Green Building Electrical Design for a new Commercial Building in Centurion

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Abstract:

Since the advent of global warming, developed countries worldwide have pursued various initiatives and have structured policies to reduce their energy consumption as well as their Greenhouse Gas emissions (GHG) through the incorporation of green building certification measures. This paper provides an insight into the philosophy and the practical techniques employed in smart energy efficient building design that reduce the negative impact on the environment and its resources. The electrical design has followed the design and performance requirements within the Green Star SA rating tools to be awarded credit points. Smart occupancy sensors are deployed to optimise lighting energy usage by switching lights on only when required. Green buildings cost on average 7 to 9% more to construct than conventional buildings and the additional costs are easily recovered through savings in bulk energy costs as well as through costs for electrical units of energy being metered.

Key Words Energy Consumption, Greenhouse Gas Emissions, Green Star SA rating tools, Green Buildings, Day-light harvesting

I. INTRODUCTION

Amongst the multiple environmental impacts brought about by buildings, energy consumption has always been the one of most concern. Buildings further waste energy through poor building construction practices and poor utilisation techniques. [1, 2]

Global warming caused by (GHG) greenhouse gas emissions is shrinking existing forests, our fishing industries have virtually collapsed, and our fresh water systems have become dangerously polluted and diminished. [1]..South Africa's coal fired power stations is a major contributor to (GHG). Approximately 80% of electrical energy generated in South Africa is achieved through the incineration of non-renewable fossil fuels to drive steam powered turbines to generate electricity.

Green buildings are beneficial to the environment as they have to balance the requirement for an energy efficient building while at the same time considering the well-being of the occupants who use the building daily. Factors such as air quality and air flow characteristics, thermal temperature, the existence of windows, light quality combined with artificial lighting and noise factor all play a vital role in energy reduction. These features influence the building occupant's production levels, their health, their overall satisfaction levels with their working environment, and their attitude to their work and their colleagues and clients. Green buildings combat sick building syndrome promoting a pleasant and healthy environment to work in which further contributes to increased productivity of employees and lowers the rate of absenteeism.

II. DESIGN AND DEVELOPMENT

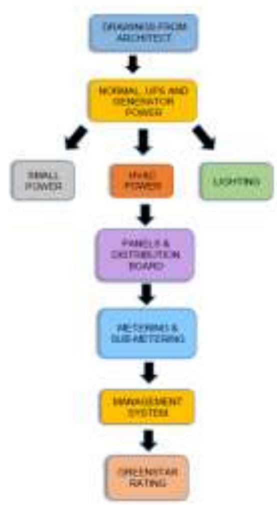

Figure 2 1 Block diagram of the design process for the electrical design of a green building

Figure 2-1 indicates the different steps to be taken to design an electrical installation for a green building.

The first steps to any electrical building design are to obtain the architectural design from the architect and to prepare a Revit or AutoCad model of the building.

The total usable floor area and gross floor area is calculated from the drawings which is then used to calculate the energy requirements for the complete building by multiplying the total usable floor area of the building by a pre-determined energy usage average watts/m² rate for Small Power (25w/m²), HVAC (75w/m²), and Lighting (10w/m²) energy usage. The data collected from this initial energy calculation is used to determine the size of the municipal incoming electrical supply.

A more comprehensive and accurate electrical load assessment is made by preparing a detailed electrical design for the lighting, small power and HVAC systems. The lighting electrical load is determined by multiplying the actual number of luminaires by their rated energy consumptions in watts to determine the total load for the building lighting requirements. A diversity factor of 1 is applied to all lighting loads. Small power loads are calculated by assuming an energy load of 300 watts per socket outlet. The total connected load for small power is then diversified by a factor of 0.7 as only 70% of all socket outlets will be in use at any one time. The HVAC electrical load requirements are calculated by adding the chiller loads, the heating loads for the heater elements in the ceiling mounted diffusers including all ventilation fan loads. A diversity factor of 0.7 is applied to the sum total of the calculated HVAC electrical load to determine the actual connected load for HVAC for the building.

The design process for all distribution boards is next. The council incoming supply is confirmed and calculations are made to determine transformer sizing and main incoming cable capacities. The short circuit fault current rating of the Main Low Voltage (MLV) panel can then be determined and thereafter the fault current ratings of the sub-distribution boards that are connected downstream from the MLV panel.

The Green Star rating system requirements are carefully monitored every step of the design process to ensure that the electrical design is eligible for assessment for green star certification.

III. ELECTRICAL INSTALLATION DESIGN

UPS power

A new 110kVA UPS will be installed to supply all the required UPS power for workstations and emergency lighting in the building.
It is important to note that when calculating the load of a UPS, an allowance of 15% over the rated kVA output of the UPS must be factored in to allow for the charging load for the batteries.

Generator power

A 1250 kVA prime rated diesel generator will be installed in the basement of the building to cater for the full electrical connected load of the building in the event of a municipal connection failure. The alternator has a power factor of 0.8 which means that the generator is only able to produce 1000kW of emergency power.

Small power, HVAC power and lighting

Small power refers to ordinary switch socket outlets (SSO's) and dedicated SSO's. The project utilised small power design criteria incorporating: 1 Outlet / 15m² in office areas, 2 x SSO's each in tea kitchens and 1 outlet/10 linear meters of wall in lobbies and walkways.

Lighting

A good energy-efficient lighting design should provide the optimum balance between initial cost, maintenance cost, lighting power density, minimum lighting level building regulations; and lighting level uniformity and aesthetic appearance. Greenstar requirements dictate that the electric lighting power density for building interiors must not exceed 10 watt/m². The maximum maintained illuminance levels must not exceed 400Lux for 95% of the office Usable Area as calculated at the working plane (720mm AFFL).

Lighting design validation calculation

The lamp lumen method should be used as a confirmation of any design that has been made using lighting simulation calculation software tools such as Relux or Dialux.
The parameters and formulas are as follows:
1. Room Index: Kr = L x W / Hm (L +W)
where
L = Length of the room (m)
W = Width of room (m)
Hm = Mounting height of luminaires above the working plane (m).
Hm-= 2.8 - 0.71 = 2.090m

Kr = 16 x 5 / 2.090 (16 + 5)
Kr = 1.8227

2. Coefficient of utilisation: Cu = 0.78

3. Total Flux Reqd: Φ = Ed x L x W / Mf x LLD x Cu
where
Ed = illuminance required in Lux
Mf = Maintenance factor (0.85 fixed)
LLD = Lamp Lumen Depreciation (0.8 fixed).
Φ = Ed x L x W / Mf x LLD x Cu
Φ =400 x 16 x 5 / 0.85 x 0.8 x 0.78
Φ = 60 331.82

4. Number of fitting required: Nof = Φ / n x Φ L
where
ΦL = Lamp flux
n = number of lamps
LLD = Lamp Lumen Depreciation (0.8 fixed).

Nof = Φ / n x Φ L
Nof = 60 331.82 / 3 x 1200
Nof = 16.75
Actual number of fittings = 16

5. Actual number of lamp used: Na (rounded off value)
Actual number of fittings x no of lamps per fitting = Na x n =16 x 3

6. Actual level of illumination
Ea = Ed x Na x n x Φ L / Φ
where
ΦL = Lamp flux
n = number of lamps

Ea = 400 x 16 x 3 x 1200 / 60 331.82
Ea = 381.88 Lux

A lighting design using Relux is made using a recessed 600 x 600mm fluorescent luminaire fitted with electronic ballast and T5 fluorescent lamps. The comparison is made over an area spanning 16 m x 5 meters of the reference area shown in Figure 3-1 in which the Relux lighting simulation software indicates that 16 luminaires will be sufficient to provide an average illumination of 400 lux. The Lamp Lumen Method is applied using the same design parameters to compare the results obtained from the Relux lighting calculation.

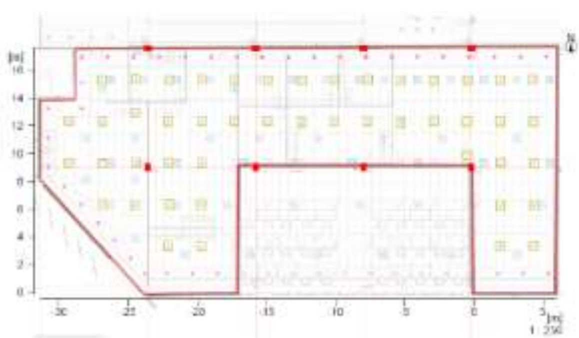

Figure 3 1 Relux Lighting design to calculate the number of luminaires required to achieve an average illuminance level of 400 lux

The results confirm that the lamp lumen method is an accurate means of validating the illumination results from lighting design software simulation programs such as Relux or Dialux.

Panels and distribution boards

The Main Low Voltage Panel shown in figure 3.2 supplies the sub-main distribution boards with the normal power, emergency power and UPS power. The metering units are installed in the main LV panel to measure the consumption and demand of each supply type for the various sub-distribution boards.

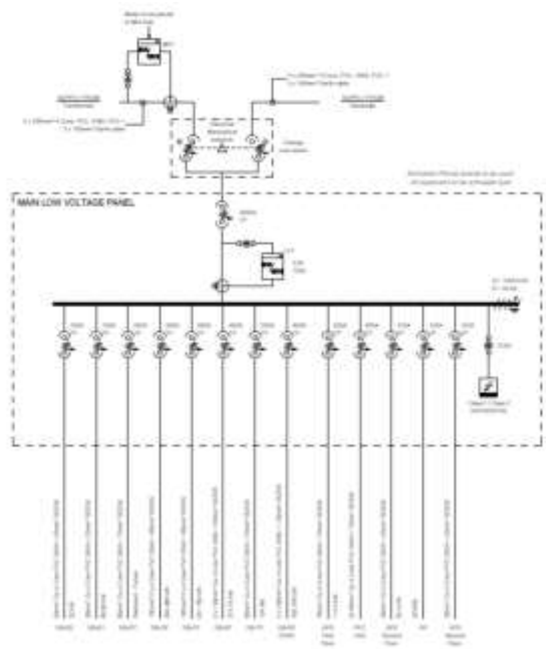

Figure 3 2 Single line diagram for main low voltage panel

Metering and sub-metering

Energy and maximum demand meters will be installed to measure the consumption of the building in each separate DB and for each separate tenant. It is essential to establish a diagnosis of where and how energy in the building is being consumed in order to improve energy efficiency through regular measurement and review of actual consumption.

Ideally information regarding the quantities of energy, power, voltage and current is required with a local display and with remote communication capabilities. All of these electrical measurement capabilities are available in a single device for installation in distribution boards.

Sub-metering is provided for all energy uses of 100kVA or greater, typically including, but not limited to, car parks, chillers, air handling fans, lifts, and common area lighting.

IV. DESIGN RESULTS

Credit criteria compliance for energy metering and monitoring (ENE-2)

Two points are being claimed for this credit since it has been demonstrated that all substantive loads in excess of 100kVA are metered and there is an effective mechanism for monitoring energy consumption data. In addition, it is demonstrated that sub-metering is provided separately for lighting and separately for power for each floor for at least 95% of the total Usable Area and an effective mechanism for monitoring energy consumption data from all energy sub-meters has been implemented.

Sub-meters have been designed to be installed separately for lighting and separately for power in each DB for each floor ensuring that 100% of the Usable Area is fully metered. Where there is more than one distribution board on a floor, sub-metering is to be provided separately for lighting and separately for power within each distribution board.

Energy Monitoring - Web Based Monitoring System

The electrical systems are monitored to ensure that the energy consumption associated with building operations is as intended by the original design and is within the specified parameters. In the instance where an abnormal trend in energy consumption is detected during the buildings' operation, an alarm is sent to the facilities managers' computer allowing for corrective action to be taken immediately.

Credit criteria compliance for individually switched lighting zones

One point has been claimed for this credit since it has been demonstrated that the size of individually switched lighting zones does not exceed 100m² for a minimum of 95% of the office Usable Area (8340m²) and individual or enclosed spaces are individually switched (controlled via motion sensors)..

In addition, since all zones that form part of the office Usable Area do not exceed 100m² and are provided with occupancy sensors, the requirement for a system that will automatically turn off all lighting outside of occupied hours has also been omitted (as per Erratum ENE4-E-OB1-0489).

Common area lighting is also controlled by occupancy sensors but these areas do not form part of the Usable Area and are therefore excluded from the calculations. Emergency lighting is provided via the generator backup system.

Table 4 1 Summary of useable floor area controlled by separately switched lighting zones

SUMMARY TABLE		
LEVEL	Zoned Area (m²)	Usable Area (m²)
GROUND FLOOR	2043	1605
FIRST FLOOR	2303	2151.5
SECOND FLOOR	2300.5	2153.2
THIRD FLOOR	2017.4	1834.9
TOTAL AREA		7744.6
TOTAL PROJECT USABLE AREA		7960
UA % COMPLIANCE		97.3%

Credit criteria compliance for lighting power densities > 95%

Three points are being claimed for this credit since it has been demonstrated that the lighting power densities for at least 95% of the Usable Area (measured at 720mm AFFL with the default maintenance factor of 0.8) results in an energy use less than 2.0W/m² per 100 Lux. The lighting power density has been calculated on an area-weighted average over each typical lighting layout as per the additional guidance section of the Green Star SA Office v1 Technical Manual.

The lighting installation for the Centurion Square Office Development Project consists mostly of 600x600mm recessed luminaires with 3 by 14 Watt lamps spaced uniformly throughout the Usable Area. In some areas (such as the reception, ablutions and passages), LED lighting has also been installed. In the basement areas 1x58W surface mounted fittings are installed.

The lighting layout for the building was modelled using Relux (simulation program), resulting in an area-weighted average lighting power density of 1.79W/m² per 100 Lux for 100% of the Usable Area. The table below shows a summary of the total area of separately switched zones and demonstrate that compliant areas jointly account for the stipulated proportion of the usable area (UA).

Table 4 2 Summary of area of separately switched lighting zones

Total Usable Area as per UA schedule	7960m²
Area modelled	7704.3m²
Area Compliant	7704.3m²
% Compliance	100%

Credit criteria compliance for light pollution

No light beam, generated from within the building or outside the building boundary, is directed at any point in the sky hemisphere without falling directly onto a non-transparent surface. In addition, façade lighting does not produce an average building illuminance greater than 10 candelas/m². 95% of outdoor spaces does not exceed the minimum requirements of CIBSE LG6 (Lighting Guide – the Outdoor Environment) for maintained illuminance levels

Credit criteria compliance for boiler and energy emissions

It was not possible to claim the one point available to comply with Tier 3 generator emissions category Emi-09 as the electrical budget for the project did not allow for the additional 20% extra-over cost for the diesel engine to comply with the required emissions standards.

V. CONCLUSION

Most of the available credit points for the design component of the electrical installation were achieved. Table 5-1 shows the comparison of green star rating points available versus the points claimed for the green requirements of the electrical installation. Budget permitting, many more energy savings techniques can be implemented such as renewable energy systems and day-light harvesting systems for the lighting system.

Table 5 1 Green star rating points claimed

CATEGORY	TITLE	CREDIT NUMBER	POINTS AVAILABLE	POINTS CLAIMED
Indoor Environmental Quality	Electronic Ballasts	IEQ-6	1	1
Indoor Environmental Quality	Electric Light Levels	IEQ-7	1	1
Energy	Energy Sub-metering	Ene-2	2	2
Energy	Lighting Power Density	Ene-3	4	3
Energy	Lighting Zoning	Ene-4	2	1
Energy	Light Pollution	Emi-7	1	1
Emissions	Boiler and Generator Emissions	Emi-9	1	0

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