are most advantageous in installations like lift motors and welding machines where the loads are constantly being switched on and off. In such cases, the response time of the cyclic power factor regulator can be set very short without straining the capacitors. Once a capacitor has been connected and disconnected; it will not be connected again until all the others has been connected. After that, it will not be disconnected again until all others has been disconnected. In short, cyclic power factor regulators can be responsive to quickly changing loads without adversely affecting the capacitors.

Disadvantage of Cyclic Power Factor Regulator

As has been discussed above, because all banks must be of the same value, the cyclic power factor regulator cannot provide for a large total capacitive load if small increments of capacitive load are needed. Conversely, if the total load required is large, the sensitivity of the regulation will be limited by the number of steps available.

Table 2: Operation of 7-Step Binary Power Factor Regulator with configuration 1:2:2:2:4:4:4 under varying load.

Required kvar	Actual kvar	Capacitor Banks kvar						
		10	20	20	20	40	40	40
10	10	✓						
40	50	✓	✓	✓				
40	40		✓	✓				
80	110	✓	✓	✓	✓	✓		
80	80			✓	✓	✓		
100	110	✓	✓	✓	✓	✓		
100	100		✓	✓	✓	✓		
70	60				✓	✓		
70	70	✓			✓	✓		
30	0							
30	30	✓	✓					
60	70	✓	✓	✓	✓			
60	60		✓	✓	✓			
90	110	✓	✓	✓	✓	✓		
90	80			✓	✓	✓		
90	90	✓		✓	✓	✓		
50	40					✓		
50	50	✓				✓		
60	70	✓	✓			✓		
60	60		✓			✓		
50	40					✓		
50	50	✓				✓		

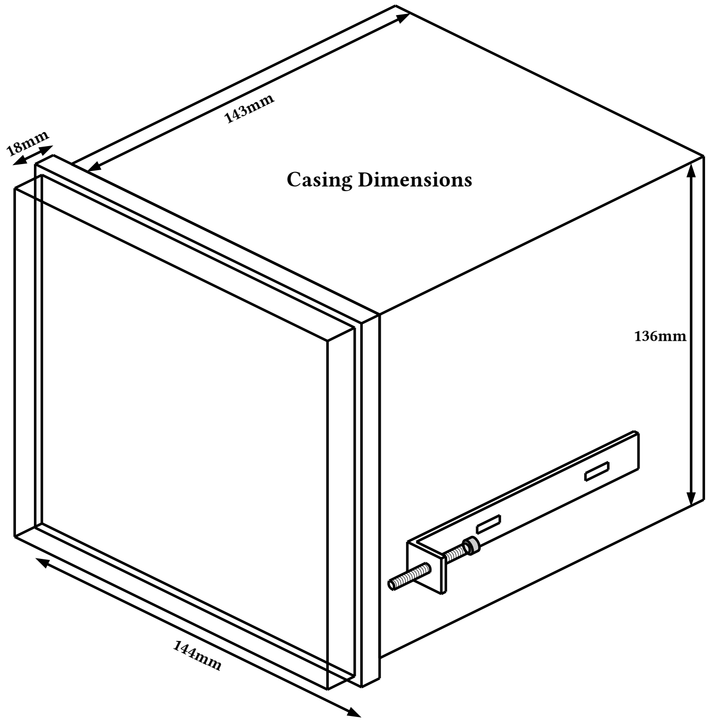


Table 3: Operation of 14-Step Cyclic Power Factor Regulator under varying load.

Required KVAR	Actual KVAR	Capacitor Banks kvar (kilo volt ampere reactive)													
		10	10	10	10	10	10	10	10	10	10	10	10	10	10
10	10	✓													
40	40	✓	✓	✓	✓										
80	80	✓	✓	✓	✓	✓	✓	✓	✓						
100	100	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
70	70				✓	✓	✓	✓	✓	✓	✓				
30	30								✓	✓	✓				
60	60								✓	✓	✓	✓	✓	✓	
90	90	✓	✓						✓	✓	✓	✓	✓	✓	✓
50	50	✓	✓										✓	✓	✓
60	60	✓	✓	✓									✓	✓	✓
50	50	✓	✓	✓										✓	✓