

APPLICATION NOTES



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Index:

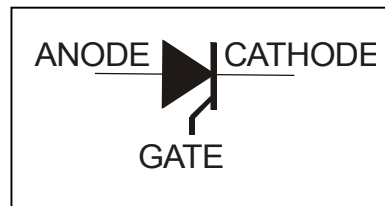
1. WHAT IS A THYRISTOR UNIT	3
1.1 VOLTAGE PROTECTIONS	7
1.2 CURRENT PROTECTION WITH FUSES	7
2. ADVANTAGES OF THYRISTOR UNITS	9
3. USEFUL FORMALS	11
3.1 SINGLE PHASE	11
3.2 THREE PHASE DELTA	11
3.3 THREE PHASE OPEN DELTA	11
3.4 THREE PHASE STAR	11
3.5 THREE PHASE STAR WITH NEUTRAL	12
3.6 ONE PHASE TRASFORMER	12
3.7 THREE SEPARATE SINGLE PHASE TRASFORMER	12
4. WHAT IS CURRENT LIMIT	13
5. WHAT IS HEATER BREAK (H.B.)	15
5.1 HEATER BREAK ALARM LOAD FAILURE	18
5.2 HEATER BREAK ALARM SHORT CIRCUIT ON SCR	19
6. SERIAL COMMUNICATION	21
WORD PARAMETERS	21
STATUS TABLE	22
COMMAND TABLE	22
CONFIGURATION	22

<u>7. HOW TO CONTROL THE POEWR WITH THYRISTOR UNITS WITH REFERENCE TO DIFFERENT INPUT SIGNAL</u>	<u>23</u>
7.1 GENERAL PRINCIPLE	23
7.2 THYRISTOR UNIT CD3000 SERIES WITH SSR INPUT	24
7.3 THYRISTOR UNIT CD3000 SERIES WITH ANAGLOG INPUT	25
7.4 THYRISTOR UNIT WITH VARIABLE DUTY CYCLE	27
7.5 DELAYED TRIGGERING	33
7.6 PHASE ANGLE	34
7.7 SOFT START + BURST FIRING	35
<u>8. THYRISTOR COOLING</u>	<u>37</u>
8.1 POWER LOSS IN THYRISTOR UNIT	38
<u>9. FEED BACK ON CD AUTOMATION THYRISTOR UNIT</u>	<u>40</u>
9.1 WITH NORMAL RESISTIVE LOADS $R(\text{OHM})$ IS COSTANT	41
9.2 WITH COMPLEX RESISTIVE LOADS R CHANGE WITH TEMPERATURE AND SOMETIME WITH AGE	41
9.3 CD3000 SERIE VOLTAGE COMPENSATION	42
<u>10. COPPER HEATING TREATMENT</u>	<u>44</u>

1.WHAT IS A THYRISTOR UNIT

Thyristor unit is a semiconductor device which acts as a switch formed by two thyristors in antiparallel.

Each thyristor is like a one way valve able to go in conduction only when are satisfied these conditions:



STATE	ANODE	GATE SIGNAL
CONDUCTION	+	ON
NO CONDUCTION	-	ON
	-	OFF

To form a real switch for alternating current is necessary to use two thyristor in antiparallel

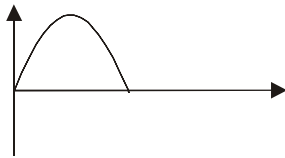
Remember that thyristor does not work with d.c. voltage power supply

The thyristor that is in conduction does not stop to conduct up to when the voltage go to zero. This also if we remove the gate signal after to have switch ON it.

With reference to figure page 6 we can see how the thyristor unit work

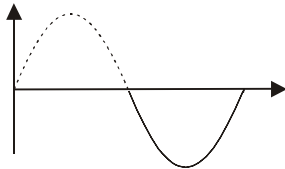
Gate signal ON

- When L1 is positive



the current flow in A versus and thyristor Th1 goes in conduction.

- When L1 is negative



The current will flow in B versus and the thyristor Th2 goes in conduction.

- If we compare the thyristor unit to a switch in this condition is ON

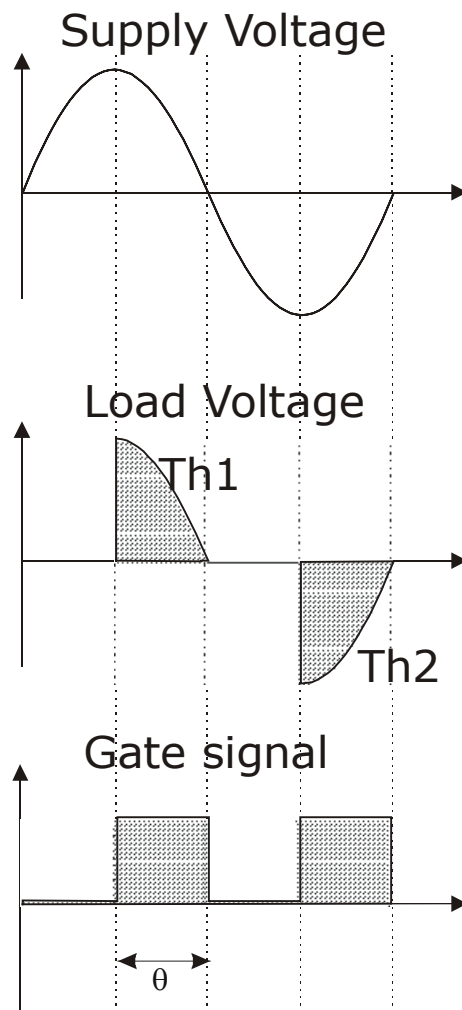
Gate signal OFF

- Both thyristor does not go in conduction
- If we compare the thyristor unit to a switch in this condition is OFF

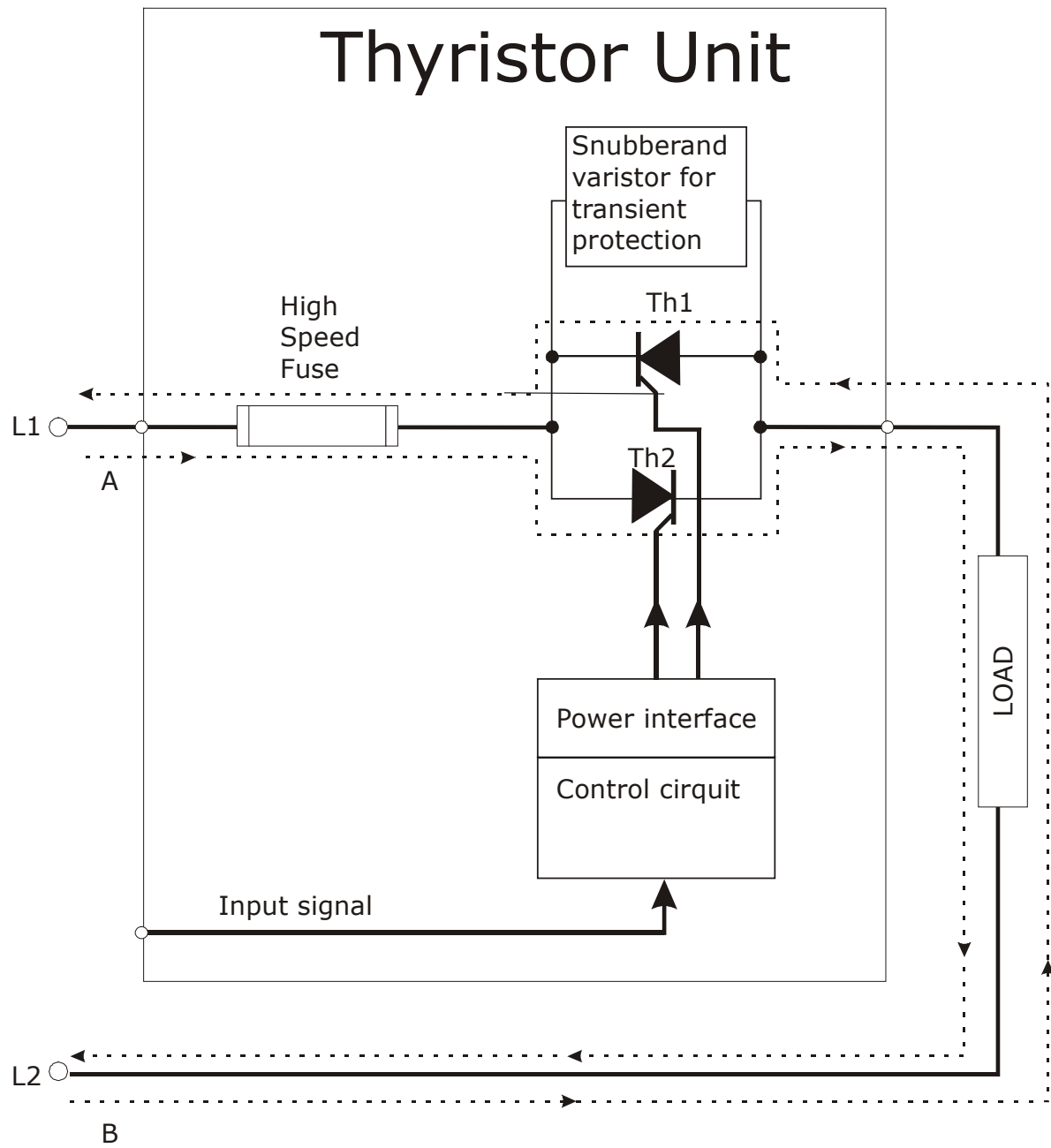
Gate signal ON when voltage is not zero

When L1 is positive the current flow A versus only if gate signal is ON.

Now we can image to give a gate signal when voltage is not zero



How is possible to understand changing the firing angle θ is possible to have a variable load voltage.



1.1 VOLTAGE PROTECTIONS

Snubber and varistor are used for voltage transient protection.

High speed semiconductor fuses with proper I²t are used to don't damage SCR. External fuses are offered with fuse holder capable to break the circuit from 15 to 110A in one phase units and 15 to 55 in 2 and 3 phases units. Over this value the unit will have internal fuses.

C.D. Automation offers as an option H.B. circuit plus SCR short circuit alarm.

1.2 CURRENT PROTECTION WITH FUSES

Fault current may result from short circuit in external connections. Thyristor due their small thermal mass have a very limited overload capacity if compared to motors, transformers etc.

Basically I²t of the fuse must be less than I²t of thyristor.

Overload protection is demanded to a thermal overload sensor mounted on heatsink to quench thyristor automatically when temperature can damage the unit.

For thyristor protection don't use circuit breaker because its speed to open circuit is too slow and thyristor will be damaged in case of short circuit.

2. ADVANTAGES OF THYRISTOR UNITS

The benefits of thyristor units compared with electromechanically contactors are numerous:

- No mechanical parts moving
- Thyristor offer a reliable long term solution
- Very fast switching
- Life of thyristor unit can be evaluated from 5 to 10 year depending on how the thyristor are stressed. The normally electrical life of contactors is 1,5 million of operations that can be reached in few months.

Ex: Imagine a furnace with contactor driven by a temperature controller with a cycle time of 20 sec. At 50% power demand is 10sec ON+10sec OFF.

That means that contactor is switched ON every 20 sec. During one working day over 3 turns(24 hours) the contactors life is given by:

1Hour = 180 switching of contactor

1Day = 180x24=4820 swicting

*Calculation life = 1.500.000 / 4.820 = **347 day***

This means that every years the contactors must be changed with labour cost and stop of production.

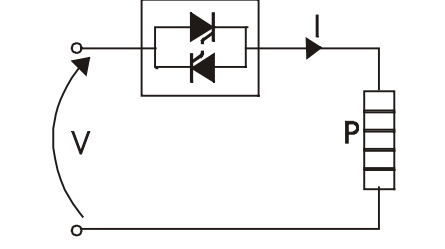
- Better temperature control due to very fast switching and better resolution in controlling the power. Save money for reduction of scrap
- Better quality because keep constant the temperature with no fluctuation
- Increase the heating element life because with very fast switching there are no thermal stresses.
- Lower maintenance cost for contactor and for heating elements substitution.

- Protection of thermal elements and building parts of furnace or machine with current limit, power limit to remain within limits specified
- Reduction of cost because is possible to establish how many elementary loads has to be fired on same time. Avoid to have peak demand power
- Capability to monitor in a control room all the loads via the communication bus available on CD Automation thyristor units.
- Possibility to diagnostic via serial link faults on heating elements or on thyristor units
- Communication can be used to control for power set point and reading of voltage, current, power, and load status. Recipe facility are also available with digital communication.

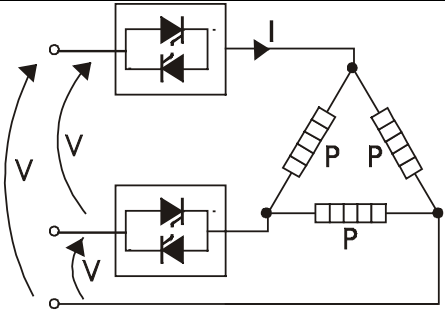
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3. USEFUL FORMALS

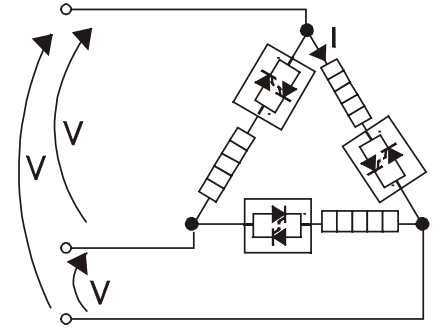
3.1 SINGLE PHASE

	P_{TOT}	I_{SCR}	V_{SCR}
	P	$I = \frac{P_{TOT}}{V}$	V

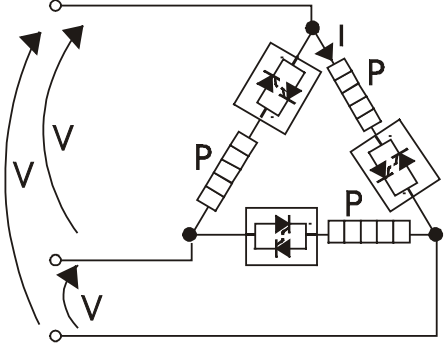
3.2 THREE PHASE DELTA

	P_{TOT}	I_{SCR}	V_{SCR}
	$3P$	$I = \frac{P_{TOT}}{\sqrt{3}V}$	V

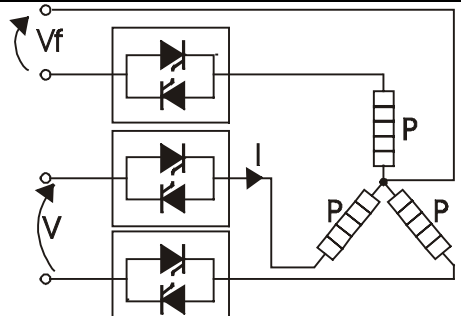
3.3 THREE PHASE OPEN DELTA

	P_{TOT}	I_{SCR}	V_{SCR}
	$3P$	$I = \frac{P_{TOT}}{3V}$	V

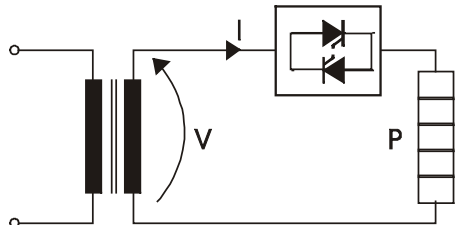
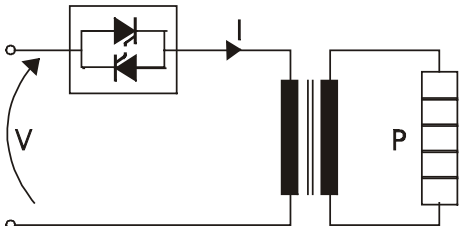
3.4 THREE PHASE STAR

	P_{TOT}	I_{SCR}	V_{SCR}
	$3P$	$I = \frac{P_{TOT}}{\sqrt{3}V}$	V

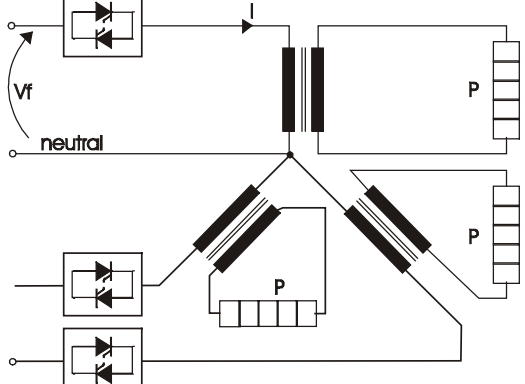
3.5 THREE PHASE STAR WITH NEUTRAL

	P_{TOT}	I_{SCR}	V_{SCR}
	$3P$	$I = \frac{P_{TOT}}{\sqrt{3}V}$	$\frac{V}{\sqrt{3}}$

3.6 ONE PHASE TRASFORMER

	P_{TOT}	I_{SCR}	V_{SCR}
	P_{TRASF}	$I = \frac{P_{TRASF}}{V \cos \Phi}$	V
	P_{TRASF}	$I = \frac{P_{TRASF}}{V \cos \Phi}$	V

3.7 THREE SEPARATE SINGLE PHASE TRASFORMER

	P_{TOT}	I_{SCR}	V_{SCR}
	$P_{SINGLE\ TRANSF}$	$I = \frac{P_{TRASF}}{V \cos \Phi}$	V_f

Useful Definitions

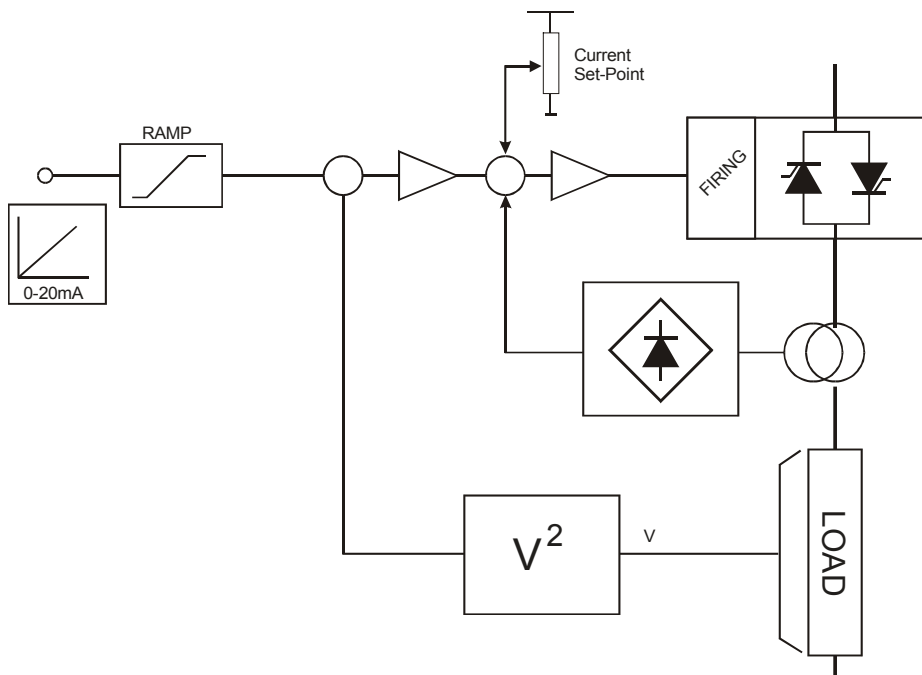
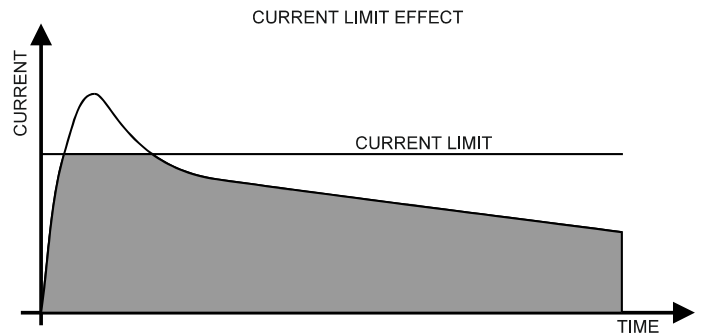
- An SCR unit is sized in terms of supply voltage and current
- Line current: it's the current flowing in one of the 3 incoming line
- Phase current: it's the current flowing in each thyristor unit
- Line voltage: it's voltage between any two line of supply voltage
- Phase voltage: it's voltage between any line to neutral.

4. WHAT IS CURRENT LIMIT

Current limit is only available on CD2200, CD3200, CD3000E, MULTIDRIVE and CD30 because is a typical features of phase angle and it is normally used with inductive loads (transformers, choches, etc.) and cold resistance (very low resistance in cold condition). In this kind of loads if full voltage is immediately applied there is a very high current (i.e. with superkanthal resistance the ratio between nominal resistance and cold resistance value can be 15 times. This means that with full voltage the inrush current become 15 times).

With inductive load there is a different phenomenon. When we apply a full voltage to a primary of transformer we have an inrush pick current that can be 6 times nominal value and with a very

high gradient (magnetic current) this blows fuses. To avoid this phenomenon is used current limit (magnetic current exists because when magnetism in transformer does not yet exit the current is limited just from primary resistance of transformer). Current limit doesn't allow to the load current to go up than nominal value (factory tuned) or to go up to a customer tuned value equal or less than nominal value. The way to drive this current is to start controlling the firing angle with a closed loop circuit. Set point value is tuned on front of thyristor unit. Feed back signal comes from a current transformer.



This loop has priority on reference signal coming from temperature controller or other device.

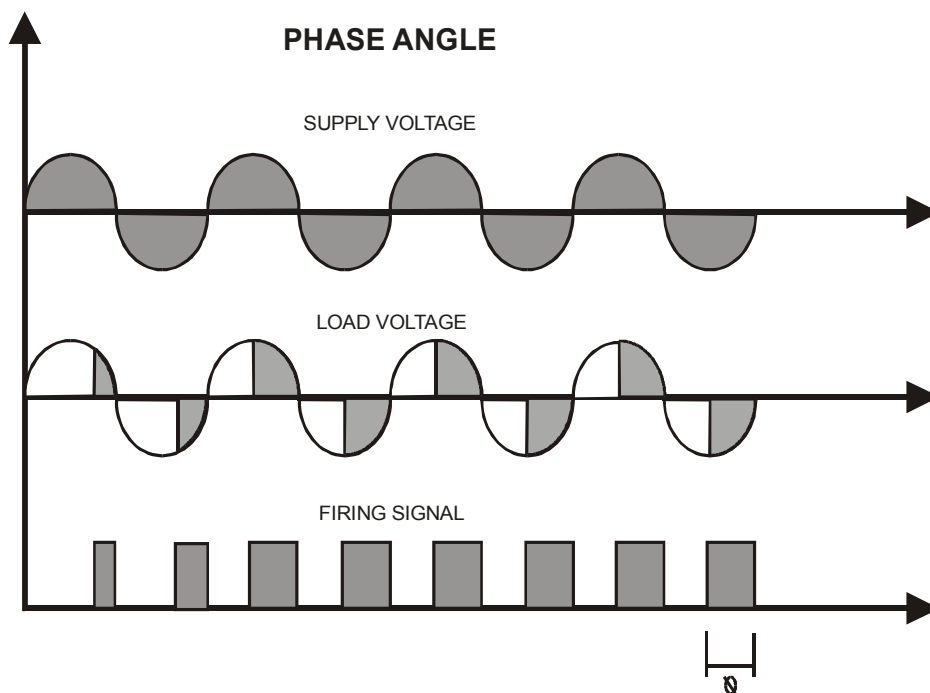
This current limit circuit must be speedy enough to limit rapid changes in load current. To help it there is also a soft start.

As represented in diagram the firing angle applied to thyristor is not immediately 90° but reach this value following a ramp.

It means that the average current on load start from zero and gradually reach the working value.

With magnetic load the inrush current is limited from current limit.

Basically there are two concomitant effect. Soft start + current limit. All these two circuits are provided as standard features on CD2200, CD3200, CD3000, MULTIDRIVE and CD30 thyristor units.



5. WHAT IS HEATER BREAK (H.B.)

It's an electronic optional circuit able to detect all types of fault that can occur on circuit below represented. HB has on front a calibration push button named CAL to set the nominal current, two LED and one relay output to give fault informations. Circuit has inside a small logic to understand if current is zero because there is an interruption on load circuit or because the temperature controller coupled with it doesn't give an output signal.

The capability to discriminate a partial load failure is 1/5. This circuit has built inside also a diagnostic to detect short circuit on SCR.

H.B. Alarm is microprocessor based and can auto set itself when a digital input is activated or CAL push button is operated. To avoid to take as a set point an unstable current value because the load is not yet in temperature the circuit read the current five times, does the average value and stock it in memory. When there are 3 equal average values in sequence take this value and multiply it by 0.8. This is HB set point value and below it an alarm occurs.

The default coefficient 0.8 can be changed on request. We suggest to use this value because on main supply voltage a drop of 15% can cause a current drop of 15%. If we set 0.9 the HB circuit gives alarm also if load is ko.

Now with reference to below figure on page 17 we start to imagine all possible faults.

1. *FUSE FAIL:*

HB detect it because there is no circulating current with input ON;

2. *OPEN CIRCUIT ON ONE SCR:*

HB detect it because the average circulating current becomes half of the nominal current;

3. *OPEN CIRCUIT ON BOTH SCR:*

HB detect it, because there is not current with input ON;

4. *SHORT CIRCUIT ON SCR:*

short circuit is detected because when there is no signal from controller and current flows it means that one or both thyristor are in short circuit

5. *PARTIAL OR TOTAL LOAD FAILURE:*

HB detect it because the current drop to a value smaller than the setted one;

6. *WIRING INTERRUPTION:*

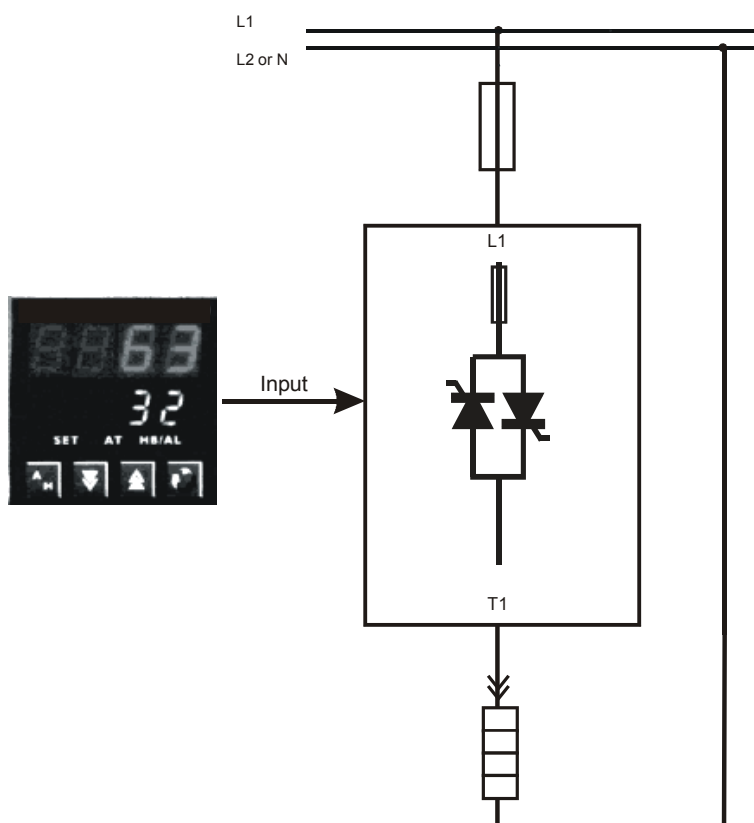
HB diagnostic it, see point 1.

When there is a fault the operator will be advised. At this point the operator can see on SCR facia the LED colour lighted and he understand the fault type.

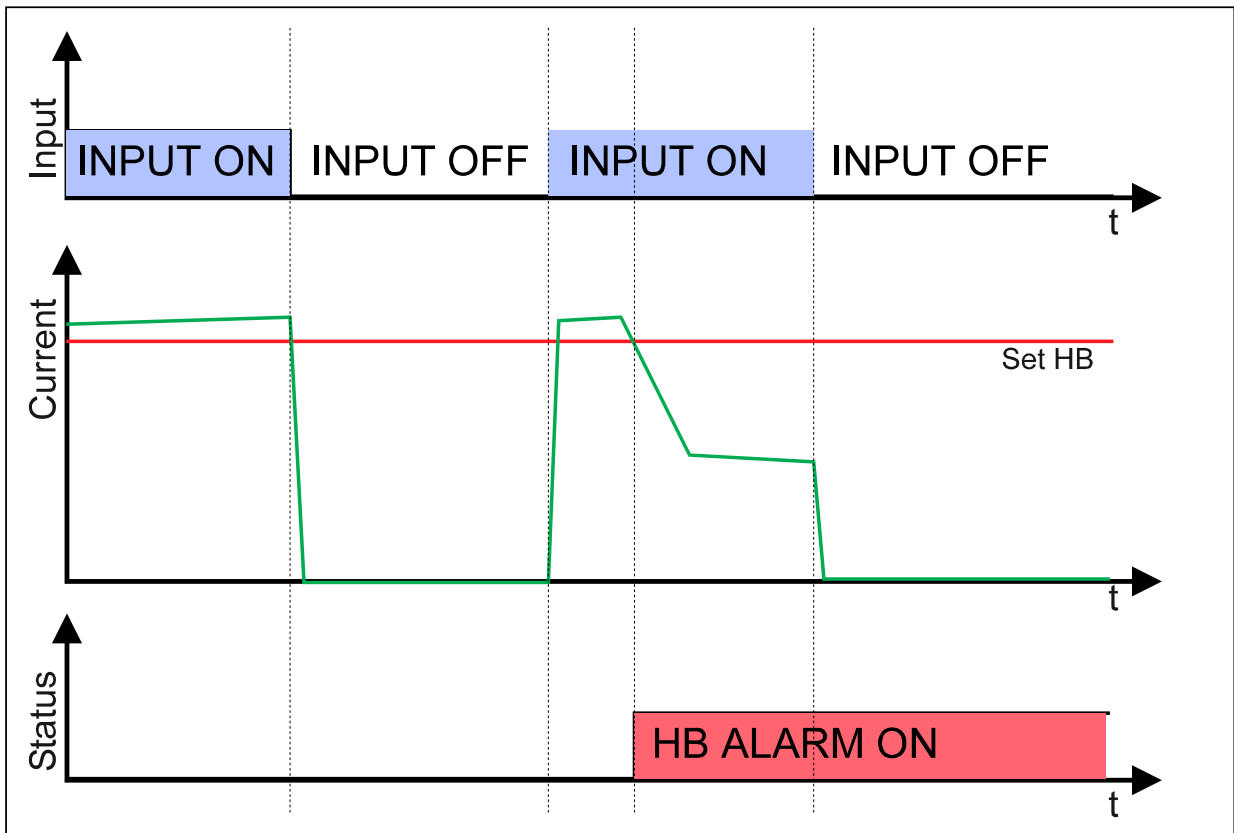
The three colours LED gives to operator following information:

- GREEN: SCR in conduction when illuminated
- YELLOW: partial or total load failure
- RED: short circuit on SCR

The HB has a relay contact output.

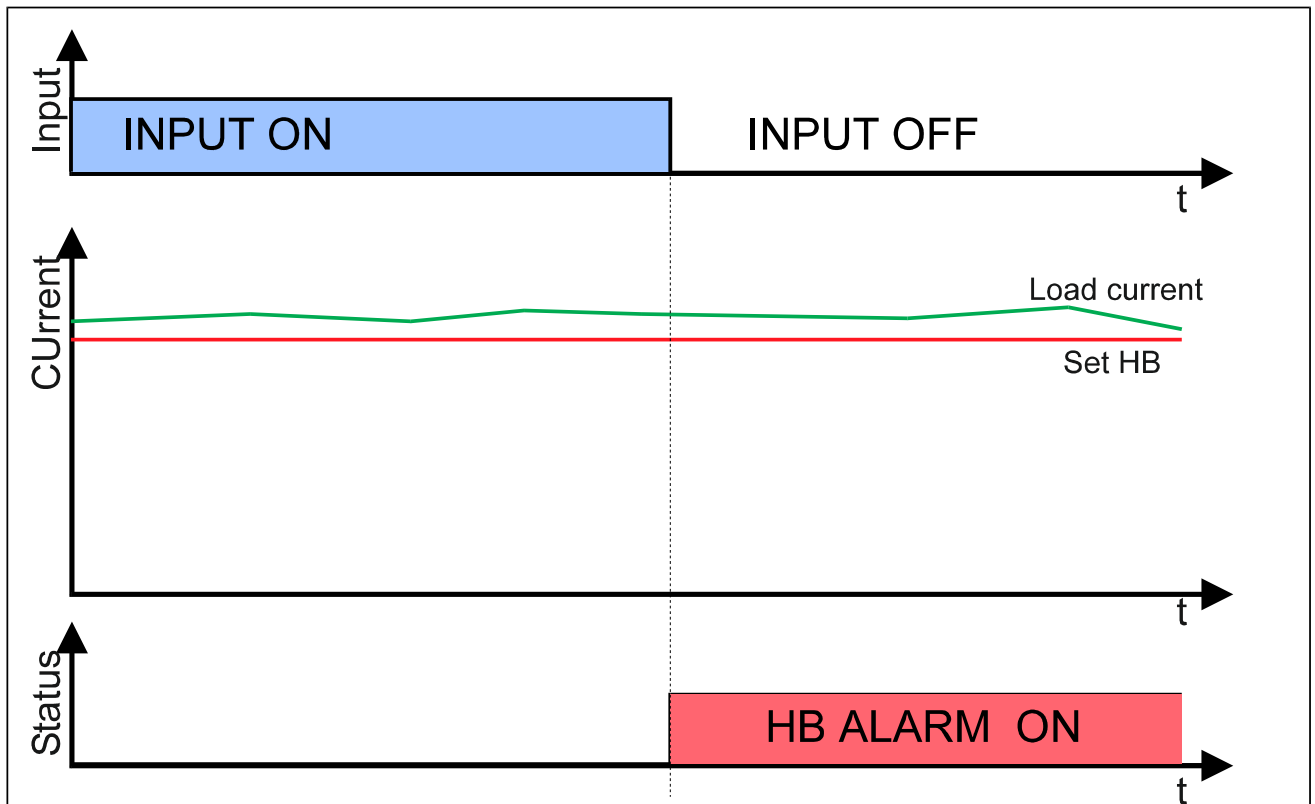


5.1 HEATER BREAK ALARM LOAD FAILURE



- Alarm setting via frontal pushbutton
- Alarm status available on serial comms, relay output and led
- Adjustable sensitivity

5.2 HEATER BREAK ALARM SHORT CIRCUIT ON SCR



- Setting by pushbutton
- Alarm by LED , Contact and Serial comms
- Sensitivity adjustable by serial comms

6. SERIAL COMMUNICATION

Communication RS485 in MODBUS protocol is available on following products:

- CD3000M
- CD3000M-2PH
- CD3000M-3PH
- CD3200
- CD3000E (the enhanced version of CD3000 family)
- MULTIDRIVE

We enclose a communication parameter list available on CD3000M

We suggest to see also configurator for CD3000E and MULTIDRIVE.

Word parameters

Parameter	N.	Notes
Heater nominal current	1	Read only
Set-point HB	2	Read /write
Status Table (shown in Tab 2.1.2)	3	Read only
Comand Table (shown in Tab 2.1.3)	4	Read /write
Output Power (0 - FFH)	5	Read (0->0% - FF->100%)
Power Adjust (0 - FFH)	6	Read (0->0% - FF->100%)*

Status Table

Bit	Meaning	Notes
0	Short circuit on SCR	Read only
1	Load Failure	Read only
2	On-Off	Read only
3	HB Calibration in progress	Read only 0=Normal - 1=Calibration

Command Table

Bit	Meaning	Notes
0	HB Calibration	Read /write 0=Off - 1=ACTVATE Calibration
1	Firing command	Read /write 0=from terminal - 1=from RS485
2	On-Off	Read /write 0=Off - 1=On
3	RESET HB	Read /write 0=Off - 1=RESET

Configuration

Parameter	N.	Note
Password	123	Write
Delay trigger	124L	Read /write
% HB	124H	Read /write
Firing type	125L	Read /write
soft start time	125H	Read /write
N° burst	126L	Read /write
Delay time HB	126H	Read /write
Max power for SSR Input	127L	Read /write
Cycle time	127H	Read /write
N° of halph period for Delayed triggering	128L	Read /write (Mantenere a 1)
	128H	Read /write

7. HOW TO CONTROL THE POEWR WITH THYRISTOR UNITS WITH REFERENCE TO DIFFERENT INPUT SIGNAL

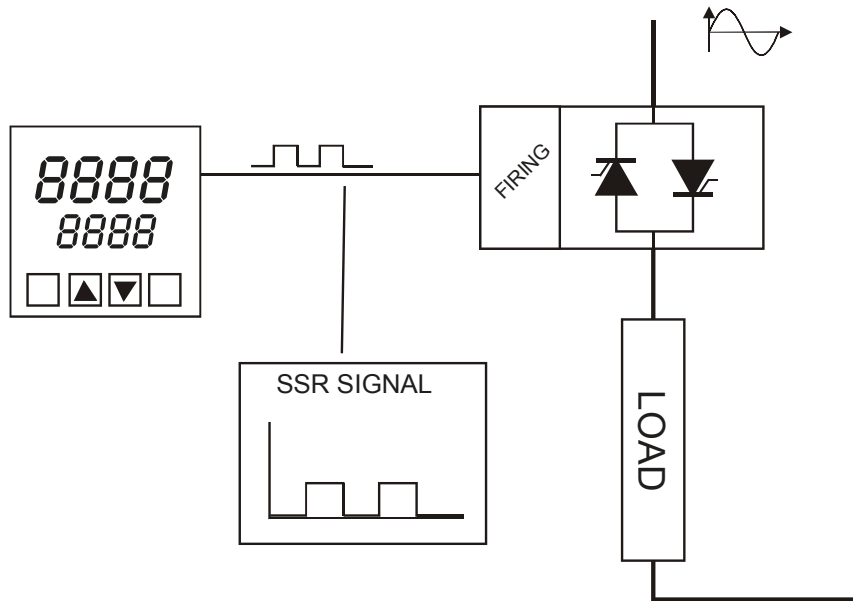
7.1 GENERAL PRINCIPLE

The control of electrical power can be done in 2 modes:

- Switching ON/OFF
- Controlling load voltage

The thyristor unit normally are coupled with a temperature controller
The power set point can be given also by an analogue input,
potentiometer or by serial link

7.2 THYRISTOR UNIT CD3000 SERIES WITH SSR INPUT



The controller with SSR logic output controls power switching ON/OFF thyristor unit.

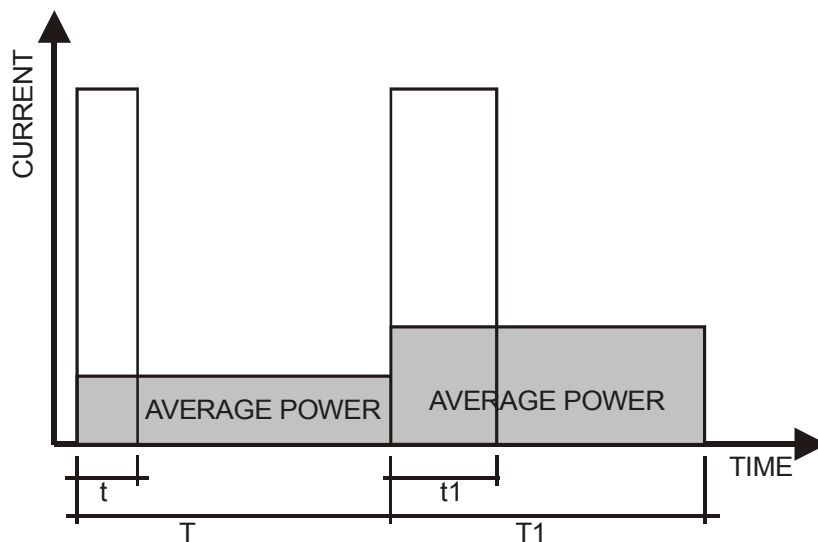
Value of average power to the load is given by:

$$AveragePower = \frac{MaxPower * t}{T}$$

t = time ON

T = time ON + time OFF

How is possible to see from diagram the controller changing the t time in respect with T changes average power with linear relationship

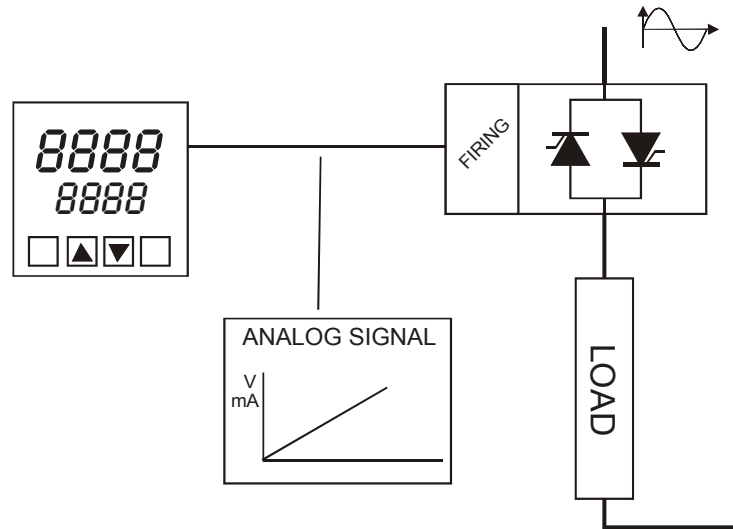


t = 2 Pmax = 10
 Paverage = 10*2/10 = 2

t = 4 Pmax = 10
 Paverage = 10*4/10 = 4

If controller twice t the average power became twice.

7.3 THYRISTOR UNIT CD3000 SERIES WITH ANAGLOG INPUT



Inside CD3000 there is a circuit able to convert DC linear input to logic.

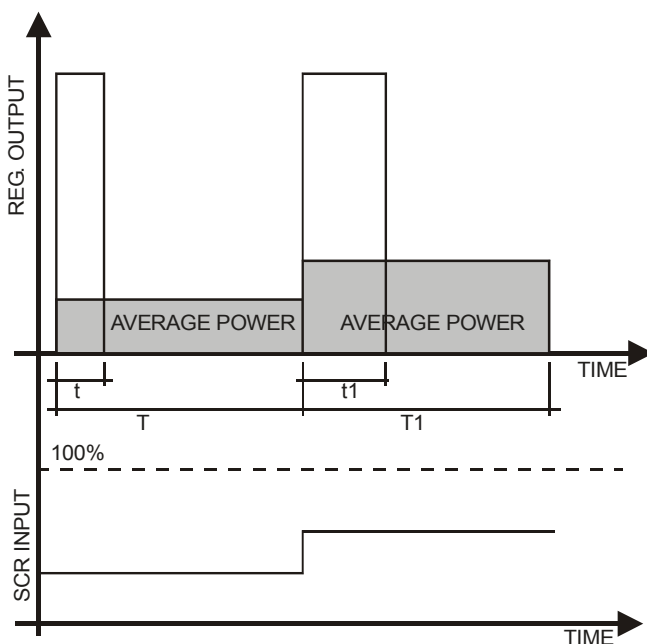
There is a linear relationship between DC input and logic output, for this reason the relation between input and power is linear This means that ON time changes in relation with input signal. The cycle time is constant..

Value of average power to the load is given by:

$$AveragePower = \frac{MaxPower * t}{T}$$

t = time ON

T = time ON + time OFF

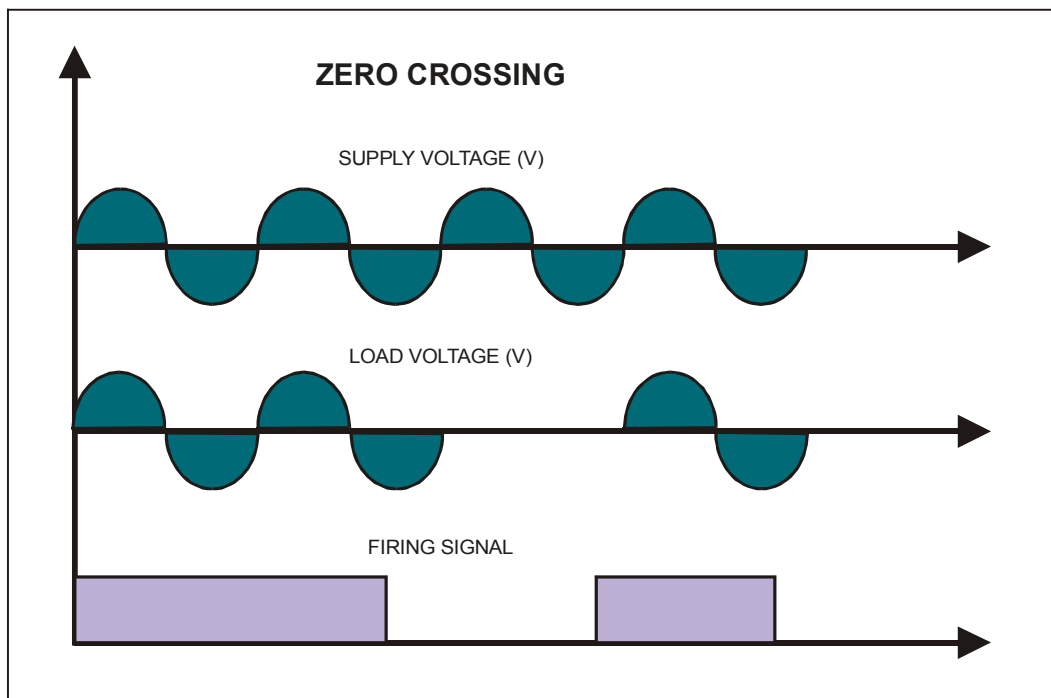


The above technique was used with Fast Cycle. Cycle Time 400 msec. This means that at 50% power demand there was 200msec ON + 200msec OFF.

ZERO CROSSING FIRING

ZC firing mode is used with Logic Output (SSR) from temperature controllers and the Thyristor operate like a contactor. The Cycle time is performed by temperature controller.

ZC minimize interferences because the Thyristor unit switch ON-OFF at zero voltage



7.4 THYRISTOR UNIT WITH VARIABLE DUTY CYCLE

To day the most advanced mode to control power is Burst Firing.

This firing is performed in digital mode in CD Automation thyristor unit and give a lot of advantages because switches thyristor at zero voltage crossing without EMC interferences.

Analogue input is necessary for BF and can be decided how many complete cycle we want at 50% of power demand.

This value can be implemented from 1 to 255 complete voltage cycle.

When 1 is setted the Firing Name became single cycle (SC).

This firing is the fasted mode to switch ON-OFF a thyristor . At 50% of power demand is 20 msec. ON + 20msec OFF .

A particular algorithm inside the micro of thyristor unit find the fasted mode to respect the power demand.

This firing is very closed to a continuous control like Phase Angle with the advantage that use a zero crossing technique.

To day Single Cycle Firing is used with low inertia loads where is necessary to switch ON-OFF as fast as possible.

Infrared elements that are a low inertia load, are becoming very popular.

When you are involved in Infrared Lamp application ask if they are:

- short infrared waveform. The thyristor must be over sized because a peak current up to 8 time nominal current can occur
- Medium and long infrared waveform elements can be treated as normal resistive loads because there are not peak

NOTE: For infrared see application note.

Calculation method for the single Cycle syncopated firing in CD3000 serie.

All the calculations will be done basing on a whole cycle of 50Hz = 20ms. The singles cycles will give the resolution of one cycle time.

Example: with a cycle time of 200ms you have 10 cycles of 20ms (sinusoides), then the resolution will be of 10%.

With a cycle time of 2 seconds we'll have 100 cycles of 20ms and a resolution of 1% (the default cycle time on the CD3000 serie is 2 seconds).

To have easy calculations, we'll consider a cycle time of 200ms with 10 cycles (complete sinusoides) at 50Hz.

We'll put the input signal at 20%.

The unit will go in conduction for 2 cycles and after it will be switched off during 8 cycles.

$$10 \text{ (cycles)} \times 20\% \text{ (requested percentage)} = 2 \text{ cycles.}$$

Now we divide the number of active cycles for the number of the total cycles.

$$2 \text{ (active cycles)} / 10 \text{ (total cycles)} = 0,2 \text{ (cycles).}$$

We have already said that we'll base our calculations on a whole cycle, then:

0,2	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,2+0,2	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,4+0,2	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,6+0,2	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,8+0,2	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0

In this case the unit will switch on every 5 cycles.

Now we'll put the input signal at 50%.

The unit will go in conduction for 5 cycles and after it will be switched off during 5 cycles.

$$10 \text{ (cycles)} \times 50\% \text{ (requested pourcentage)} = 5 \text{ cycles.}$$

Now we divide the number of active cycles for the number of the total cycles.

$$5 \text{ (active cycles)} / 10 \text{ (total cycles)} = 0,5 \text{ (cycles).}$$

We have already said that we'll base our calculations on a whole cycle, then:

0,5	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,5+0,5	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0
0,5	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,5+0,5	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0

In this case the unit will switch on every 2 cycles (switch ON – switch OFF – switch ON – switch OFF...).

Now we'll put the input signal at 75%.

The unit will go in conduction for 7,5 cycles and after it will be switched off during 2,5 cycles.

$$10 \text{ (cycles)} \times 75\% \text{ (requested pourcentage)} = 7,5 \text{ cycles.}$$

Now we divide the number of active cycles for the number of the total cycles.

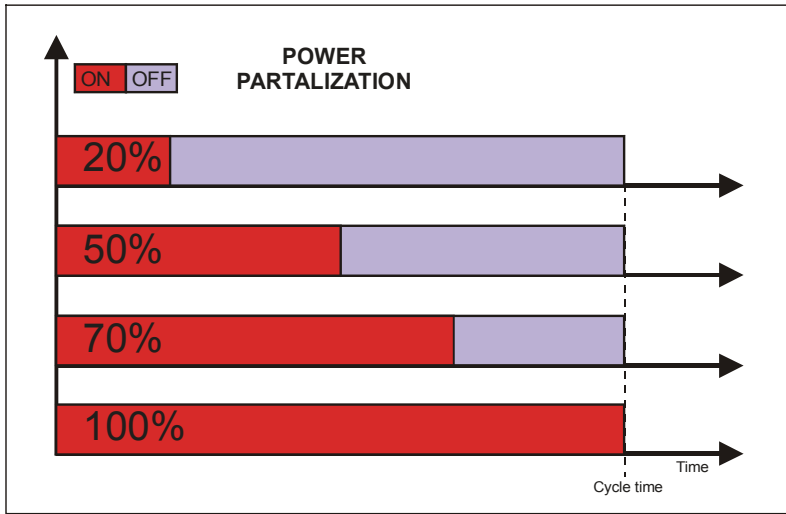
$$7,5 \text{ (active cycles)} / 10 \text{ (total cycles)} = 0,75 \text{ (cycles).}$$

On a déjà dit qu'on fera les calculs selon cycles entiers donc :

0,75	Is this a whole cycle?	No, then the unit will remain switched off during this cycle
0,75+0,75	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0,5
0,5+0,75	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0,25
0,25+0,75	Is this a whole cycle?	Yes, then the unit will switch on for one cycle (20mS) and will start again from 0

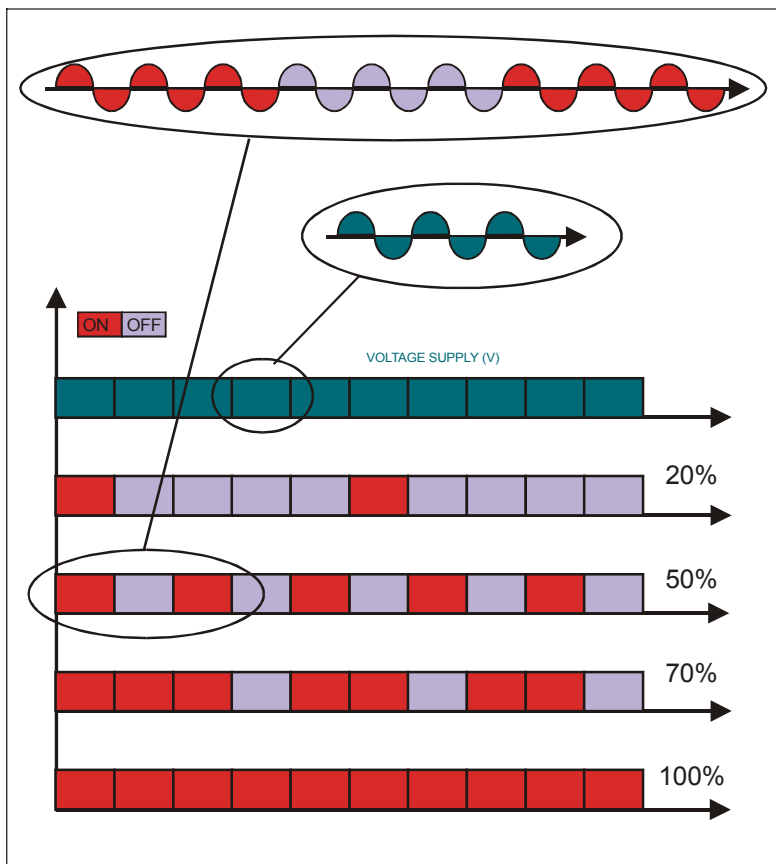
In this case the unit will perform 3 cycles ON and one cycle OFF.

FIRING VARIABLE DUTY-CYCLE



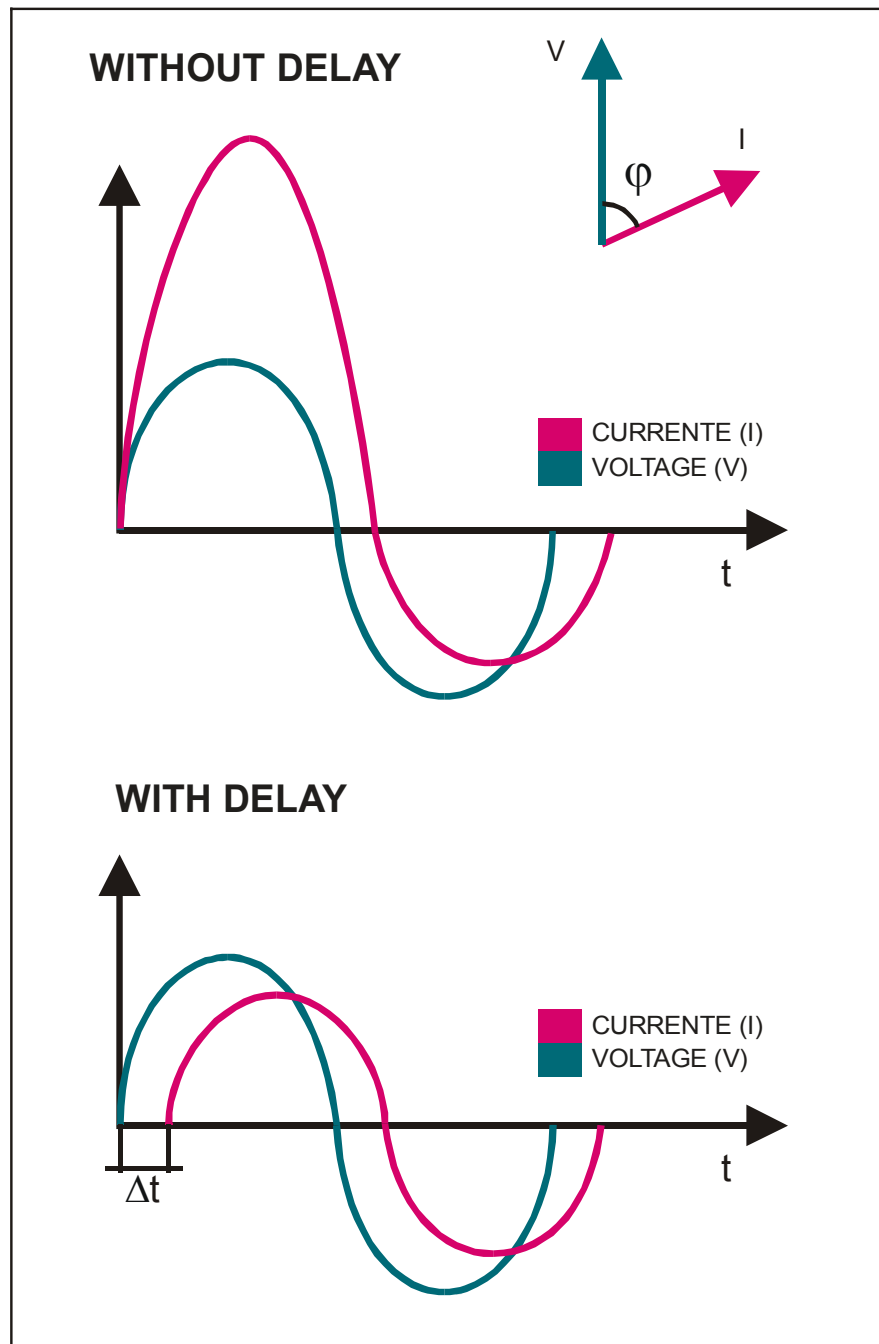
- Cycle time adjustable by serial communication
- Duty-cycle (ON time) is proportional with input signal

BURST FIRING



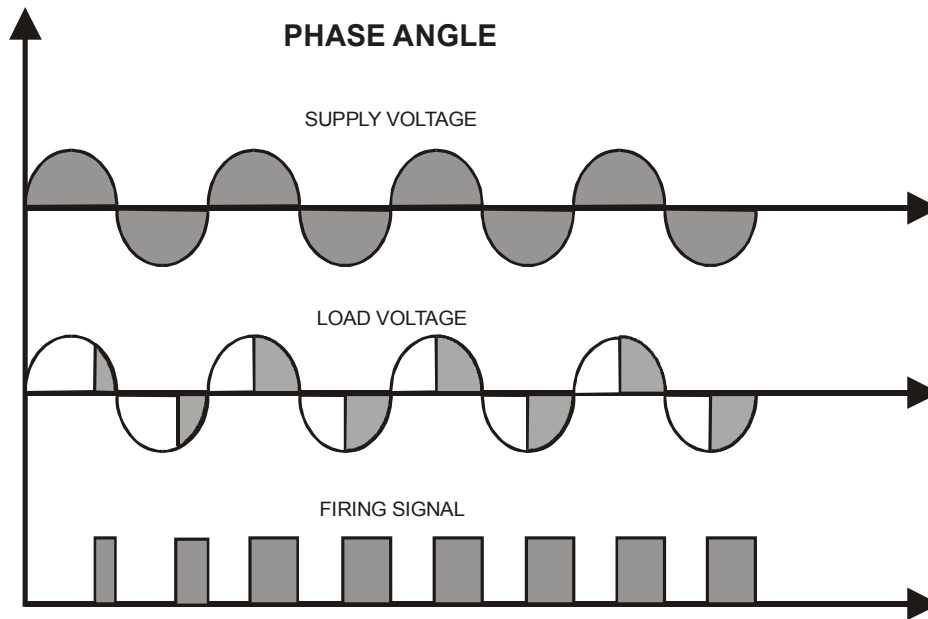
- Right to drive infrared lamp medium and long waves form.
- More uniform distribution of power in respect to the time
- Packet Wave's number adjustable from 1 to 255
- Minimum resolution is 1 cycle (20 msec)

7.5 DELAYED TRIGGERING



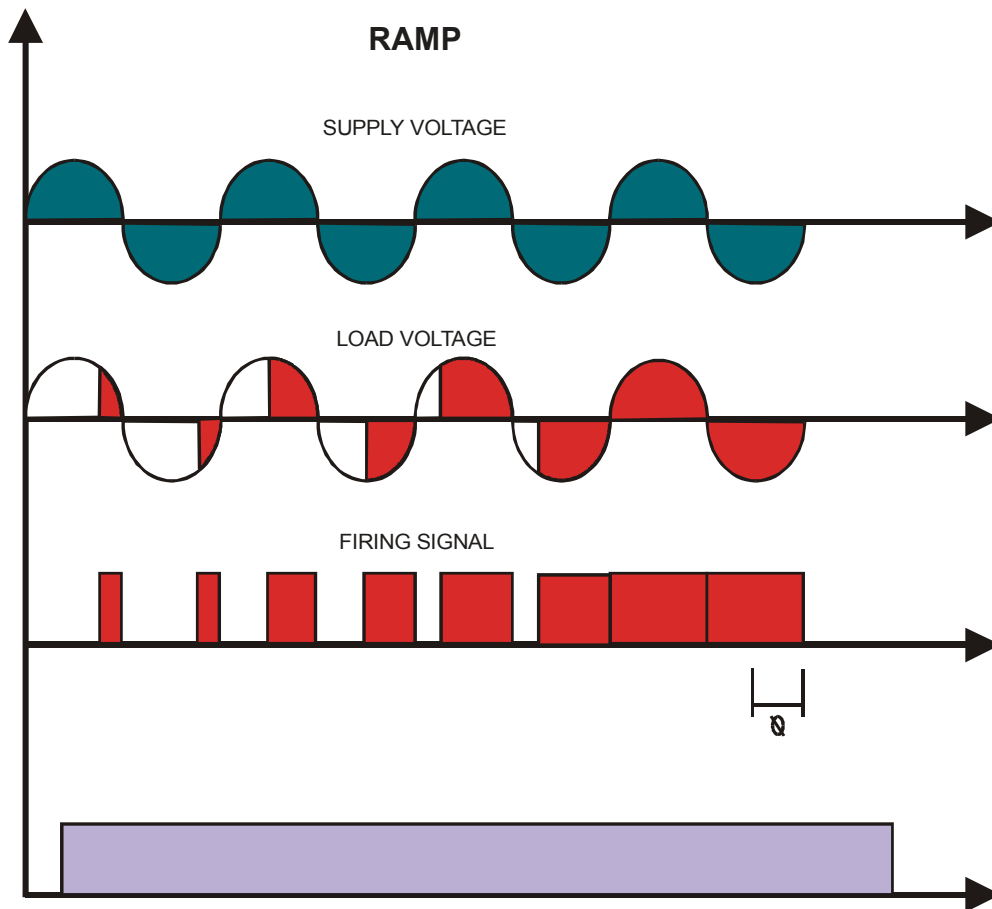
It's used to switch ON-OFF primary of transformer coupled with resistive load on secondary. It's used to prevent inrush surge current when zero voltage switching is used. First time that unit is supplied it must be tuned the delay of triggering. The delay of current is memorized and when the unit will be switched ON a second time it will start when current is zero. Another feature is to switch ON when voltage is positive and to switch OFF only when is negative. (See application note on transformer

7.6 PHASE ANGLE



With Phase Angle is possible to control the power to the load allowing to Thyristor to be in conduction for a variable part of the voltage supply cycle. The load power can be adjusted from 0 to 100% as a function of analog input signal, normally delivered by temperature controller or by potentiometer. It's used with inductive loads. The only disadvantage with phase angle is the generation of interferences that can be reduced with filters.

7.7 SOFT START + BURST FIRING

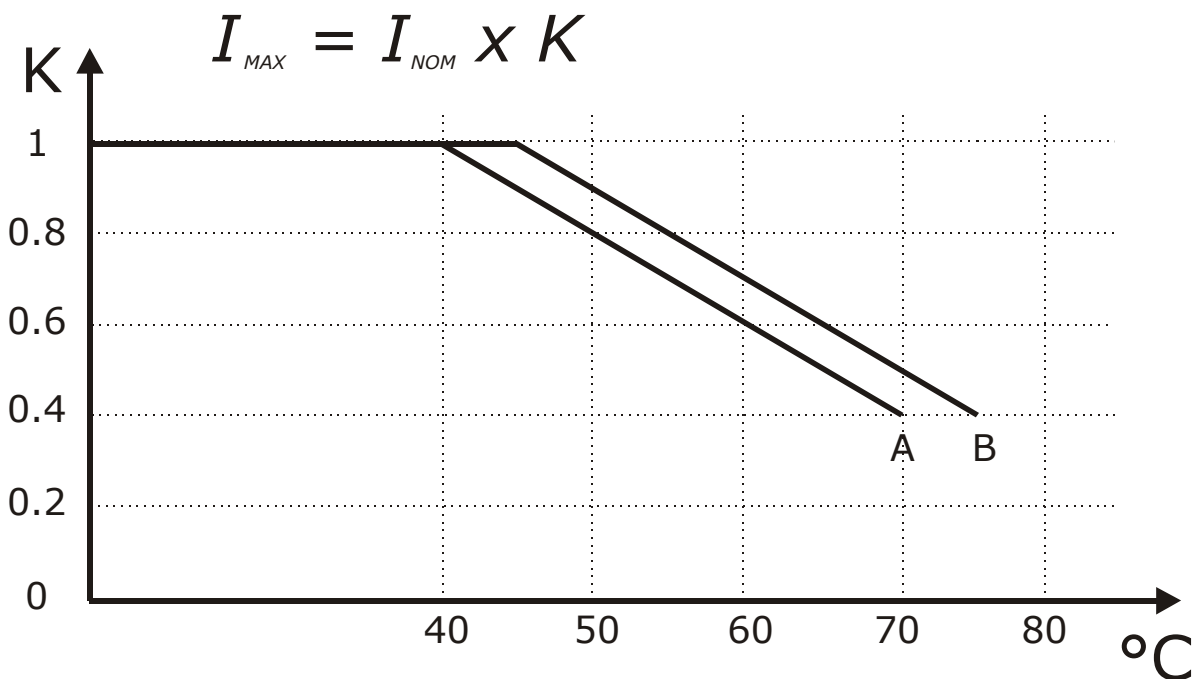


Soft start is an additional feature to Burst Firing. The unit starts in phase angle mode with a ramp from zero to full voltage in a preset and adjustable time. After which the rest of the ON period will be at full conduction.

This firing S+BF is used to switch ON small inductive loads to avoid inrush surge current and to reduce to a minimum electrical interferences.

8. THYRISTOR COOLING

The nominal current of the units in specification are referred to continuous service at 40 or 45°C ambient temperature. For higher temperature multiply the nominal current times derating coefficient K below represented



The curve named "A" is for thyristor with nominal current at 40°C.

These units are below listed

- CD3000S ≤ 110A
- CD3000A/M ≤ 110A
- CD3000A/M 2PH ≤ 55A
- CD3000A/M 3PH ≤ 55A

The curve named "B" is related to all the others thyristor units which nominal current is at 45°C.

8.1 POWER LOSS IN THYRISTOR UNIT

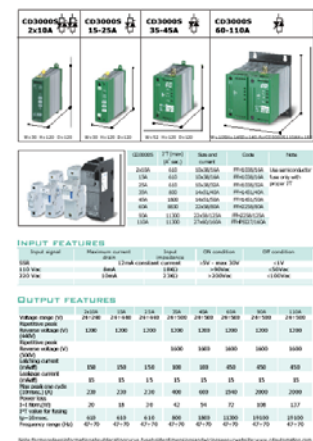
All the thyristor units when are in conduction produces power loss that is dissipated inside cubicle in terms of heating.

Due to this fact the internal temperature of cubicle is higher than ambient temperature.

To be cooled the thyristor need of fresh air cooling and to do it is normally used a fan mounted on the front door.

Procedure to size fan air mass flow is:

- For each thyristor mounted see power loss on its bulletin. On www.cdautomation.com for each product there is a bulletin and on second page there is power loss.



- Make the addition of power loss of the units mounted inside and use the formula:

$$V = f * \frac{Q_v}{t_c - t_a}$$

- Qv= total power losses (w)
- ta= ambient temperature (°C)
- tc= cabinet temperature (°C)
- V= fan air mass flow (m3/h)
- f= altitude coefficient

altitude	f	eng unit
0:100	3.1	m ³ k/Wh
100:250	3.2	m ³ k/Wh
250:500	3.3	m ³ k/Wh
500:750	3.4	m ³ k/Wh
750:1000	3.5	m ³ k/Wh

Example :

$$\mathbf{3 \text{ OFF CD3000M-125A} = 3 \times 146 = 438}$$

$$\mathbf{2 \text{ OFF CD3000M-300A} = 2 \times 320 = 640}$$

$$Q_v = 438 + 640 = 1078W$$

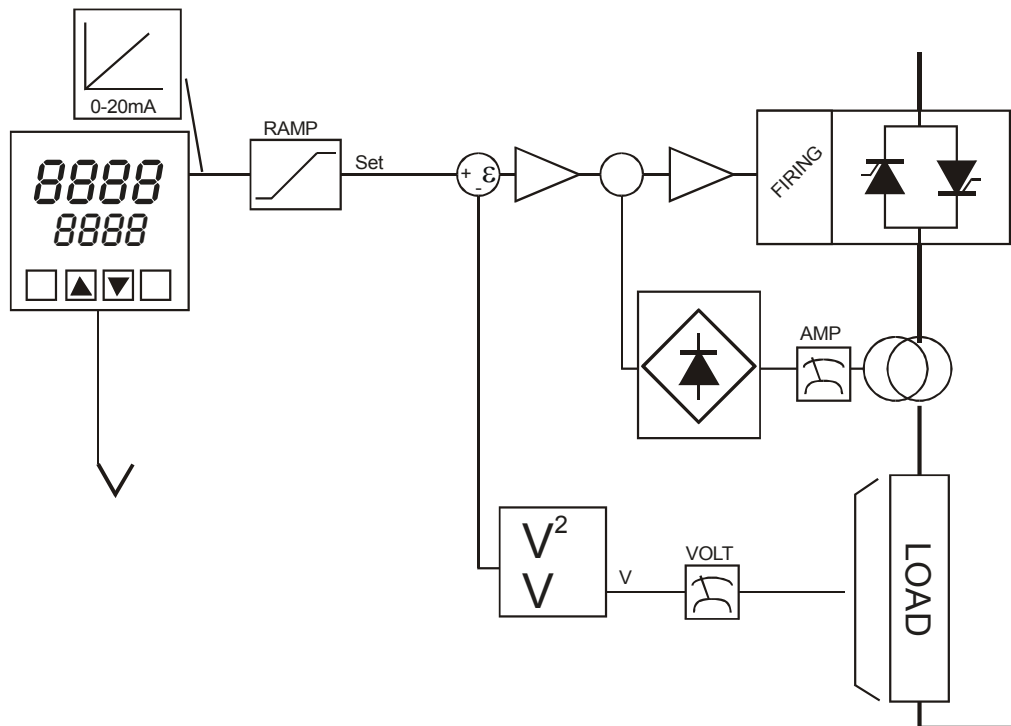
$$V = 3,1 * \frac{1078}{45 - 30} = 223m^3 / h$$

this example is for altitude 100m and maximum ambient temperature of 30°C

9. FEED BACK ON CD AUTOMATION THYRISTOR UNIT

It's important to have a feed-back to keep power constant.

A thyristor unit is formed by two loops as represented below



The external loop is the main one.

The internal one works only when the current exceed the value setted with current limit (current limit loop is available only with Phase Angle because the only way to reduce the current is to reduce the voltage).

- From controller come Set Value
- In control node is calculated the error $\varepsilon = \text{Set} + Pv$ where set positive and Pv negative
- Error signal change the firing of thyristor to keep the system at desired value

This desired value can be power voltage or current. This depend on feed-back thype and we have:

Power Reference signal	⇒	V^2 feed-back
		$V \times I$ feed-back
Voltage Reference signal	⇒	V feed-back
Current Reference signal	⇒	I feed-back

What is the desired value depend on feed-back type

9.1 With Normal resistive loads R(ohm) is constant

$$P = \frac{V^2}{R} \quad P \equiv V^2$$

How is possible to see the power is proportional to voltage square.
Thus is possible to have a constant power unit at low cost.

9.2 With complex resistive loads R change with temperature and sometime with age

In this case is necessary to use power feed-back.

$$P = VxI$$

9.3 CD3000 SERIE VOLTAGE COMPENSATION

Some units have not voltage feed-back but have just a compensation of voltage supply fluctuation of $\pm 15\%$ on nominal voltage.

This circuit works on all CD3000 serie units with analog input.

To compensate the voltage drop the thyristor unit change its on time compared with value before perturbation.

If there is a drop 10%, it increase the power of 19%.

$$P = \frac{V^2}{R} \quad R = \cos t$$

$V_{\text{NOMINAL}} = 1$ before drop voltage

$V_{\text{NOMINAL}} = 0,9$ after drop voltage

$$P = V^2 = 0,9^2 = 0,81$$

This means that with a drop of 10% we lose 19% of power.

With reference with the block diagram happens that the temperature fall down if there is no V^2 feedback. Temperature controller modify its output and change the power demand to thyristor unit.

Unfortunately the temperature controller reaction time plus inertia process time take typically 15minutes to cure voltage drop (~ 10 minutes of integral constant time).

If we have feed-back when voltage drop the Error become bigger and an action on thyristor is taken immediately.

In this mode we have more stable temperature system.

10. COPPER HEATING TREATMENT

Before to coat a cable with PVC or other material sometime is necessary a copper preheating.

Preheating is obtained with current circulation. To have a constant heating treatment we must give to cable a constant energy considering that cable can change its speed in the extrusion process.

W = energy

$$W = P \times t$$

P = power

t = treatment time

S = space

$$S = V \times t$$

$$t = \frac{S}{V}$$

$$W = P \times \frac{S}{V}$$

V = velocity

This is obtained because if we twice caterpillar speed power pot deliveries a double signal so we have a new power that is two time first one. We have to notice that thyristor unit must have V2 feedback because in this way the reference signal is a power signal demand.

