LED TUBE RETROFITS FOR FLUORESCENT LIGHTING IN OFFICES

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ABSTRACT

Two case studies are presented, showing the feasibility of retrofitting LED tubes to replace fluorescent lights in a single office as well as in a suite of offices in the Engineering Faculty Building of the Cape Town Campus of the Cape Peninsula University of Technology. The new type of LED tubes used, require no change of light fittings, thus facilitating retrofits. In order to convince management that it is worth investing in LEDs, their light intensity and energy-saving potential were measured. They also have a much longer life-span, reducing regular necessary replacements, irritating down-times and inexcusable delays. Measured results in a simple office show annual energy savings of 1288kWh, or R1574 per 12 LED retrofits at the current electricity tariff of R1,22 per kWh. Even more impressive gains, shown in Table 1, are achievable in a composite suite of offices, which used to be controlled by a single light switch, with the use of pull switches installed in selected areas. It is also shown that the breakeven point for installing the more expensive LED tubes is around three years.

1. INTRODUCTION

The subject of 'light emitting diode' (LED) lighting has in recent years been debated as a viable alternative to the more conventional means of lighting used in industry and domestic applications [1]. This is due to the fact that although they present a substantial savings in power, they are more expensive per unit and have been inferior in their light diffusion characteristics. In addition, the claims regarding their long-term financial savings and vastly superior life-span have not been substantially validated by research. More recently, LEDs have grown in popularity due to greatly improved light diffusion and overall light quality. Moreover, the stigma around LED lighting is beginning to dissipate as market confidence improves due to more common usage. The ability to replace fluorescent lamps with LEDs, without having to change the fitting, has recently become a major advantage for retrofits.

In this paper the financial savings of retrofitting LED tubes in existing fluorescent light fittings in an academic office environment is investigated. A system was selected based on affordability, ease of retrofit without the need for electricians and an acceptable (wide) light dispersion angle for an office environment. Two case studies are cited. Based on these findings, projections regarding long-term financial savings are made. Measurements of power usage and lighting (lux) levels are taken before and after the retrofits. Additional power-savings by the installation of pull-switches in certain offices is also investigated, since the suite of offices only had a single light switch.

The purpose underlying this research was to compile a report for the CPUT Energy Institute to demonstrate to management how much energy and money could be saved in the long-term by improving the energy efficiency through improved lighting on campus. The findings are compiled using a Measurement and Verification (M&V) approach where a combination of a baseline, post-implementation and performance assessment report is issued.

2. METHODOLOGY

Two demonstration case studies were undertaken:

2.1 CASE STUDY 1: In the first case study power usage and lux measurements were taken in a small office having six light fittings, each comprising two 58W, 1.5m T8 fluorescent tubes controlled by a Zumtobel EC 65 A90 old inductor-type ballast adding an extra ~20W of power consumption per lamp. The energy consumption for the average weekday baseline, based on a usage profile of 09h00 to 17h00 Monday to Friday, which does not change, was 7.51kWh and the average light intensity, measured on the work surfaces, was 199.75lux. These lamps were then directly replaced by 22W, 1.5m T8 LED tubes, having removed the starters, and the same measurements taken.

2.2 CASE STUDY 2: In the second case study power usage and lux measurements were taken in a shared office space, having thirty-seven light fittings on five lighting circuits, all controlled by one, single central switch, with each fitting comprising two 58W, 1.5m T8 fluorescent tubes controlled by a Zumtobel EC 65 A90 old inductor-type ballast again adding an extra ~20W of power consumption per lamp. In this case, the usage profile varied from day to day as the office occupants worked various flexitime hours and so the energy consumption was measured over one full working week, i.e. 00h00 Monday to 23h59 Friday. It was found that, similar to Case Study 1, the working hours for an average week day were in the region of 8 hours per day. This gave an average weekly baseline of 233.12kWh. The average light intensity, measured on the work surfaces, was in this case 397.5lux. These lamps were once again directly replaced by 22W, 1.5m T8 LED tubes, having removed the starters, and the same measurements taken as before.

In addition, power usage measurements were taken after the installation of pull-switches in the five least-used areas, e.g. store room, kitchen etc, in order to get an idea about the additional savings that are possible by introducing the option of individual switching. Although motion sensors may provide a more reliable energy-saving solution, pull switches were chosen to minimise expenditure for this project. Measurements were once again taken over one full working week on the retrofitted LED installation, this time with the lights in these five rooms being switched off individually when not in use.

In order to validate the power consumption of the ballasts used in this study, one light fitting having one 58W fluorescent tube was powered on its own circuit and measurements were taken. It was found that, over a period of around 2 minutes, the power consumption rose from 75W to 80W, giving the approximation of 20W per ballast. In order to validate the power consumption of the LED tubes, one 22W LED tube was powered directly from the supply, without being connected to any control gear, and measurements were taken. It was found that the power consumption of one tube was around 25W, with the extra 3W being attributed to the driver incorporated in the lamp.

All power measurements were done with a Fluke 435 Power Quality Analyser and all lux readings were taken with a Meterman LM631 Light Meter. The values of measured light intensity before and after each retrofit are considered as relative values, thus avoiding the pitfalls of taking absolute readings.

3. RESULTS

The following results were recorded for the two office spaces studied:

3.1 CASE STUDY 1: After fitting the LED tubes, the energy consumption for an average weekday, based on the same usage profile, dropped to 2.3kWh. This translates to a 69.37% decrease in power usage. The average light intensity, measured on the work surfaces, was now 248.56lux, giving an improvement of 19.64%. This was confirmed by the reports received from office staff that preferred the quality of light provided by the LEDs to that provided by the fluorescent tubes. A graph showing the power consumption for an average weekday before and after the retrofit is shown in Figure 1.

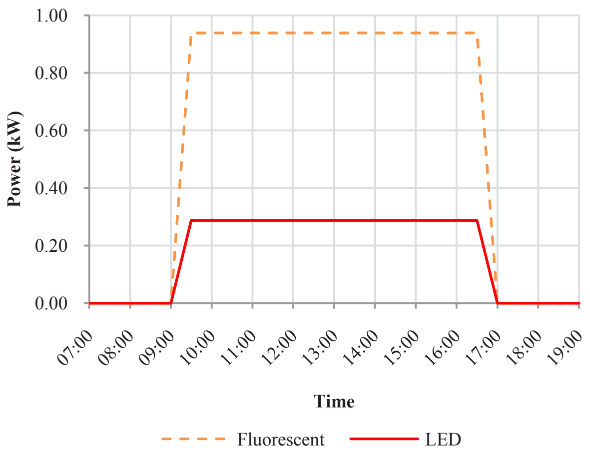

Figure 1: Average weekday power consumption

3.2 CASE STUDY 2: After fitting the LED tubes, the energy consumption for an average week, based on measurements taken from 00h00 Monday to 23h59 Friday, dropped to 79.2kWh. This translates to a 66.03% decrease in power usage. In this case, it was found that the average light intensity, measured on the work surfaces, was now 504.25lux, giving an improvement of 21.17%. A graph showing the power consumption for an average week before and after the retrofit can be seen in Figure 2.

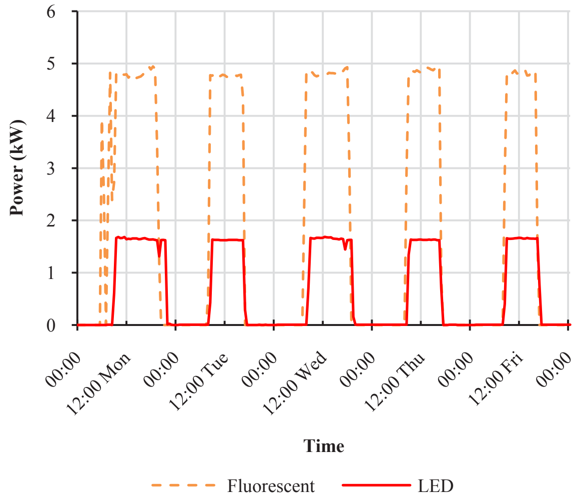

Figure 2: Average weekly power consumption

After installing the pull-switches, the energy consumption for an average week, based on measurements taken from 00h00 Monday to 23h59 Friday, dropped further to 60.36kWh. This translates to a 74.11% decrease in power usage when compared with the average weekly baseline. A graph showing the power consumption for an average week for the LED retrofit before and after the installation of pull-switches can be seen in Figure 3.

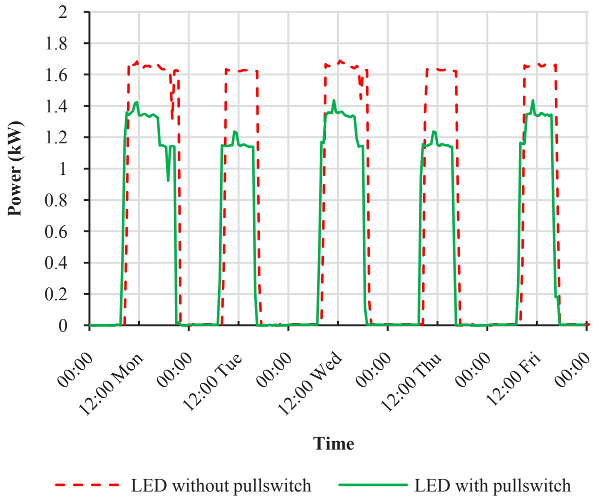

Figure 3: Average weekly power consumption

According to The Code of Practice for Interior Lighting (SABS 0114-1) a range of 320 – 630 lux is desirable for computer-based work in offices. Over-lighting due to the improved lux levels is therefore not a problem in this case

4. FURTHER CONSIDERATIONS

According to the measured data provided by Case Study 2, using the Fluke 435 Power Quality Analyser, a 90% reduction in total voltage harmonic distortion and a 2% improvement in power factor was achieved after retrofitting the LED tubes. Total current harmonic distortion remained unchanged. However, with regard to harmonics and power factor, the full potential of LED tubes can only be realised if the ballasts of the light fittings are bypassed and the LED tubes are hardwired directly in the lighting circuit. This was not done here as it was necessary to revert back to the fluorescent tubes after project completion. The slight difference in results between the two case studies is attributed to the fact that these circuit parameters were not measured for Case Study 1.

In addition, the data sheet for the LED tubes used in this project, provided by the manufacturer, gives a relatively conservative life expectancy of 40 000 hours per tube [2]. Extra savings are therefore incurred when compared to a T8 fluorescent lighting installation based on an average life expectancy per tube of 18 000 hours at 12 hours per start [3].

Finally, the LED tubes used in this project were found to be significantly cheaper than the same specification LED tubes offered by a number of local lighting suppliers, and the quality of the product was found to be more than satisfactory. These tubes were provided by Meteor Lighting who offer a three-year guarantee on all their LED products.

5. FINANCIAL IMPLICATIONS

When considering the financial impact associated with such an intervention, a number of factors are considered. Firstly, money saved on the electricity bill as a direct result of a reduction in kWh, and secondly, money saved due to a reduction in lamp replacements and maintenance callouts. The third factor, which falls outside the scope of this paper, considers the design of a new office installation, where less light fittings per square metre can be specified due to the improved lux levels and quality of light.

For these two case studies, the financial savings directly related to the savings in energy are shown in Table 1, based on the current Eskom tariff of R1.22/kWh [4].

Table 1: Projected average measured savings achieved with LED tube retrofits (without pull switches)

Case No	Monthly		Annual	
	kWh	Rand	kWh	Rand
#1 with 12 LEDs	113,32	138,25	1359,84	1659,00
#2 with 74 LEDs	669,55	816,85	8034,62	9802,24

There are further possible savings incurred by a reduction in lamp replacements and maintenance costs, which are not included in the calculations in Table 1. Savings will increase in direct proportion to an increase in the amount of retrofitted lamps and when maintenance costs are considered.

In order to get an idea about the overall savings that are possible for a retrofit installation as described in this paper, a hypothetical office installation is considered. This office has one thousand T8 58W fluorescent tubes which are then replaced by one thousand T8 22W LED tubes. Over a period of ten years, the lights are switched on for 12 hours a day from Monday to Friday, giving a total of 60 hours per week. A comparison is drawn between the costs incurred by the installation before and the installation after the retrofit. This study should be considered as a snapshot, thus ignoring the annual increase in the electricity tariff or any estimate for the increase in the price of fluorescent lamps.

As seen in Figure 4, the initial purchasing cost of the fluorescent tubes is zero as it is an existing installation, and the initial purchasing cost of the LED tubes is shown. According to the switching cycle which determines the average life expectancy, the fluorescent tubes would have to be replaced every 18 000 hours. According to the data sheet of the LED manufacturer, the LED tubes would have to be replaced every 40 000 hours. Therefore, based on these maintenance figures, and the current Eskom tariff of R1.22/kWh, the costs of running each installation over a period of ten years is shown in Figure 4.

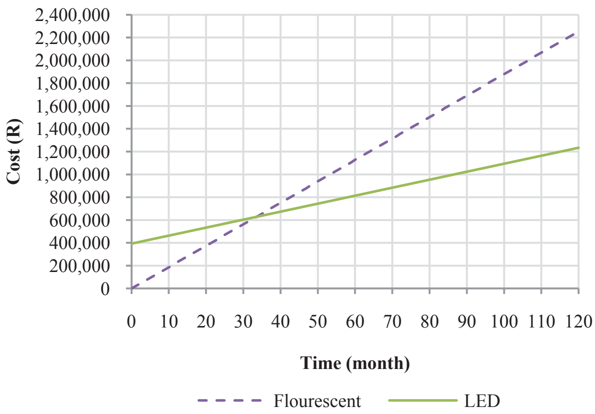

Figure 4: Savings achieved by one thousand LED tubes

According to the accumulated data the 'break-even point' according to Figure 4 is realised after 34 months. This means that, for the LED installation, the initial cost of the retrofit is recovered in less than 3 years and at this point the installation starts to save money. Over the period of ten years, this savings equates to R1 022 574. In addition, this switching cycle affords an approximate life expectancy of 5.75 years for the fluorescent tubes, and 12.77 years for the LED tubes. This means that, for this office installation, no LED tubes would have been replaced over this time period.

6 CONCLUSIONS

The feasibility of replacing the fluorescent tubes of existing fluorescent light fittings with corresponding LED tubes in an office environment as a means to save money has been shown by two case studies. It is acknowledged that savings are also achievable in other applications by changing over to LED lighting, as most LED lamps are made to fit the existing light fittings of their corresponding 'older' light technologies. However, in the office environments of large commercial applications, the possible savings are significantly increased due to the vast number of light fittings used. It is also suggested that, in this environment, productivity may even be increased due to the improvement in the quality of light. By undertaking such a retrofit as described in this paper, a business may experience a number of positive impacts. Firstly, after an initial period of approximately three years, profit margins will be increased in proportion to the reduction in overheads and reduced maintenance; secondly, staff are immediately provided with better working conditions which may lead to better productivity; and thirdly, a significant step would have been taken towards 'greener use of energy' which is playing an ever-more important role in the business sector's social responsibility. This final point is important as the reduction of lighting loads by approximately two-thirds will take pressure off the Eskom power grid meaning that less coal will have to be burned in order to meet the increasing high demand for electricity. By taking all of these factors into account the authors are convinced that there need no longer be misgivings about the use of LED lighting for commercial applications.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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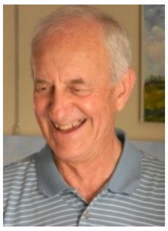

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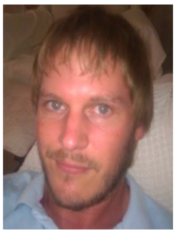

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