

Management of public lighting

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ABSTRACT

Public Lighting Consumes a lot of Energy!

About 5% of energy used in lighting is consumed by public lighting. Energy for public lighting is the biggest part in the energy usage of a town and the maintenance and operation of the lighting is a considerable expense for every city.

Telemanagement

It is therefore important to allocate resources most efficiently and make use of the technologies available today. Dimming Technologies for HID lamps and not to a lesser extent communication technologies such as power line carrier and GSM telephone play an important role. Communication to the distribution board and even to each individual lighting point is used today. The data collected is stored in a database and managed by a central control station essentially consisting of a PC. Not only the proper operation of an individual lighting point is monitored. Information such as luminaire voltage, lamp current, capacitor current, and power but also each individual lamp voltage is recorded and analysed. The lamp voltage in particular gives us an important information about the state

of the lamp itself and so we can predict a lamp failure months before it actually occurs. This means lamps can be changed before they fail and the lighting can be guaranteed to a very high degree. Safety and security is guaranteed for the users of public spaces.

Dynamic Public Lighting

A recent three-year study by the transport and public works department in the Netherlands tested the concepts of reduced luminance during low traffic hours and under good metrological conditions. It concluded that the concept of dynamic public lighting should be used. A similar conclusion can be found in the new European Standards for public lighting. Luminance levels can be reduced by as much as 50% under favourable conditions. Considerable energy savings are achieved (30% - 40%) and due to the proper operation of the lamps (no over voltage) the service life of the lamps is extended.

Systems Pay for Themselves

Because of the energy and maintenance savings systems pay for themselves within 3-5 years. They can be installed on a energy performance contract bases (ESCO) without using financial resources elsewhere needed.

This paper shall discuss the technologies available, use of forecasting techniques, the various benefits to be derived from management systems.

INTRODUCTION

“RIGHT LIGHT!” What does this really mean? We all know that horizontal and vertical illuminance, luminance, uniformity, colour temperature, colour rendering, energy

Figure 1

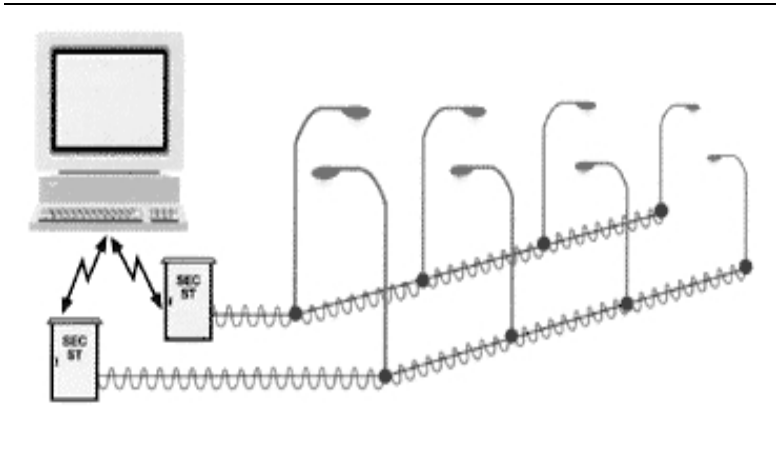


Figure 1 is showing a bloc diagram of a "point to point" management system. Power line communication is used between the luminaires and the distribution board (DB) and mobile phone modem (GSM) is used to communicate between the DB and the central computer.

consumption, maintenance cost and aesthetics define the lighting environment to a large part for a given installation with given parameters. But what if the parameters change? Are we able to change the lighting accordingly?

Not without an appropriate control system!

In public lighting these surrounding parameters change constantly! One of the more important parameters is traffic density, e.g. vehicles per hour. This parameter as we all now can change easily 1:10 or up to 1:100. This is why the "RIGHT LIGHT" at 18.00 is not necessarily the "RIGHT LIGHT" at 23.00! An other parameter that keeps changing is the weather, this greatly influences the visual performance, just think of fog!

"RIGHT LIGHT" means as well, that the "right lighting" we installed is working! How can we guarantee this if we don't know? How can we guarantee this if we wait for somebody to complain about the malfunctioning? Isn't the public responsibility greater than that? How can we wait for the accidental and random reporting of failures? Or how can we send out maintenance people night after night to check the proper functioning of the lighting? Are we not in the 3rd millennium? Today's technology is able not only to adjust luminance levels in accordance to traffic and whether conditions but also to detect and report failures of lighting circuits and even single lamps.

THE COST RATIONALE BEHIND LIGHTING

Provision for lighting can be divided in two different cost components, initial investment and operational cost. Unfortunately the initial investment influences to a high degree the operational cost which are by far more substantial over the life span of a lighting installation.

If we have a look at the simple diagram further on it seems clear where the priorities should be! It is an easy calculation that should be done for every installation. It shows that saving 30% by buying a cheaper luminaire that is 15% less efficient is not worth it.

Figure 2

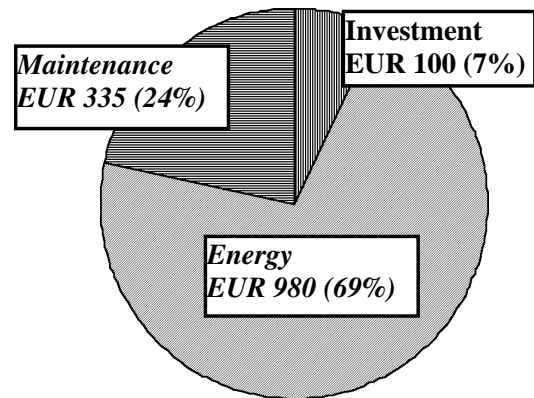


Figure 2 is showing the lifetime cost of a luminaire

Cost of energy: 0.07 EURO / kWh

Luminaire: 1 x 150W HPS (high pressure sodium)

Cost of luminaire: EURO 100.00

Operating hrs: 4000 h / year

Lamp life: 12'000 hrs

Cost of lamp: 15 EURO

Cost of exchange: 35 EURO

Three cost components need to be considered:

- initial investment
- cost of energy
- cost of maintenance

A small example shall give you a better understanding of this: We take a high quality high pressure sodium (HPS) luminaire fitted with a 150W lamp and a reactor ballast (losses 25W).

- Initial investment:** The cost of the above luminaire is about EUR 100.00.
- Cost of energy:** Operated for 4000 h per year at a cost of energy of 7.0ct the annual energy cost of this luminaire is:

$$\text{EUR } 0.07 \times 4000 \text{ h} \times 175\text{W} = \text{EUR } 49.00 \text{ p.a.}$$

Assuming a 20-year live and a constant price of energy the energy cost over the life of the luminaire is:

$$\text{EUR } 49.00 \times 20 \text{ years} = \text{EUR } 980.00$$

or 10 times the cost of the initial investment. In a 24h application (tunnel) this figures would more than double:

$$\text{EUR } 0.07 \times 8760\text{h} \times 175\text{W} \times 20 \text{ years} = \text{EUR } 2'146.00$$

c) **Cost of maintenance:** Assuming a lamp life of 12'000 h the lamp needs to be changed about 6.7 times in case of 4000 h p.a. of operation. The cost for this would be about EUR 15.00 for the lamp and about EUR 35.00 for the labour and machinery. The total maintenance cost for 20 years with 4000 hrs p.a. is:

$$6.7 \times \text{EUR } 50.00 = \text{EUR } 335.00$$

The decision to choose adequate lighting is many times left to a contractor, who has in most cases no incentive to look at the overall efficiency and quality of such an installation. It is many times only after the construction phase when operational cost becomes apparent and ways are thought to reduce them.

The trend to design and construct facilities eliminates the expert advice specialised electrical engineers would be able to provide.

It is therefore of great importance that operators put great emphasise in the provision of energy efficient lighting and lighting controls in order to minimise energy consumption and operating cost.

COMPETITIVE PAYBACK

Because of the energy and maintenance savings systems pay for themselves within 3-5 years. This makes the investment in lighting controls very attractive.

Not taking into consideration the cost of the investment and the depreciation thereof the total cost of operating one lighting point high-pressure sodium 150W is:

Energy:	EUR 0.07 x 4000 h x 175W =	EUR 49.00 p.a.
Maintenance:	EUR 50.00 / 3 =	EUR 17.00 p.a.
Total cost is:		EUR 66.00 p.a.

With 25% energy saving and a doubling lamp life we achieve the following savings:

Energy:	EUR 12.25 p.a.
Maintenance:	EUR 8.50 p.a.
Total savings:	EUR 20.75 p.a.

In order to achieve a three-year return the capital investment has to be < EUR 62.25, for a five-year return some EUR 103.75 can be invested.

As a rule of thumb the capital investment for lighting controls with a three-year payback should not exceed EUR 400.00 per kW of installed lamp power.

LIGHTING CONTROLS WITHOUT ANY INITIAL INVESTMENT

Because of the good return systems can be installed on a energy performance contract bases (ESCO) without using financial resources elsewhere needed. In many countries interest free loans or even funds are available for energy saving control systems for lighting. In the future I think ESCO type contracts however will become more impor-

tant. The advantages are simple to understand. The owner of a lighting installation can have a control system installed free of charge signing a contract with the supplier of sharing the savings the system creates for a certain time period. Unfortunately such contracts are illegal in some countries e.g. France. Municipalities are not allowed to sign such long-term contracts here! In most other countries however there are no legal problems and the amount of business done this way is steadily increasing.

Example

Taking the parameters from the example in chapter II EUR 553.33 can be spent per kW of installed lamp power in order to achieve a payback of 4 years. A payback of four yours means capital earnings of 25% p.a. Taking into account the cost of funds of e.g. 5% the capital earnings are reduced by the same percentage;

$$25\% - 5\% = 20\%$$

A return of 20% now leads to a return of investment (ROI) including the cost of funds of 5 years.

What does this mean?

It means that if this equipment is installed free of charge and the savings generated by the equipment during the first 5 years are used to pay back the investment the customer obtains the ownership after five years without paying a single cent! Too good to be true say some! Not possible! Say others.

THE ENERGY RATIONALE

Public Lighting Is Important... But... Public Lighting Consumes a lot of Energy!

About 5% of energy used in lighting is consumed by public lighting. Energy for public lighting is the biggest part in the energy usage of a town and the maintenance and operation of the lighting is a major expense for every city. **It is therefore abundant that that any public lighting installation is as efficient as possible safeguarding of course good lighting practice and national / international standards.**

The new international standard for road lighting (CIE115 1994) [1] and the new European standard (EN13209) [2] as well as most national standards allow a reduction in luminance during non peak-hour traffic. According to CIE115 1995 class M1 can become M2 with medium density traffic and M3 with low traffic density. That means the illuminance can be dimmed from 2 cd/m² (class M1) to 1,5 cd/m² (M2) or even to 1,0 cd/m² (M3) as long as the uniformity is maintained.

These new standards are as well supported by a study "Visibility and Energy Savings in Public Lighting" [3] which concludes that a luminance reduction by up to 50% is having no negative effect on the visibility as long as the uniformity is not reduced.

In the beginning of energy saving in public lighting one in two luminaires were switched off. This does save 50% of energy but destroys the uniformity to an extent witch is

Figure 3



Figure 3 is showing two different ways how to save 50% of energy in public lighting.

dangerous. Objects in the dark part are not visible anymore. This is not acceptable any more nor supported by any neither national nor international standards. An acceptable solution is to dim the lights when full luminance is not needed.

In the Netherlands for example the Public Works department undertook a three-year study (DYNO) on dynamic public Lighting [4]. All traffic parameters on a 15km piece of motorway were measured first for one year without lighting, then for a further year with a fixed lighting of 1 cd/m² then for an other year with dynamic lighting 0.2 to 2.0 cd/m². Metrological conditions as well as traffic density were measured and an appropriate luminance was chosen. The study concluded with the recommendation of installing dynamic public lighting on all motorways in the Netherlands.

DIMMING OF DISCHARGE LAMPS

A reoccurring controversy attracting today support from all major lamp manufacturers for a wide range of lamps as long as minimum performance specifications are met. HPS lamps show very little signs of decay of the colour rendering index nor a big change in colour temperature. With metal halide lamps however a decrease of Ra and an increase of the colour temperature can be measured. The acceptance of such a change depends on the application. When discharge lamps are dimmed the efficiency is decreased. This is not really important as long as energy can be saved. In case smaller wattage lamps are used a significant decrease in efficiency has to be taken into account as well.

Two different technologies are widely used today:

Dimming by decreasing the mains voltage by means of a magnetic transformer (for high pressure sodium and mercury vapour lamps only).

Dimming by the use of an electronic controller either triac or IGBT based (for all types of discharge lamps).

Both technologies are acceptable and both have their strengths and weaknesses. Other technologies such as electronic control gear are available for some smaller wattage lamps (<150W) however it seems this technology is not suitable for dimming of bigger wattage lamps because of the physical limitations of the lamps themselves. In addition these technologies are expensive and do not yield a reasonable payback. An other quite old technique are split ballasts. But because of the limited flexibility (two steps) and because some minimum performance specs of the lamp manufacturers cannot be met with these devices they have a limited future only.

Dimming With Magnetic Transformer

The technique is as old as the lamps it dims! But still, it looks much easier then it is! This way HPS and MV lamps can be dimmed to about 50%. Many of the products available today still use moving parts (variac type). This of course is not acceptable because of the maintenances such devices require. More advanced systems use taped type transformers. This seems to work quite satisfactory as long as no electronic taping is used because such taps can introduce harmonics and usually they are not working as reliably as they should. Most systems can stabilise the voltage, which is an important point for a good lamp life. Some systems can even increase the supply voltage to the lamps in case of under voltage. This is particularly important as the lamps must be started under nominal conditions (230V) and operated there for at least 15 minutes before any dimming takes place. If not, the lamp life will be shortened. An other very important point is the ramp time. Discharge lamps can only be dimmed very gradually. Systems that cannot perform this are not acceptable because again, they shorten lamp life, more so lamps may extinguish and create an unsafe lighting of a public place. Users experience usually very good lumen maintenance and a very low lamp mortality. Reports indicate that a doubling of lamp life is

Figure 4

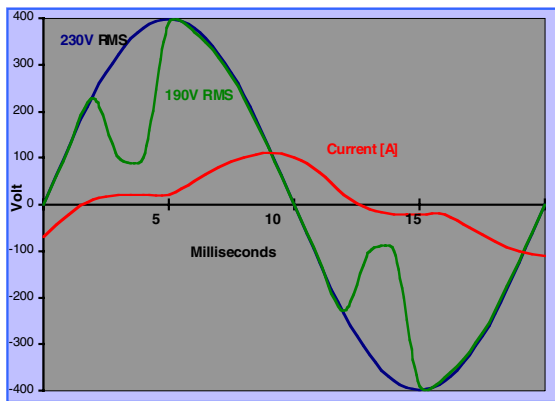


Figure 4 is showing the principle of NCWI [4]
x: time (ms), y: voltage (V)

possible. In addition a good controller does record the savings as well as all the other electrical parameters. Units must have the option of a modem for communication.

Triac or IGBT Dimming

This technology is known since about 1979. It has gone through many stages and is much more difficult than most companies manufacturing such devices assume. Still, some good and reliable products are on the market today. Practically all discharge lamps can be dimmed to about 50% of luminous flux. HPS lamps however can be dimmed to as low as 10% of luminous flux. This is used in most tunnels in Germany, The Netherlands and Switzerland as well as in the DYNO project mentioned above. Lamp life does not suffer from this technology more ever when used on HPS lamps a lamp life extension of up to 100% is possible. Some newer generation equipment does stabilise the voltage and can be used for high and low power factor circuits.

REMOTE CONTROL SYSTEMS

Communications to the distribution board (DB) and even to each individual lighting point are used today. Between the DB and the central station either a GSM modem, telephone modem or a radio modem is used. Between the luminaires and the DB either power line carrier or radio can be used. The data collected is stored in a database and managed by a central control station essentially consisting of a PC. Not only the proper operation of an individual lighting point is monitored. Information such as luminaire voltage, lamp current, capacitor current, and power but also each individual lamp voltage is recorded and analysed. The lamp voltage in particular gives us an important information about the state of the lamp itself and so we can predict a lamp failure months before it actually occurs. This means lamps can be changed before they fail and the lighting can be guaranteed to a very high degree. Safety and security is guaranteed for the users of public spaces.

Figure 5

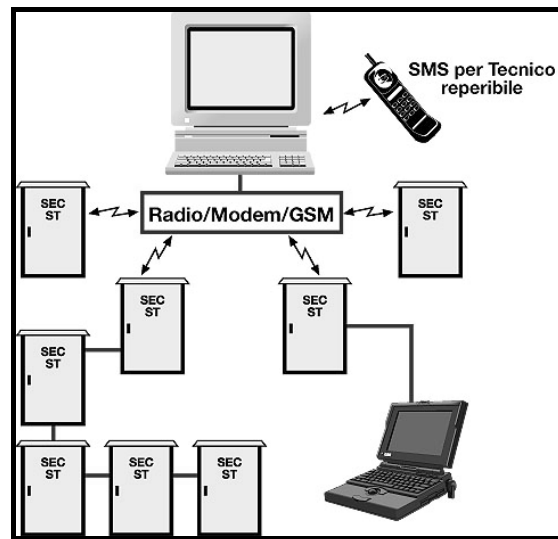


Fig. 5 Block diagram of a remote controlled installation.

Figure 6

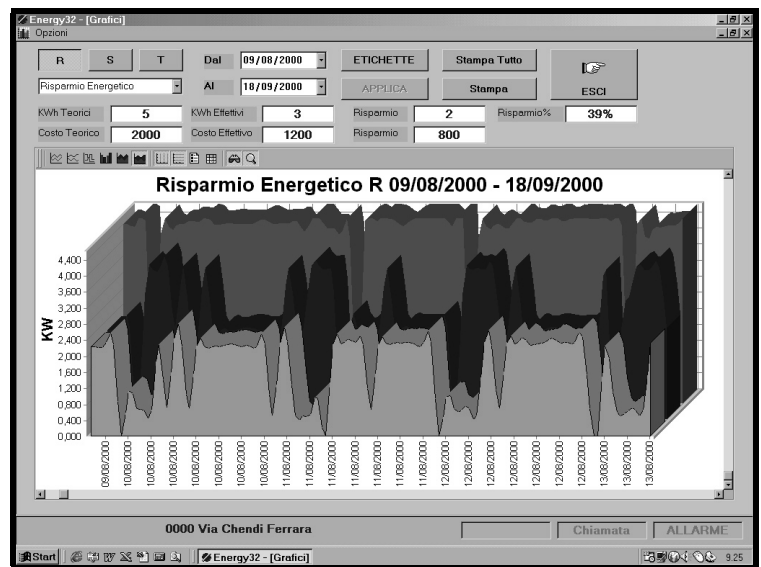


Fig. 6 The Software to manage the information connected
x: time scale (date), y: power consumption (kW)

LIGHTING MAINTENANCE

General

Our experience shows that many towns do not have a proper maintenance scheme in place nor a person responsible and educated to perform this important task.

Lamps are exchanged one by one or in small groups when they fail. The replacement lamps are bought in rather small quantities and the person in charge of buying the lamps has usually no knowledge of lighting and lamps. The cheapest lamps are bought.

This is often done because people in charge think that this is cheapest solution!

This is by far the most expensive way to have a lighting installation which does not even fulfil the minimum recommendations and standards!

The Right Maintenance

Proper maintenance of a lighting installation is important. To exchange lamps when they fail is not good enough. The majority of older type lamps fail when their light output has depreciated by some 50% or more. That means the lighting level is not sufficient to perform the task comfortably and safely, but still, the power consumed by the lighting is at 100%. That means you pay for 100% and you get 50%! It is therefore essential and cheaper to bulk replace lamps when their economical life* is finished. The economical life of a lamp differs from product to product. Good lamps would last some 12'000 hrs or more, this is about 3 years at 4000h p.a.. Lamps failing before that are replaced when they fail. We recommend the installation of a counter, counting the hours of operation of a representative circuit.

* **Economical life:** This is the time, when the lumen output has dropped to around 80% of the initial output. At that stage the illuminance of the installation has dropped to the target illuminance. The other 10% are a provision for the dirt depreciation of the luminaire.

Choice of Replacement Lamps

The person in charge of buying lamps must have some knowledge about lighting. If this is not possible talk to a lighting engineer, ask him what the best lamps would be for your installation. Price is not everything! In order to ensure good pricing the replacement lamps should be bought in big quantities.

CONCLUSION

Lighting Control for Energy Management has become an important issue. 25% to 35% of energy can be saved in public lighting installations and the lamps last up to two times as long.

Management and remote control systems ensure a efficient operation of the lighting, they guarantee the performance of the lighting installation.

Virtually all types of HID lamps are dimmable utilising standard magnetic (reactor) control gear. No modifications are necessary on inductive luminaires.

Finally a successful application has not only something to do with energy savings and short pay-back periods, but with happy customers. Service, credibility and reliability add to the requirements discussed as they do in most of the cases, where new technologies are implemented.

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