The design and manufacture of photocell control units

By S. Marais

The use of photocell controllers can cut both installation and running energy costs of streetlighting. The chosen controller must be cost-effective, reliable and of high performance in order to satisfy the requirements. Initial thinking centred around unit cost in the hope that 'technology' would take care of unit function. This paper describes the design and development of controllers and the associated pitfalls in an attempt to enlighten manufacturers and to guide consumers.

In a world of advancing technology one may be forgiven to assume that the design and manufacture of a 'simple' photocell controller is an easy task. The function of the controller is simply to switch lighting on at dusk and off at dawn. It must repeat this process efficiently for many years and require no maintenance. Murray Cronjé (SANCI 1988) has shown the energy saving in effective switching and given the vast number of controllers used in a typical reticulation an additional burden is placed on the controller in terms of sample variation and cost.

Increasing performance/cost ratios have opened up new possibilities. Instead of using one controller to switch a row of streetlights, what about using one controller per streetlight? The advantages are:

1. No need for a dedicated (switched) cable. In urban areas the consumer reticulation runs past the streetlighting anyway, making it cost-effective to supply streetlights from adjacent CDUs (consumer distribution units).
2. The failure of the controller only affects one streetlight. All too often, large areas are plunged into darkness because of the failure of one controller.
3. Effective lighting distribution. Local ambient light levels would determine when each streetlight switches on. It is not uncommon to see a streetlight on top of a hill shining brightly whilst the ambient light levels are still high because its controller is many metres away, covered by a tree.
4. Lower switch-on surge. The streetlights will switch-on randomly at dusk inducing less mains-borne interference.
5. Increased flexibility. If the streetlight fittings are designed to accept the controller directly, there will be no need for on-site wiring. This becomes more advantageous in rural areas where streetlight spacing is greater or irregular.

Requirements

The requirements facing the designer are cost, performance and reliability.

The unit must be cheap enough to be cost-effective in an installation and be treated as a consumable. No end-user is interested in forming a repair facility for photocell controllers. Initially, the photocell controller had only to compete with the cost of the timeswitch but the increasing cost of electricity and the corresponding drive for efficiency has placed new demands on unit cost.

Given the energy savings possible with effective switching times, it is important that the units maintain their switching threshold over their operating life. This must be the case whilst being subjected to temperatures varying from freezing winters to sweltering summers. This temperature cycling ages the uinit due to repeated expansion and contraction of its components. Cycling also places heavy demands on sealing. The ingress of moisture and dirt would adversely affect the unit's performance by corroding the electronic circuitry and switching element.

The continued exposure to UV rays from the sun places further demands on the design. Stabilised plastics must be used and expansion coefficients of different materials matched. The light sensor must also not degrade with prolonged UV exposure.

The unit must also contend with physical abuse. The sensitive electromechanical switching element must be tough enough to withstand vibration induced by transportation and rough handling. The units may spend weeks rattling around at the back of a service truck before installation.

Reliability is of prime importance. Maintenance is both expensive and time-consuming. Modern semiconductor technology has produced components with a service life of many years and it must be the designer's aim to produce a product whose service life tends toward that of the components. Reliability is adversely affected by load and line conditions. The repeated switching of high currents into reactive loads places heavy demands on the switching element. The design must prevent contact chatter. This undesirable effect reduces both streetlamp and contact life as well as producing interference.

The mains supply can also be a problem. The unit must be designed to operate effectively with widely varying mains voltages. Fluctuations in the supply must not cause spurious switching. The sensitive electronic circuit must be protected against mains-borne surges. This problem is aggravated in areas with high incidence of lightning.

The energy saving in correct switching time would be offset by high unit quiescent power. It must use a small fraction of the power consumed by a single streetlamp. The unit must also have dead time to negate the effects of passing motorists at night. The transient incidence of the car's headlights on the controller must not affect switching.

The failure mode must be predictable. The unit must fail with its switching element closed, thereby switching the streetlighting on permanently providing illumination at night and serving as an indication for maintenance teams during the day.

In the absence of a South African standard, the British Standards Institution specification BS 5972 should be used as a guideline for development. The specification details the form, fit and function of photocell controllers for road lighting to ensure compatability and reliability. The specification details:

1. *Marking*. This shall include the manufacturer's ID mark, the model and type number, rated voltage and current, switch-on level and the month and year of manufacture.
2. *Construction*. It must plug into a NEMA-type socket. It must survive instantaneous accelerations of 40 *g*. The unit shall be sealed to prevent the ingress of moisture and the pins shall be fabricated from a corrosion-resistant metal such as brass.
3. The unit shall have an insulation resistance of greater than 5 MΩ.
4. The creepage and clearance distances shall be greater than 0,2 and 0,1 mm respectively.
5. *Electrical performance*. The unit must be capable of switching loads of 10 A at 240 V at least 2500 times (the load is specified in BS 5972). The switch-on level shall be within 20 % of the declared level and the switch-off level shall not be greater than twice the switch-on level.

The Author

Stirling Marais matriculated at Westville Boys High School in 1974 and then studied at the Natal Technikon, receiving a Higher National Diploma in heavy current and a Masters Diploma in light current. During his studies he received numerous awards for academic achievement (including SAIETE most outstanding student of 1979). He gained experience in heavy current (consumer distribution, switchgear and protection systems) at the Durban Corporation and then pursued a career in electronic design. His experience includes feedback control systems, microprocessors and system modelling. Stirling is the technical director at Dynamic Electronics in Durban and is currently involved in the design of photocell controllers, fluorescent light inverters and automated test equipment.