Technical Summary

1 Introduction

The Active Reactor is an electronic device used for the control of HID lamps. The device uses electronics and built in intelligence to start and run HID lamps is a predefined manner. It is applicable for the control of all higher wattage HID Metal Halide (MH) and High Pressure Sodium (HPS) lamps in the power range 150W-2000W.

Using the device in HID lighting applications results in significant energy savings (and greenhouse gas emissions), lamp life extension and improved lumen maintenance.

The device has been developed by The Active Reactor Company Pty Ltd, Melbourne, Australia. The device is trademarked and has patents granted in Australia, New Zealand, China, India and the United States with patents pending in other countries.

2 The Device

The Active Reactor system consists of a fixed power main ballast and an electronically controlled variable power control ballast as shown diagrammatically in **Fig 1**.

The fixed power main ballast supplies approx 70% of the lamp power while the variable power control ballast supplies 0% - 30% of the lamp power as required. The ratio of fixed power to variable power delivered to the lamp depends on the overall Maintenance Factor for the lighting design which can be adjusted on the Active Reactor to match the lighting design parameters.

Fig 2a shows the components of the Active Reactor system installed in a luminaire comprising a main ballast, a control ballast and the Active Reactor controller.

Fig 2b shows the Active Reactor system installed on a gear tray comprising a main ballast, control ballast and Active Reactor controller. The Active Reactor controller is installed as a “plug & play” device which is easily removed from the circuit.

Fig 3a shows the Active Reactor printed circuit board (PCB) and components for a 150W – 400W HPS/MH controller

Fig 3b shows the Active Reactor cassette which houses the PCB. The cassette is die cast aluminium and has an IP 67 rating to protect the electronics from moisture and airborne contaminants.

The Active Reactor circuit topology and mode of operation enables the Active Reactor system to operate at "**variable power, constant light**", as opposed to a conventional magnetic (or electronic) ballast which operates essentially at "**constant power, variable light**". These two different modes of operation greatly affect lamp energy consumption and lamp performance.

3 Constant Light Output Operation

One of the most desirable (and demanding) modes of HID lamp operation is constant light output, that is, constant design value illuminance.

Constant design value illuminance can be realised if the power to the lamp is varied in such a way as to compensate for lamp depreciation and dirt depreciation (luminaire maintenance factor) during the life of a lamp. The Active Reactor achieves this by varying the power to the lamp, starting with a lower than rated power for a new lamp and gradually increasing the power to full power as the lamp ages.

This mode of operation results in significant energy savings during the life of a lamp as well as significant lamp life extension and higher lumen maintenance. The energy savings are in the order of 18% for MH and in the order of 25% for HPS while the lamp life increase is up to 50% for MH and up to 100% for HPS.

The exact energy savings and lamp life increase depend on many design and site factors including design maintenance factor, supply voltage levels and voltage fluctuations, fixture effect on the lamp and lamp replacement cycle.

4 Circuit and Operation of the Active Reactor

Circuit Diagram

A schematic wiring diagram of the Active Reactor connected into a HID lamp circuit is shown in **Fig 1**. The following describes the operation of the circuit:

1 The Active Reactor is connected into the circuit be removing the standard reactor ballast and replacing it with the Active Reactor components. The power factor capacitor and ignitor remain in the circuit.

2 The Active Reactor components are:

a the Active Reactor PCB which contains the electronics to control the lamp power and lamp starting.

b a main ballast which supplies approx 70% of the lamp power. For example, for a 250W HPS lamp this is a standard 150W ballast.

c a control ballast which supplies approx 30% of the lamp power. For example, for a 250W HPS lamp this is a modified 100W ballast.

Note: for some lamps both the main and control ballasts are standard ballasts while for other lamps both ballasts are modified ballasts. The required impedance for the main and control ballasts determines whether they are standard or modified ballasts.

Operation

The Active Reactor utilises the main ballast as the primary source of power for the lamp and injects additional current (and power) into the circuit via the control ballast to achieve the required lamp power profile.

The minimum power the lamp runs at is when the control ballast is completely **turned off** and the maximum power the lamp runs at is when the control ballast is completely **turned on**. Hence the lamp can run at any time in its life between 70% and 100% power by appropriate current injection into the lamp, that is, by appropriate switching of the control ballast into the circuit.

This operation is summarised below:

Main ballast	Control ballast	Lamp power
ON	fully OFF	70%
ON	fully ON	100%
ON	partially ON/OFF	70 - 100%

The 30% variable power which can be delivered to the lamp is just enough to offset the 30% flux depreciation during the life of a lamp.

Note: The 70/30 ratio is typical for a MF=0.7 only. The Active Reactor can be configured for other ratios, for example 66/33, 75/25, 80/20, etc.

Operating characteristics

1 If the Active Reactor electronics fails then the lamp runs only on the main ballast at 70% rated power.

2 The Active Reactor can operate to specification for input voltage variations of +/- 10%. Above these voltage variations it will still operate but will not regulate the power to the specified value. The voltage ranges for typical 50Hz and 60Hz supplies are:

System	Acceptable Variation in Supply Voltage
240V, 50Hz Supply	216V-264V (48 volt range)
277V, 60Hz Supply	249V-305V (56 volt range)

3 The Active Reactor monitors the supply voltage, ballast voltage, lamp voltage and lamp current to control the lamp power.

4 The Active Reactor uses the lamp voltage as the basis for determining lamp life. Typically HPS and MH lamps have the following voltage characteristics:

Lamp	New Lamp Volts	Old Lamp Volts
MH Lamp	130V	160V
HPS Lamp	90V	170V

Thus if a lamp fails and is replaced by a new lamp it will automatically be adjusted in power by the Active Reactor to run at the same light output as it did before it failed, that is, at the same light output as all the other lamps in the installation.

5 The ballast losses of the Active Reactor compared to the losses of a standard reactor ballast are summarised below:

Lamp	Active Reactor Losses	Standard ballast Losses
New lamp	85%	100%
Old lamp	105%	100%

Overall, throughout the life of a lamp the Active Reactor ballast losses are lower than the standard reactor losses by approximately 5%.

6 Active Reactor controllers are factory calibrated for either HPS or MH operation and for a specified design maintenance factor.

Energy Savings

Because the Active Reactor runs a lamp all of its life below its rated power (to reduce the initial lumen output of a lamp to the design level output) then energy saving are realised by using less power. The energy savings are compared to the power and energy consumed by a standard ballast running the same lamp.

Fig 4 shows the operation of a HPS lamp under standard ballast control and under Active Reactor control. Under standard ballast control the lamp power follows the standard ballast curve for a HPS lamp. The power starts slightly below rated power when the lamp is new, rises to a maximum when the lamp is middle aged and falls below rated power when the lamp is very old.

Note: The average power above rated power over the life of a HPS lamp is typically 5%-10% at nominal supply voltage but can increase dramatically to 15%-20% overpower for high supply voltages.

Fig 4 also shows the power delivered to the lamp under Active Reactor control. For MF=0.7 the lamp power starts at 0.75pu rated lamp power and increases in time until it reaches rated lamp power at the end of lamp life. In the graph shown the end of lamp life is up to twice the lamp life shown for the standard ballast controlled lamp.

The shaded area between the standard ballast and Active Reactor power curves is the energy difference between the two control methods or simply the energy saved. Note that the energy saved during the first half life of an Active Reactor lamp is greater than the second half. Taking into account several lamp cycles the following energy savings result:

Lamp	**Energy Saving**
150W-400W HPS	in the order of 25%
150W-400W MH	in the order of 18%

Lamp life extension

Because lamps controlled by the Active Reactor run all their life below their rated power, the mechanisms which reduce lamp life and lumen depreciation are inhibited to a significant extent.

The Active Reactor inhibits the following mechanisms which affect lamp life and lumen depreciation:

1. Electrode burning
   The lamps carry a lower electrode current and hence tungsten evaporation from the electrodes is reduced. Electrode “burning” is a main cause of lumen depreciation and lamp failure.

2. Diffusion of fill elements
   The lamps run at a lower temperature and hence diffusion and reactions in the arc tube are reduced. Diffusion of sodium through the arc tube

and chemical reactions of sodium and other fill elements with the quartz tube are also causes of lumen depreciation and lamp failure.

3 Lamp starting
The Active Reactor has a preset starting current during lamp ignition. This current is such that the glow to arc phase time is minimised which reduces electrode sputtering during lamp starting which improves lumen maintenance.

Note: Extended lamp life implies low lumen depreciation and low lamp failures.

5 Summary

The principal features of the Active Reactor are:

1 The device uses robust and reliable magnetic inductors as the primary control elements and electronics only for data acquisition, signal processing and control strategy implementation.

2 The electronics is housed in a die cast aluminium cassette which is rated at IP67. This high IP rated cassette protects the electronics from moisture and pollutants which otherwise would affect the life and operation of the electronics.

3 The device can accommodate all HID lamps in the range 150W to 2000W. Because the device runs at power line frequencies (50/60 Hz), high frequency acoustic resonance, which is a common problem in high power high frequency electronic ballasts, is completely eliminated.

4 The lamp keeps on burning even if the electronics fails.

5 **Substantial power and energy savings** in the order of 18% for MH and 25% for HPS can be achieved by running lamps under variable power control and very large power savings of 40% can be realised by dimming strategies.

6 **Substantial Extension of lamp life** of up to 50% for MH and up to 100% for HPS can be achieved by running the lamps under variable power control.

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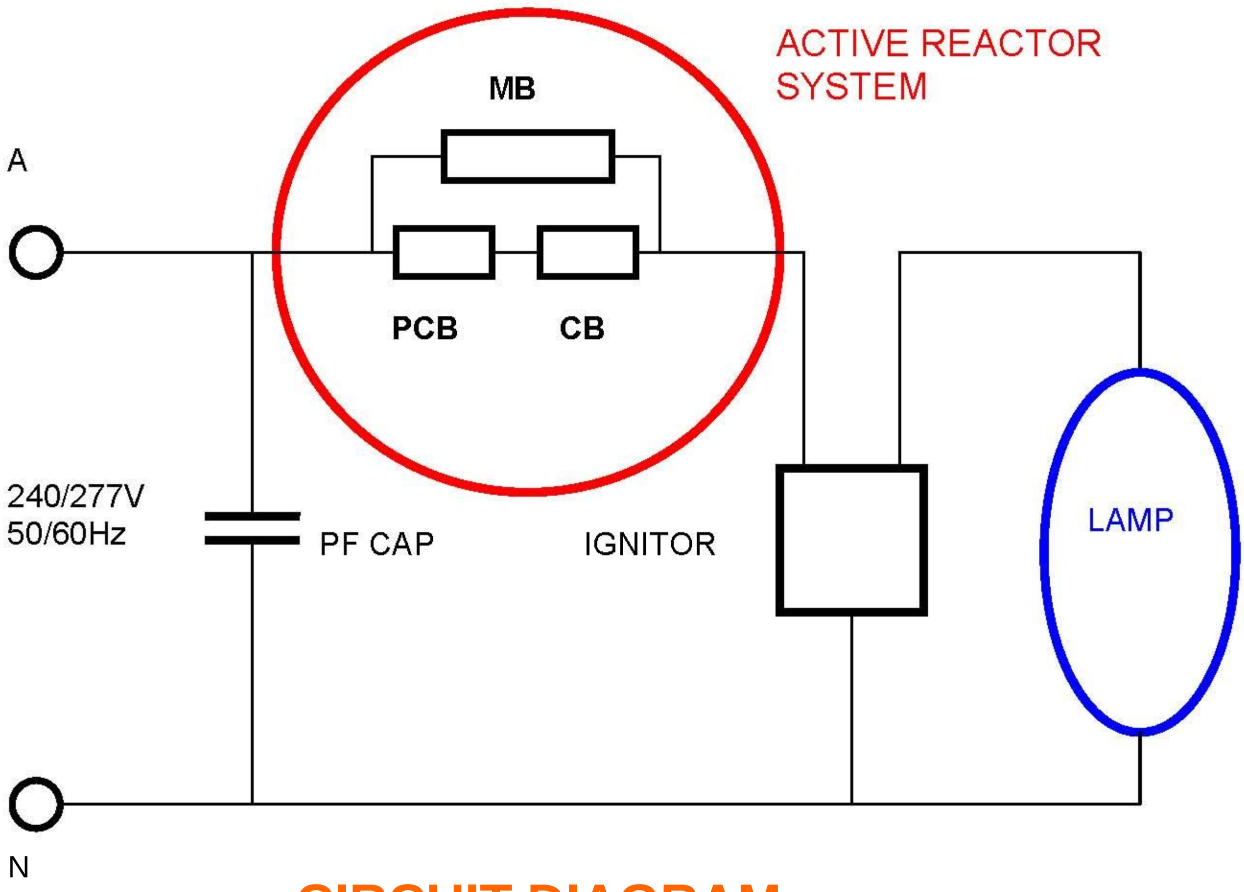
FIGURE 1

HID Lamp Controller



CIRCUIT DIAGRAM

LEGEND

MB MAIN BALLAST
CB CONTROL BALLAST
SW ELECTRONICALLY CONTROLLED TRIAC SWITCH
PCB ACTIVE REACTOR PRINTED CIRCUIT BOARD

FIGURE 2a

FIGURE 2b

the ACTIVE REACTOR

FIGURE 3a

FIGURE 3b

FIGURE 4

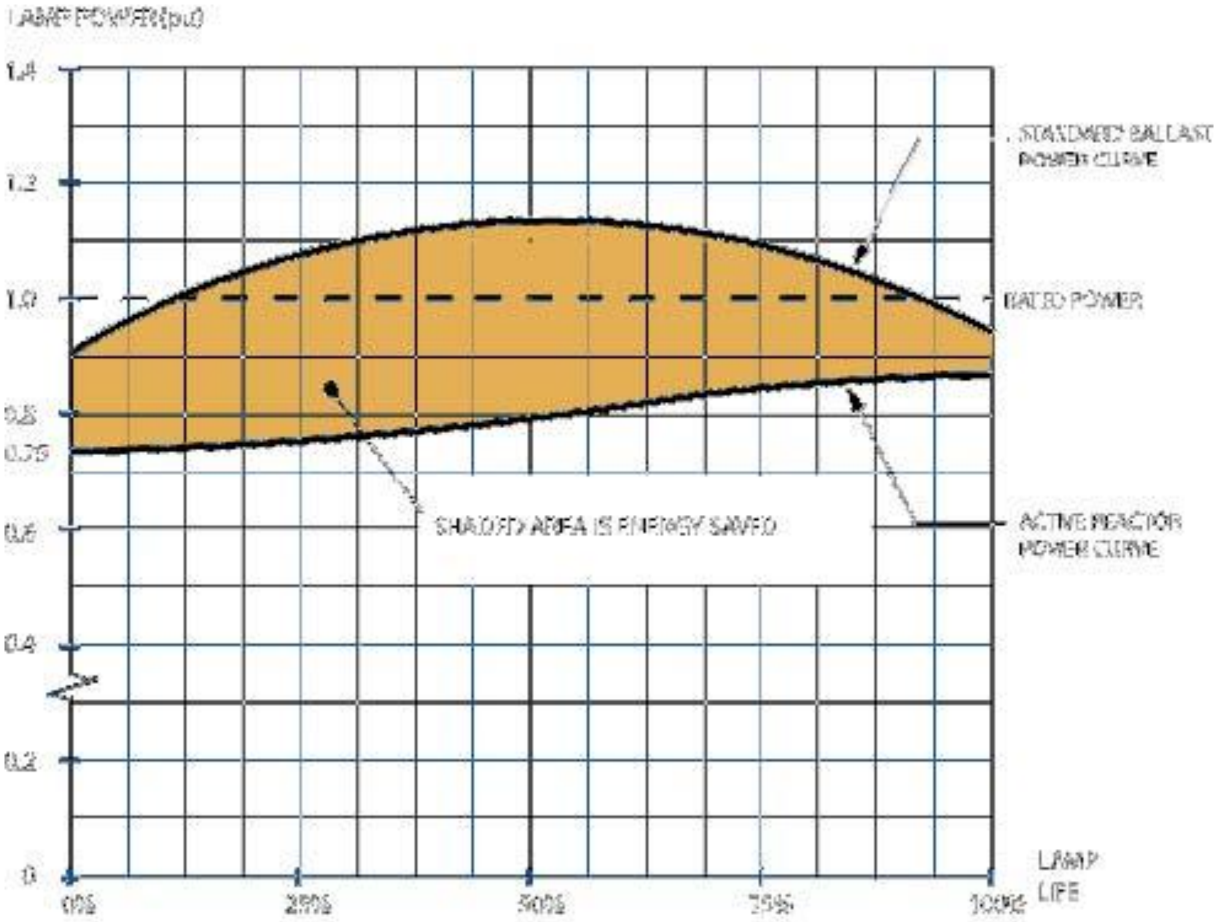


FIG. 4: Standard HPS ballast & Active Reactor power curves