UNIVERSITY OF GÄVLE

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Energy Analysis & Effects on Power Utility of LED's compared to Conventional Bulbs

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Energy Analysis & Effects on Power Utility of LED's compared to Conventional Bulbs

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Abstract

All around the world energy is commonly used for lighting purpose of households, industries, buildings, streets...etc. There are many different types of bulbs used for lighting but in this study the attention was given on LED bulbs which are said to be most energy saving lamps giving substantial lumen as the ordinary bulbs under low energy consumption. If the energy saving of LEDs are true as the LED suppliers show in graphs or any other utility charts can be screened through this study.

Due to the low Power Factor (PF) of Light bulbs, they draw rather higher current, higher reactive power which burden for the power utility. The PF does have a significant effect on the amount of energy that is used to provide the effective power at the point of use and the PF is an indicator of how much more power is really consumed than the claimed amount. Most electrical devices consume both active power and reactive power. Due to increase of power demand, the power utility has introduced LEDs and Compact Fluorescence Light (CFL) bulbs as one way of reducing power consumption to enhance security of energy supply. The purpose of this study was to determine the utility power consumption of LED bulbs compared to incandescent, CFL and Florescent tube light bulbs technologies. This study analyzes several existing life-cycle assessment studies, which include academic publications, as well as manufacturer and other independent research reports to determine the energy consumption in manufacturing phase.

A sample of LED, CFL and Conventional bulbs were used to analyze the apparent power requirement to light up same buildings separately to maintain a fix lighting level of 38 foot candles [410LUX] and has compared the apparent power value against different power factors to clearly see which type draws more energy to emit the same light level within the power factor range for each bulb types. Then total power required to light up the buildings were calculated with aid of Dialux Software for each bulb type and there by the energy analysis at use phase was also done. The energy saving by use of LED is 24% than CFL and 64% than incandescent at this “use” phase.

The PSSE (Power Simulation Software for Engineers) was used to analyze the energy loss at generation and distribution related to the load requirement at the end point for LED, CFL and Conventional bulbs. It shows 130% excess losses by CFL and 760% excess losses by conventional bulbs compared to the losses cause by LED. The manufacturing phase energy for all the light bulbs were calculated with use of literatures. LED consumes 700% & CFL consumes 375% excess energy than manufacture an incandescent bulb.

Load curve analysis was done after considering peak electricity demand in Sri Lanka and then calculated the energy savings at peak time by replacing each type with LED. The expected daily cost saving was Rs. 8,421,800.00 and the expected annual cost saving was Rs. 3,073,957,000.00.

Acknowledgement

First of all I would like to give my sincere gratitude to Swedish government and KTH University for giving such a great and valuable opportunity to follow a Sustainable Energy Engineering Master Program in a European university. Then I would like to much appreciate Dr. Anders Malmquist who supervised this thesis project and Prof. Andrew Martin to giving his enormous service for betterment of DSEE program. I must admire the service of my local supervisor Ms.Tharaanga Wickramarathna with great feeling on extending her utmost helps and courage to driving me in right path on completion of this arduous task. It is a privilege to thank Mr. Ruchira Abeweerawho played the most difficult role of coordinating the presentation sessions and help sessions for DSSE student with great enthusiasm. Further I must remember Ms.Chamindie Senarathna who was facilitating all the services related to the DSSE program being as the coordinator of this program from KTH.

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Nomenclature

SLSEA-Sri Lanka Sustainable Energy Authority

PSSE –Power Simulation Software for Engineers

P.F – Power Factor

LED –Light Emitting Diode

CFL – Compact Florescent Light

IEEE-Institute of Electrical and Electronics Engineers

DOE- Department of Energy

CCT- Co-related Color Temperature

CRI -Color Rendering Index

HID – High Intensity Discharge

UV –Ultra Violet

THD-Total Harmonic Distortion

CAD-Computer Aided Design

PDF-Professional Document Format

RCL-Regional Centre for Lighting

fc –foot candle

Pd- Active power ,

Qd-reactive power

MJ-Mega Joul

kW –Kilo Watt

kVA –Kilo Volts Ampere

kVAr –Kilovolt Amperes Reactive

MWh- Mega Watt Hours

BOM-Bill of material

LCA – Life Cycle Analysis

1.0 Introduction

Existence of the mankind without light is only a dream. That's why the people living in this world use number of ways to light up there residencies, living and working places. It could be candles, kerosene/petrol lamps, solar lamps, grid electricity or generators that are used to lighting the space. But when we consider huge buildings, factories, institutes and streets they should have more reliable lighting systems for continues operation. There the grid electricity has become quite indispensable source to power up these systems and the national grid has to meet this demand any how to keep on supplying the total requirement.

In an electrical lighting system there are different types of light bulbs used as to the prerequisite. There are incandescent bulbs which are the second form of electric light to be developed for commercial use after the carbon arc lamp which is the second most used lamp in the world today behind fluorescent lamp, then PHILLIPS developed compact fluorescent SL model in 1980first successful screw-in replacement for an incandescent lamp, In 1985, OSRAM started selling its model lamp, which was the first CFL to include an electronic ballast. Then it has turned a new phase with semiconductor light sources call as LED (Light Emitting Diodes) which consumes very low energy compared to incandescent or CFL bulbs. In this study the main effort was to find the energy consumption separately for different types of light bulbs (LED, CFL, and incandescent) to maintain an equal lighting level on a working plane of a known space. The main focus was to analyze the energy consumption of each type of light bulbs compared to their change of power factors.

As the first step of the study relevant light bulb test data's were collected from Regional Center for Lighting in Sri Lanka(RCL) and Sustainable Energy Authority (SLSEA) were preliminary analyzed to have an idea of the range of power factor available for LED,CFL,FTL and Incandescent bulbs in the global market.

Then the sample bulb types from 8 world leading manufacturers were selected from their online catalogues and they were simulated with advanced and certified light simulation software (Dialux software). Dialux plugins for all suppliers were down loaded from their web sites. The simulations part was done for all the selected luminaires and the results gained were analytically compared with each luminaire type.

Calculating the energy consumption in manufacturing phase for all the bulb type was the most challenging task, but after referring a vast range of literature sources, successfully found the required information and thereby calculated the manufacturing energy for each bulb type.

There after next endeavor was how to find the energy losses at power generation and transmission. For that a hypothetical industrial zone with number of similar buildings were considered. Power System Simulation for Engineers (PSSE) software was used for power simulation of that particular industrial zone.

There after analyze the energy usage of Sri Lanka at the peak hours. When analyzing the daily load curve of Sri Lanka, the peak demand (18.30-21.30) was very high compared to the off peak time and a considerable portion of electricity is used at night time. The National Survey on Household Lighting report shows the contribution of peak load for the lighting and further it shows percentage contribution of different light types for it. The whole study was structured properly in order to achieve the objectives and it comprises the following steps.

- How much energy is consumed to light up a same area to a same lighting level separately with LED,CFL and conventional bulbs?
- How does the energy consumption of LED lamps compare to that of incandescent lamp and CFL products?
- Manufacturing phase energy of LED,CFL and incandescent.
- Power flow simulation, Transmission and Generation loss discussion for lighting load from LED,CFL and Conventional bulbs.
- Load curve analysis, equivalent LED energy calculation and financial saving calculation for selected LED bulb sample.

This report analyzes the energy consumption associated with manufacturing phase and end user phase (energy require to maintain a fixed lighting level). The majority of data collected for this energy assessment of incandescent lamps, CFLs, and LED lamps were gathered from RCL, SLSEA and some information was provided in an existing Life Cycle Analysis report, see ref [9]. A number of publications and websites provided the data and information necessary to develop a comprehensive analysis of the energy comparison for each lamp type. Incandescent, CFL, and LED lighting products represent different lighting technologies each having varying performance characteristics. The manufacturing energy profile of incandescent lamps, CFLs, and LED lamps were developed solely based on the existing life cycle energy report.

2.0 Literature Review

1. As the first literature it was found the OSRAM Opto Semiconductors study in 2009, *"Life Cycle Assessment of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps,"*.The attention of this study has put on to find the environmental performance separately owing to LED,CFL and Incandescent and compare the performance against each bulb type and the environmental impacts were also has been examined such as human toxicity, resource depletion, greenhouse gas generation….etc. The energy consumed by each bulb over its entire lifespan has been examined inclusive of the energy related to raw material production ,manufacturing or assembling ,transportation, use phase and disposal .The final conclusion of this study was the "efficiency of LED lamps increases in the future, they will be capable of achieving even greater levels of efficiency."

2. The 2nd literature referred was *"Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part I: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps which has been prepared for: Solid-State Lighting Program ,Building Technologies Program Office of Energy Efficiency and Renewable Energy U.S. Department of Energy. Prepared by: Navigant Consulting, Inc."*

   This study was the most useful resource referred in order to find the manufacturing phase energy of LED, CFL and Incandescent. In this study the author has examined the life cycle environmental and resource cost for the manufacturing, use, transportation and disposal of LED light products relative to traditional lighting technologies and the prediction of manufacturing energy for LED in 2015.

Table 2.1 Performance of Conventional and LED lighting technologies

Lamp Type	Watts	Lumens	Operating Lifetime (hrs)
Incandescent	60	900	1,000
CFL	15	900	8,500
LED (2011)	12.5	800	25,000
LED - future (2015)	5.8	800	40,000

Above table shows the future (2015) LED lamp operating hours determined using efficacy projections provided by the 2011. According to the 2011, LED package efficiency is expected to upsurge to 202 lm/W by 2015 (ref [9])

Figure 2.1 Number of lamps needed to supply 20 million lumen-hours

As shown in Figure 2.1, it is obvious that one would need twenty-two lamps to provide 20 million lumen-hours because the incandescent lamp has a lumen output of 900 (lumens) and an operating lifetime of 1,000 hours. As same for the CFL with 900lumen and operating hours of 8,500 need 3 lamps to provide the 20million lumen hrs. All energy consumption standards presented within this study are in terms of the energy needed to provide 20 million lumen-hours of lighting amenity.

3. The power Factor of CFL may vary from 0.5 to 0.9 depending on the sort of integrated ballasts (magnetic or electronic high-frequency), and also depending on manufacturer for ballast and quality of the ballast. The Power Quality, The Lighting Research Center:, which is consisting of graphical illustrations & tables of how CFLs, computers and other non-heating appliances disturb power supply harmonics, shows the difference between incandescent (including halogen) and fluorescent (including CFL) lamp influence on the power system.

   Vienna University of Technology has found in one of their study that, distortions may be vary with the real situation and rest on the CFL in relative to other utilizations and other CFLs, e.g distortions may go down if different brand of CFLs are considered and vise-versa if same brand is considered. *CFLs with poor power factor may use up to twice as much power as claimed.*

4. Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part I: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps February 2012 Updated August 2012

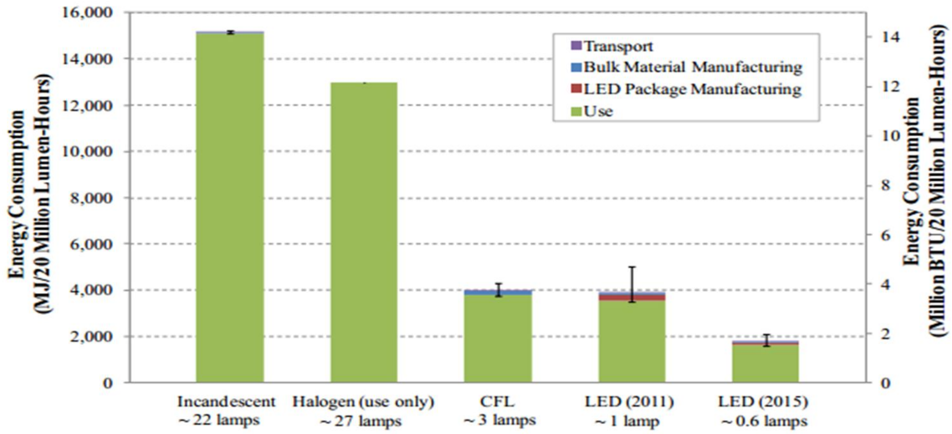

Figure 2.2 Life-Cycle energy of Incandescent Lamps, CFLs, & LED lamps(ref[9])

Figure 2.2 show that the average life-cycle energy usage of LED lamps and CFLs are quite similar, at about 3,900 MJ per 20 million lumen-hours. This is around one quarter of the incandescent lamp energy consumption of 15,100 MJ per functional unit. Predicted By 2015, if LED lamps meet their performance targets by the predicted time, their life-cycle energy is anticipated to reduction by approximately one half. In addition, based on this analysis, the “use” phase of incandescent, compact fluorescent and LED lamps is the most energy concentrated phase, on accounting approximately for 90% of total life-cycle energy. This is followed by the manufacturing and transport phases, respectively with transport representing less than one percent of life-cycle energy for all lamp types.

Table 2.2 Total Life-Cycle primary energy (MJ/20 million lumen-hours)

Life-Cycle Phase	Incandescent			CFL			LED (2011)			LED - future (2015)		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Bulk Lamp Material Manufacturing	10.1	42.2	106	11.3	170	521	38.0	87.3	154	25.4	58.5	103
LED Package Manufacturing	N/A	N/A	N/A	N/A	N/A	N/A	1.88	256	1,340	0.54	73.0	381
Total Manufacturing	10.1	42.2	106	11.3	170	521	39.9	343	1,490	26.0	131	484
Transport	0.26	0.27	0.27	1.42	1.57	1.71	1.23	2.71	4.19	0.77	1.69	2.62
Use	15,100	15,100	15,100	3,780	3,780	3,780	3,540	3,540	3,540	1,630	1,630	1,630
Total	**15,100**	**15,100**	**15,200**	**3,790**	**3,950**	**4,300**	**3,580**	**3,890**	**5,030**	**1,660**	**1,760**	**2,120**

Below list shows the studies done at different universities/countries from 1991 to 2010.

Table 2.3 List of Studies Utilized for Life-Cycle Energy Consumption Comparison

	Publication Title	Organization/ Author	Year	Lamp Types Evaluated		
				Incandescent	CFL	LED
1	Life-cycle Analyses of Integral Compact Fluorescent Lamps Versus Incandescent Lamps	Technical University of Denmark	1991	X	X	
2	Comparison Between Filament Lamps and Compact Fluorescent Lamps	Rolf P. Pfeifer	1996	X	X	
3	The Environmental Impact of Compact Fluorescent Lamps and Incandescent Lamps for Australian Conditions	University of Southern Queensland	2006	X	X	
4	Comparison of Life-Cycle Analyses of Compact Fluorescent and Incandescent Lamps Based on Rated Life of Compact Fluorescent Lamp	Rocky Mountain Institute	2008	X	X	
5	Energy Consumption in the Production of High-Brightness Light-Emitting Diodes[1]	Carnegie Mellon University	2009			X
6	Life-Cycle Assessment and Policy Implications of Energy Efficient Lighting Technologies	Ian Quirk	2009	X	X	X
7	Life-cycle Assessment of Illuminants - A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps	OSRAM, Siemens Corporate Technology	2009	X	X	X
8	Life-cycle Assessment of Ultra-Efficient Lamps	Navigant Consulting Europe, Ltd.	2009	X	X	X
9	Reducing Environmental Burdens of Solid-State Lighting through End-of-Life Design[2]	Carnegie Mellon University	2010			X
10	Life-cycle Energy Consumption of Solid-State Lighting[3]	Carnegie Mellon University, Booz Allen Hamilton	2010			X

Above table shows 10 numbers of studies that have been carried out further to find life cycle energy of different light bulbs. Those literatures can be referred for more understanding on life cycle energy assessment of light bulbs.

3.0 Problem definition

Here in this study problem was identified as the wastage of electric energy through light bulbs in massive industries/factories which are running continuously (day &night).Most of the operations (production/assembling) are in need of having standard lighting level [LUX level] to the working area to increase the efficiency of the work done and effectiveness of the operators. To gain a recommended lighting level for an operation, it needs to have a certain lumen from the lamps selected to light up the particular working area. As most common convention of the current world LED is considered as the best option in terms of energy efficiency for lighting projects and subsequently CFL. But from the utility power point of view of lamps/bulbs the situation may change and it could be a different scenario when comes to the final results. The reason that it should be not only wattage of the lamps matter for efficiency but also the power factor which directly affect to the utility power and gives a low lighting level under the claimed wattage. So even power consumption is lower, the lighting level may also be insufficiently lowered. To gain the required lighting level, it will have to use more and more lamps with the same wattage and then total power requirement is going up, on the contrary to what was estimated. So this research is done with aid of some simulation software like Dialux, PSS/E….etc. to evaluate the power utility by comparing light level for a particular application with different types of bulbs. This study is linked with power factor, luminous flux and wattage of the electrical lamps/lights.

3.1 Case Study

An industrial lighting application was selected as the case study to calculate the load requirement to light up a similar buildings separately with LED,CFL & Conventional bulbs(separately) using Dialux software and then load values were used to simulate with PSSE software to find the generation and transmission losses(for the load required to lighting) and to see the way of power flowing as well.

For this application, 8 buildings situated in one hypothetical industrial zone were considered in which apparels are manufactured. Each of these buildings was same in geometry and interior conditions. The light level on work plane for garment manufacturing was taken as 38foot candle (410LUX).Each type of light bulbs were simulated with Dialux software to have the same lighting level on the working plane. There the power required to produce such lighting level from each type of bulbs were calculated based on Dialux results and there after the apparent power required for light up whole industrial zone was calculated considering previously categorized power factor range for each type based on RCL test data. The reason for having had such number of buildings for this industrial zone was to create a higher lighting load which was required to run the power simulation with PSSE software. So the power simulation with PSSE was able to bed one using IEEE 6 bus bar system and finally the utility power consumption was calculated and at the same time generation and transmission losses were also calculated. The PF significantly has an effect on the amount of energy that is used to provide the effective power at the point of use. The selected building size for the hypothetical industrial zone as below in feet, Length 225ft,Width 60ft, Height 12ft where the height of working plane is 2.49ft from the floor level .

The industrial zone which was used to light up with different type of bulbs to the fixed lighting level ,thereby calculating the lighting load required for the whole application as in below figure.

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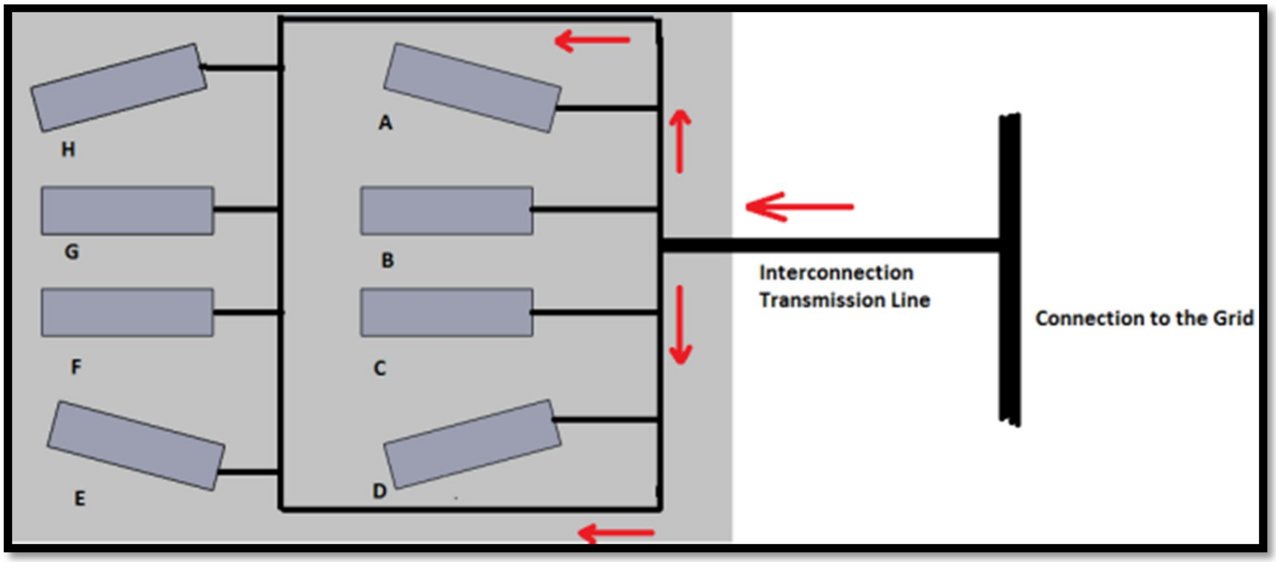


Figure 3.1 power distribution system of the defined industrial zone

For this energy analysis study, a simple industrial zone was selected which was consisting of 8 buildings with above mentioned length, width and height. Whole industrial zone was considered as powered by the grid electricity and it was assumed that the total electrical load drawn only for lighting purpose. The power demand required to light up all the buildings to 38 foot candle lighting level was separately calculated from Dialux software for different luminaire types selected from online supplier catalogues under LED, CFL and Conventional bulbs. i.e the simulation was done for 15 LED products by adding each product to the software for 15 times and light load(kw) required to produce 38fc(for each type) was calculated separately and they were recorded in to a table. And the same was done for 15 CFL and 13 conventional types and results were recorded in to a table as below

Table 3.1 Light level Vs Total Load

Type of bulb	number of luminairs used for 38 fc	Luminair wattage(w)	Total load (w)	Total lumen(lm)

This table was separately done for all 3 types(LED,CFL,CONVENTIONAL) and then they were used for comparison.

4.0 OBJECTIVES

- Comparison on utility power consumption of LED, CFL and Incandescent bulbs in real world.
- Prediction on Total energy consumption of LED,CFL and incandescent in life time.
- Establish the best options for energy optimization in electrical lighting systems

5.0 BASICS OF LIGHTING ENERGY

5.1 Light

The radiant energy in the form of electromagnetic waves (380~780nm wave length) capable of exciting the retina and producing the Visual Sensation. The Radiant energy that excites the human eye is produced by natural and artificial light such as day light, incandescent, fluorescence, LED…ect.

5.2 Photometric, Colorimetric & important Parameters

Light bulbs do have special features described below.

5.2.1 Correlated Color Temperature (CCT)

The color of the light has an significant influence on the color brand of the area, the color temperature of the light source plays an vital role. Light is widely termed ‘cool’ or ‘warm’. However, to allow an objective comparison of the color impressions from several sources, subjective impressions such as these are insufficient. A particular scale is required, and this is given by the term ‘correlated color temperature’; the color gradation of the light is compared with the light emitted by an intensely heated iron bar of which the temperature is known. In this way, the light color can be specified by a value in Kelvin (K).

○ Below 3200 K - (Yellowish white)
○ Between 3200 K & 4000 K (Neutral)
○ Above 4000 K – Cool (bluish white)

5.2.2 Color Rendering Index (CRI)

The ability of a light source to render colors naturally, without distorting the hues seen under a black full spectrum radiator (like daylight or incandescent lamps). The color-rendering index CRI ranges from 0 to 100.

5.2.3 Intensity (Candlepower)

The luminous flux in a given direction (e.g. from a floodlight, projector).

Unit: candela (cd) = one lumen per steradian, Symbol: I

Light emitted by a source in an exact direction, remains the same irrespective of the distance,

Value of the Intensity hinge on the direction; Constant intensity source has same intensity in all directions. Defined as amount of light in a unit Solid angle i.e. Lumens per steradian also called Candela (Cd)

5.2.4 Illuminance

The luminous flux density at the surface being lit. The unit is lux, being one lumen per square meter. The illuminance in the full summer sun is approx.100000 lux. Recommended illuminances for workplaces range from 200 lux for rough work to 2000lux for detailed critical work.

Unit: lux (lx) = lm/m^2,Symbol: E

5.2.5 Luminance

The light intensity per square meter of specious area of the light source, luminaire or illuminated surface (cd/m^2). Where surfaces are lit, the luminance is dependent upon both the lighting level and the reflection features of the surface itself.

Unit: cd/m^2,Symbol: L

Luminance of surfaces nearly adjacent to the task should not exceed the luminance of the task but should have at least 1/3 of the task.

5.2.6 Luminous efficacy

The amount of light source emits per watt (lm/W) of electrical power of energy consumed. Note that both the lamp luminous efficacy and the system(lamp and ballast) luminous efficacy could be specified. The system luminous efficacy is always lower than the lamp luminous efficacy. At 555 nm there are 683 lumens/Watt (at maximum sensitivity point of human eye)

Source	Efficacy (lm/W) including Ballast
Standard Incandescent	5-15
Tungsten Halogen	10-25
Halogen Infrared Reflecting	20-35
Fluorescent (linear & U-tube)	25-100
Compact Fluorescent Lamp	25-70
Mercury Vapour	25-50
Metal Halide	45-100
High Pressure Sodium	45-110
Low Pressure Sodium	80-150
Natural Light	105
LED	50-150*

(*Source:E source Lighting Atlas)*

Figure 5.1 luminous efficacies of different light bulbs

5.2.7 Lamp Rated Life

The rated life of a lamp means how long it takes for half the light bulbs in a test bench to fail. Even the rated life is a median value of life expectation of a light bulb it could be changed with the working conditions and the usage.(temperature hours per start) this may directly affect to change the actual life time of a bulb. As an example if we consider a sample of 100 bubs testing for average rated life and observed 50 bulbs were failed by 1000 hrs then the average rated life of the tested sample of bulbs are 1000hrs

5.3 Light Emitting Diodes

LEDs (light-emitting diodes) are semi-conductors that convert electricity into light. It consists of a p-n junction semiconductor which emits a light when it works in forward biased direction. The output from an LED can range from red (at a wavelength of approximately 700 nanometers).An LED consist of two types of processed material called P-type semiconductors and N-type semiconductors. Earlier LEDs were used just as indicator lights for electronics, where now it has become more popular in lighting houses, streets and industrial facilities as well. LEDs have been advanced by it is latest technology with long operational hours, higher energy efficacy, durability, flexibility and non-toxicity etc.. Which may alter the future of overall illumination. It is still under technical evaluation and process improvements to fully realize the cost and energy saving.

LED lighting is gradually standing as a preferred light source because of above mentioned high efficacy, long life, and free of mercury. As the low efficient incandescent lights are phasing out globally, opening up a new venture for LED sources which is a long life alternative for the energy crisis all over the world.

As far as the incandescent bulbs are concerned the only real disadvantage to incandescent bulbs is their rather low efficacy which is in the range of 8–16 lumens per watt although it does have near ideal power factor

(PF = 1). The efficacy of state of the art LEDs is about 125 lumens per watt. So today, LEDs are 10 times better than incandescent. Lamps or will produce the same

lumens for one tenth the power. To further put this into perspective, if a light source could convert 100% of this electrical power to light, it would make 640 lumens per watt.

5.3.1 LED Lamps

An LED (Light Emitting Diode) is an electro-chemical light source,when the diode is forward-biased,light is generated .The light is monochromic,the colour is dependent on the materials used.white light can be produced by using phosphorouse similar to those used in fluorescent and coated HID lamps.

- Solid state light source,
- Powerful enough and becoming cheaper to replace conventional lamps
- highly adaptable in form
- LED's need special packaging for protection
- light distribution & heat dissipation
- White LEDs are the state of art, Heat dissipation has a huge impact on life
- Efficacies in 40-55lm/w, life 100000 hrs, Low UV no Hg content

5.4 IncandescentLamps

An incandescent bulb emits light by heating a tungsten filament surrounded by various inert gases to about 4000 F. These bulbs light well and cost little, but die quickly and are highly inefficient, releasing 90 percent of their energy as heat. An standard incandecent bulb nomenclature(ex:40T 10) is having normal life span 750-2000hrsWhich will enhance if light is dimming. switching will not make a considerable effect for the life but the usage at rated or higer voltages directly effects to the life of the bulb.distribution is either directional or non directional having CRI> 95 and CCT 2500-3000K for warm white,efficay is really low like 10 - 15lm/w.

5.5 Compact Fluorescent Lamps

Inside a CFL, an electric current is driven through a tube filled with argon and a small amount of mercury vapor. This creates invisible UV light, which excites a phosphor coating that reacts by emitting visible light. CFLs are efficient and long-lasting, but take time to warm up.

Nomenclature (same as linear with CF lamp type),life span is 7500-10000hrs,distribution is normally directional .CRI is around 80-85,CCT 2700-5000K,efiicacy is 25-70lm/W .

6.0 Data Analysis

Test data collected from Regional Centre for Lighting (which is in Colombo, Sri Lanka) were properly arranged to spread sheets and examined their P.F range , lumen , life time hours....ect.

6.1 Sample Data Collection

Regional Centre for lighting is one of the laboratory testing facility available in Colombo, Sri Lanka which released their test data's of CFL and LED bulbs for this study. These data's received from RCL were in their report format has been put in to a spread sheet for feasible analyses. Below is the RCL test data sheet format.

RCL Regional Centre for Lighting

Photometry Laboratory
Regional Center for Lighting
3G-4A, BMICH, Bauddhaloka Mawatha, Colombo 07, Sri Lanka
Tel: 94(0)11 267 7445 ext. 777/268 4584

REPORT NO: 12/B64035-I

TEST REPORT

1. **Item Description** : **20W 3U DL CFL**
2. **Lamp samples supplied by** : **SRI LANKA STANDARD INSTITUTION**
   NO.17, VICTORIA PLACE,
   ELVITIGALA MAWATHA
   COLOMBO 08
3. **Date Submitted** : 13th June 2012
4. **Manufacturer** : Not Specified
5. **Sample No** : B 64035
6. **Model No** : W 20 DLU
7. **Nominal Device Ratings** :

Item No	Make	Lamp ID Number (for office use)	Nominal Device Rating					
			Voltage (Vac)	Current (mA)	Wattage (W)	Lumen o/p (Lumens)	Color Characteristics	Life time (Hours)
1	WUSLEY	B 64035-1	220-240	140	20	1,055	DAYLIGHT	8,000
2	WUSLEY	B 64035-2	220-240	140	20	1,055	DAYLIGHT	8,000
3	WUSLEY	B 64035-3	220-240	140	20	1,055	DAYLIGHT	8,000

Figure 6.1 Test data format of RCL

It includes type of lamp, voltage, Current, Wattage, Lumen , and life time of the bulb, P.F and other colorimetric parameters…..ect. These initial data's were closely examined and then these bulb data's were arranged to separate tables as LED , CFL and Incandescent so that each of above mentioned parameters were reflected on those tables.

6.1.1 Sample test data of LED lamps collected from RCL

Below is the test data's of certain number of LED's tested at RLC lab. This table contains P.F, THD, photometric and colorimetric parameters for each LED bulb tested at the laboratory conditions. The table was arranged in P.F ascending order and there by the P.F range for LED's were obtained.

Table 6.1 Sample test data of LED lamps collected from RCL

Electrical Parameters								Photometric & Colorimetric Parameters					model/type
Rated Wattage	Std. used	in put vol(V)	In put Current(mA)	Power (W)	PF	Freq(Hz)	THD(%)	Luminous Flux (lm)	CCT	CRI	Luminous Efficacy	Radiant Flux (mW)	
5	IES LM-79-08	230	57	4.77	0.37	50		208.1	6318.2	79	43.62		LED(6000-6500K)
5	IES LM-79-08	230	45	4.36	0.42	50	50	399.4	863.8	77	91.61		LED/DL/B22
7	IES LM-79-08	100-240	42	8.75	0.48	50	29	868.8	5393.6	74	99.29	2662	KV5/B22/9W/DL/LED
7	IES LM-79-08	100-240	71	7.85	0.48	50	179	468.2	2819.9	57	59.64	1237	
5	IES LM-79-08	230	30	3.37	0.49	68	55	317.7	6901.2	74	64.34	1873	
9	IES LM-79-08	180-260	44	8.64	0.64	50	58	753.3	6008.2	88	87.19	2509	KV2/E27/9W/DL/LED
9	IES LM-79-08	220-240	48	8.97	0.82	50	55	577.1	6484.1	74	64.34	1873	9W/ E27/ DL/LED
9	IES LM-79-08	180-260	46	8.97	0.85	50	57	732.9	2756.3	80	81.71	2322	KV1/E27/9W/WW/LED
9	IES LM-79-08	180-260	46	8.97	0.85	50	57	732.9	2,756.30	80	81.71	2,322	
7	IES LM-79-08	100-240	33	7.04	0.91	50	23	761.1	5413.2	73	108.11	2327	KV3/B22/7W/DL/LED

According to above data it can be categorized to different groups considering the power factor values .It shows the P.F changes from 0.37 to 0.91 for this sample gives information that the bulbs available in the market are with different power factors where ordinary people never focuses. This low power factor is the fundamental cause to reduce the light output from the each bulb than the claim output from the supplier's end. It is not sure if a 100pcs of bulb sample from same type, same manufacturer is considered for P.F test will pass for all 100pcs (achieve the P.F spec) due to having manufacturing problems/issues and quality failures. So P.F is an important parameter should be focused when purchase a light bulb. In this case P.F ranges have been categorized as below for the LED lamps considering the P.F of the RCL tested sample.

P.F=0.4 | P.F =0.5 | P.F = 0.8 | PF =0.9

Then the certain number of LED's were selected from Dialux online catalogues from different suppliers worldwide and those were simulated with Dialux software for a defined building and found the active, reactive and apparent power for above P.F categories and entered them to tables so that they will be easily compared with other bulb types.

6.2 Sample test data of CFL lamps collected from RCL

Below is the test data's of certain number of CFL's tested at RLC lab. This table contains P.F, THD, photometric and colorimetric parameters for each CFL bulb tested at the laboratory.

Table 6.2 Test data of CFL lamps

Electrical s		Electrical Parameters					Photometric & Colorimetric Parameters							
Rated Wattage (W)	Std. used	in put vol(V)	In put Current(mA)	Power (W)	PF	THD(%)	Luminous Flux (lm)	CCT	CRI	Luminous Efficacy	Radiant Flux (mW)	Item	model No	life Hrs
45	SLS – 1231:part 1: 2002	230	316	39.45	0.54	136	2542	6502.4	39.45	65.43	8395	45W SP DL CFL	MHSP 45	8000
11	SLS – 1231:part 1: 2003	230	358	50.45	0.55	112	2235	6559	77.7	44.3	7358	20W SPT DL CFL	ASLS20W	8000
20	SLS – 1231:part 1: 2004	230	358	50.38	0.55	112	2235	6559	77.7	44.3	7358	20W SPT DL CFL	ASLS20W	8000
15	SLS – 1231:part 1: 2005	230	358	50.38	0.56	112	2235	6559	77.7	44.4	7358	15W 2U DL CFL	MHNF2U415	10000
20	SLS – 1231:part 1: 2006	230	358	50.45	0.56	112	2235	6321.9	77.7	44.3	2791	23W CFL	FE247T2FST23W	8000
20	SLS – 1231:part 1: 2002	230	137	17.85	0.56	132	1127	6287	83	64.17	3613	20W SP DL CFL	ASLS20W	8000
23	SLS–1225:2002	230	171	22.69	0.57	122	1432	6319.8	82.8	63.39	4701	23W 3U DL CFL	SKT 23	8000
15	SLS–1225:2003	230	105	14.19	0.58	121	791.4	2587	81.1	57.14	2587	15W20CFL	SKLB152U	8000
14	SLS – 1231:part 1: 2006	230	102	13.87	0.59	116	778.9	6224	80.4	56.2	2542	14W 3U DL CFL	RM14 U3-D	8000
16	SLS – 1231:part 1: 2006	230	110	14.79	0.59	118	762.9	6652	77.5	51.6	2522	16W 3U DL CFL	DULUXSTAR 16	6000
20	SLS – 1231:part 1: 2002	230	127	17.6	0.59	119	1044	6220.8	81.5	61.18	3370	20W SP DL CFL	Eurolex 20W Spiral	8000
13	SLS – 1231:part 1: 2006	230	92	12.55	0.59	111	726	6279	80.2	57.8	2354	13W SP DL CFL	UXSTAR MINITW	6000
20	SLS – 1231:part 1: 2002	230	123	16.13	0.6	116	968.3	6081.5	80.9	60.41	3167	20W 3U DL CFL	MHNF3U420	8000
23	SLS – 1231:part 1: 2002	230	155	21.35	0.6	112	1278	6241.6	21.35	61.21	4221	23W 3U DL CFL	ESSENTIAL 23W	8000
23	SLS – 1231:part 1: 2005	230	102	14.1	0.6	112	855.6	6321.9	81.1	60.7	2791	23W CFL	FE247T2FST23W	8000
14	SLS – 1231:part 1: 2006	230	107	14.8	0.6	112	888	6388	81.1	60	2935	14W 3U DL CFL	RC14U3-D	8000
14	SLS–1225:2002	230	99	13.96	0.61	107	761.4	6440.3	80.6	54.82	2523	14W 2U DL CFL	ESSENTIAL 14W	8000
20	SLS–1225:2002	230	142	19.77	0.61	110	1189	6348	81.4	60.14	3914	20W 3U DL CFL	W20DLU	8000
30	SLS–1225:2002	230	143	30.07	0.9	40	61.08	6145.1	81.7	61.08	6284	30W 4U DL CFL	SKQ 30	8000

The above data has been arranged in P.F ascending order and the P.F ranges were categorized as below in order to compare with Dialux simulated CFL products as described above under LED case.

P.F=0.5 | P.F =0.6 | PF =0.8| PF =0.9

For incandescent bulbs the power factor is not changed and it is considered as 1.For some other conventional bulbs which couldn't found in local labs were assumed their P.F 's according to normal average.

7.0 Dialux Simulation

DIALux software has been developed for professional light planning, is now open to luminaires of all manufacturers. This software is used by many number of light planners and designers around the world and currently their number is gradually growing. It creates virtual worlds simply and intuitively with this DIAL**ux software**. Delight customers with daylight and artificial light scenarios over which they can glide with wild camera runs. Rely on the CAD data of other architecture programs and re-export files simply or use any 3D models from the internet while planning creatively, DIAL**ux** determines the energy light solution requires and helps in complying with the corresponding national and international regulations. With Dialux, following are easily done

- Interior layout & lumen method design calculation
- Results are automatically build in to a report.(pdf or a text file)
- Luminaire selection
- Working with modular spacing of luminaires
- Calculation exercise
- Artificial light calculations
- Viewing the results report
- Task uniformity understanding
- Introducing customized objects e.g. stairs
- Alternative lighting assessment and calculate
- Emergency lighting assessment and calculation along a corridor
- Importing & exporting CAD files & using integral CAD viewer
- Ray tracing 3D rendering of scenes
- An exterior lighting explored using storage area
- Selection, placement & aiming of luminaires
- Adjusting luminaire aiming with immediate dynamic results on grid layout
- Producing irregular zones to be lit
- Observing the results and understanding them
- Creating a report of selected results for printing

7.1 Lighting simulation with Dialux software

There are many lighting manufacturers in the world and most of their products are compatible with Dialux software. Out of them 7 supliler's products were selected for light simulation study.The selected manufacture products are as below.The references websites are mentioned in the reference chapter.

1. Phillips
2. Artemide
3. OMS
4. Begga
5. Castaldi
6. Bright
7. Alto

7.1.1Phillips Luminare Catalogue

Phililps catalogue was downloaded from their website as a Dialux plugin and installed to the software.Thereby the luminairs required for the study were selected from the updated online catalogue.

7.1.1.1 Selecting LED lamp from the catalogue

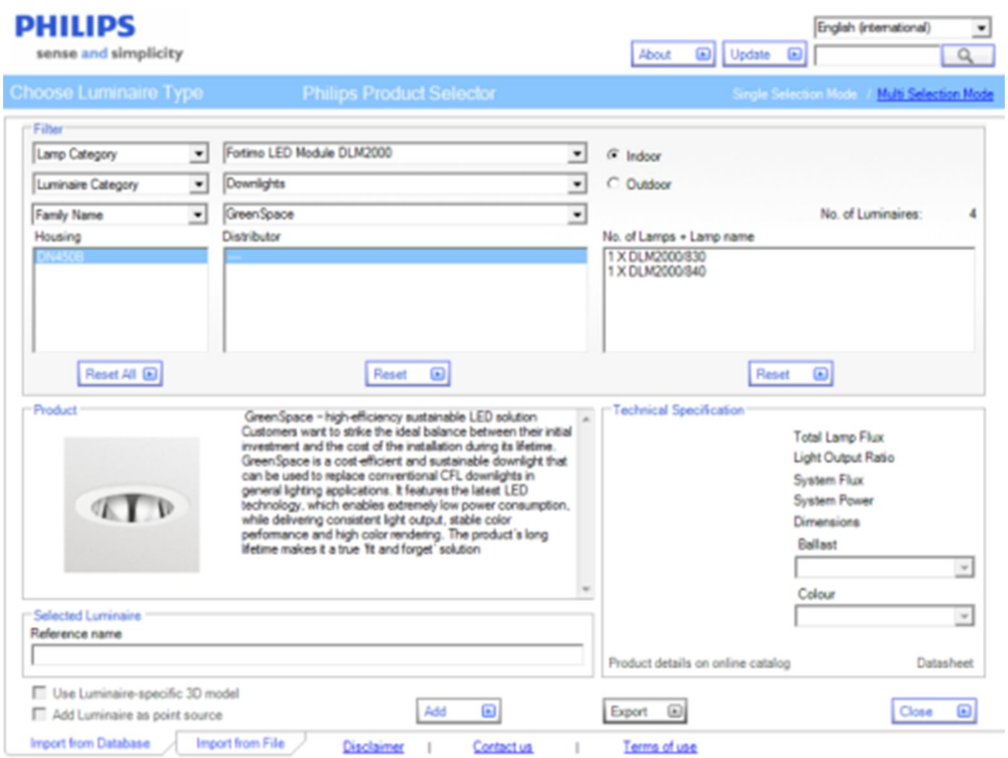


Figure 7.1 Phillips lamps catalogue

Above catalogue was used to select a particular co-efficient and sustainable down light bulb to simulate with Dialux.

7.2 Simulation Steps of Dialux Software

1. Starting a new interior Project

2. Define and creating the room geometry.(define length,width& height)

3.Selecting luminair from the catalogues and adding to the software

4.Defining the light arrangement type (single ,line,field,circular arrangement)

5. Adding required number of luminairs and setting the light level,luminair height from the ceiling,defining light loss factor,reflections from the ceiling,wall and floor.

6. Calculation or lighting simulation

7.Result generation as a Report

7.2.1 Starting a new project,creating a room and luminare adding as below

Here the size of the room can be defined first and then mounting height of bulbs, then select the required luminaire from the catalogue and select the type of arrangement and then add it to the software

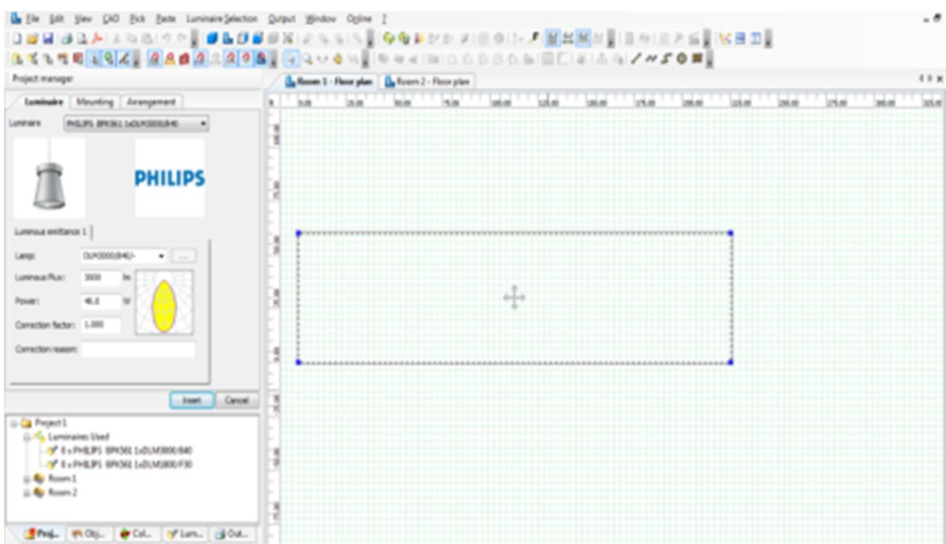


Figure 7.2 Starting a new project with Dialux

7.2.2 Light Mounting

Under this step,light mounting location and the distance from working plane and arranging order were selected,mounting loacation for this study was selected as seiling and distance from ceiling to the luminair was taken as 0.5ft .Luminair arrangement can be selected in circular arrangement ,field arrangement ect…and here for this study it was selected as field arrangement .where the total number of luminair were arranged so that,

luminairs per row x rows perceiling.

So this information should be entered to the software program to start simulation process.the height of the mounting from the work plane also should be defined here.

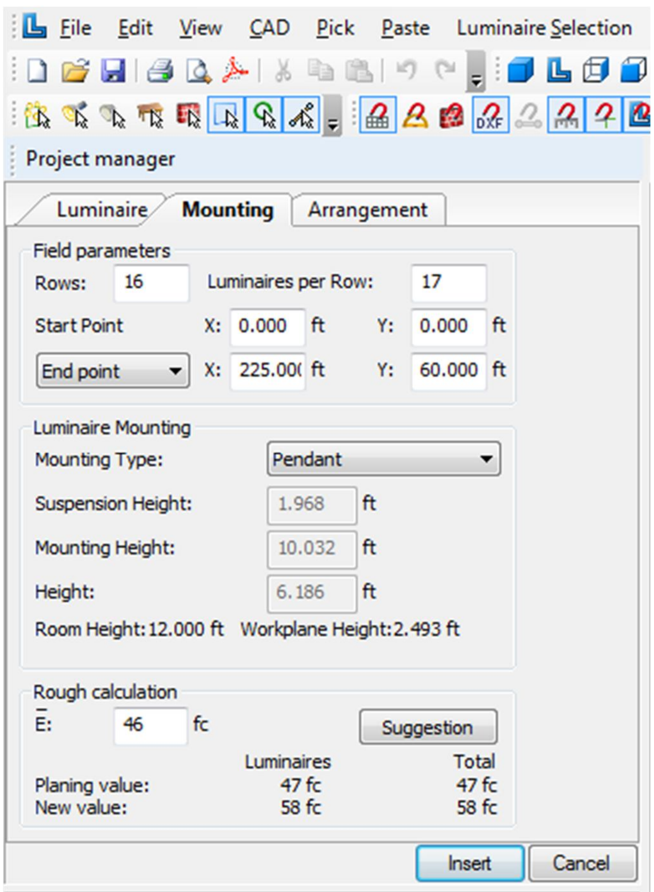


Figure 7.3 Light mounting step of Dialux

7.2.3 Adding Lights (Field arrangement)

Luminair has been added to the defined building in software as field arrangement.there are flexibility to add single luminairs too as designer wish or as to where higher light levels are required.

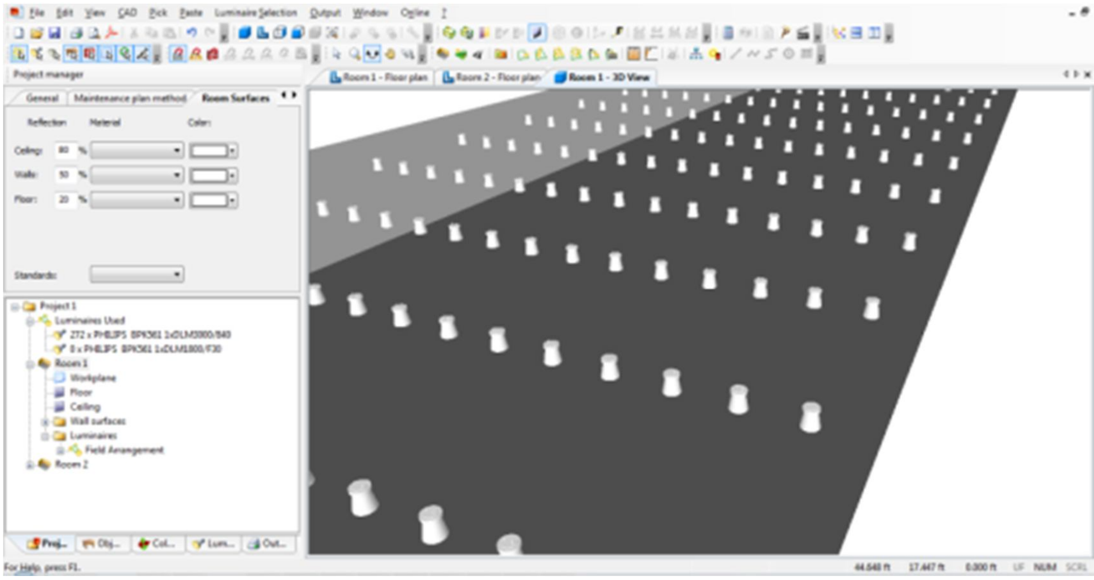


Figure 7.4 luminair added to the selected space in Dialux

7.2.4 lighted building with dialux software

Once the luminairs has been added according to relevent order then the simulation stuff is ready to be begun.There is a feature call “calculate” in the software and once it is done the simulation is started and show as below.

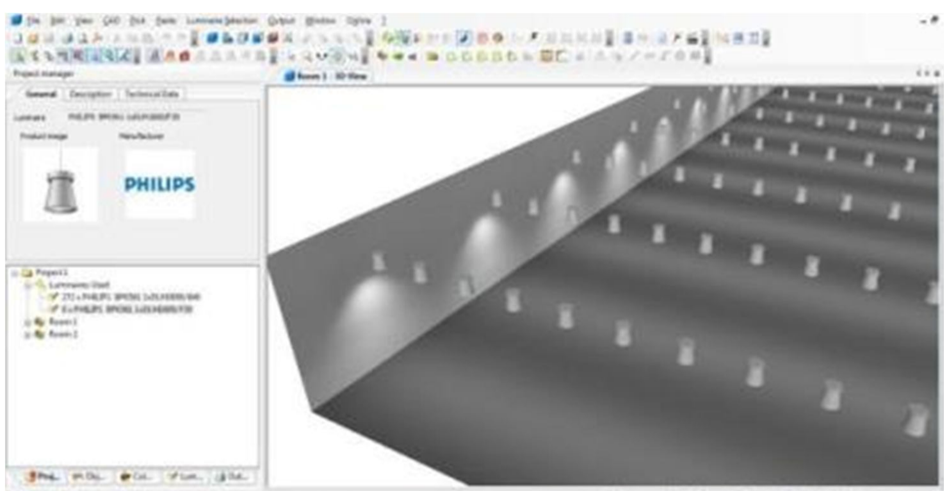


Figure 7.5 luminair added to the selected space in Dialux

For this case number of luminaires used 16*17=272

7.3 Dialux Results

After the simulation,there is a facility to generate a report incuding all the results as below.So each and every luminair simulated results were generated as a report in this study.In this report minimum maximum and average light levels on working plane, floor, walls …ect and total lumen and power out put ,number of luminair used are also available.

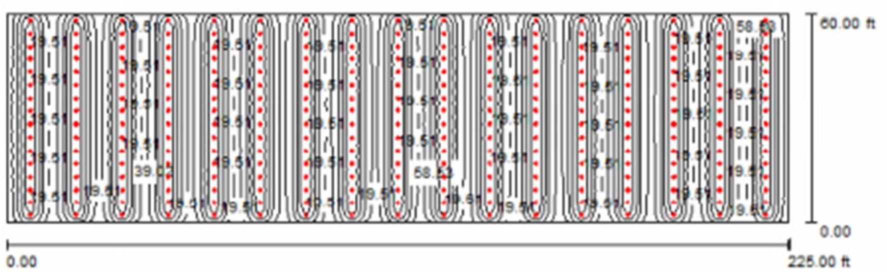
Project 1

DIALux

04 / 19 / 2013

Operator
Telephone
Fax
e-Mail

Room 1 / Summary



Height of Room: 12.000 ft, Mounting Height: 10.032 ft, Light loss factor: 0.80

Values in Footcandles, Scale 1:491

Surface	ρ [%]	E_{av} [fc]	E_{min} [fc]	E_{max} [fc]	u0
Workplane	/	49	8.67	102	0.176
Floor	20	48	18	74	0.366
Ceiling	80	8.75	5.60	9.87	0.640
Walls (4)	50	12	5.77	54	/

Workplane:
Height: 2.493 ft
Grid: 128 x 128 Points
Boundary Zone: 0.000 ft
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.222, Ceiling / Working Plane: 0.178.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ [lm]	P [W]
1	272	PHILIPS BPK561 1xDLM3000/840 (1.000)	3000	46.0
		Total:	816000	12512.0

Specific connected load: 0.93 W/sq ft = 0.19 W/sq ft/10 fc (Ground area: 13500.31 sq ft)

Figure 7.6Results of the simulation

7.4 Light Simulation with Artemide Product

Artemide is a supplier whose catalogue products were supported for Dialux which was initially selected as a supplier catalogue for this study. Below is a brief introduction about Artemide.

Lamp Manufacturer : Artemide Group
Design, Innovation & Made in Italy

Artemide is a professional light bulbs manufacturer and a potential supplier to the global market having proved its product reliability over certain decades. They are much in to R&D works on light bulbs and fruitfulness of them has proved with considerable improvement of efficacies of their products. It was a reason to select this supplier for this energy study because they are continuing researches for the betterment of the light bulb industry and the energy saving through efficient product releasing.

7.4.1 Artemide Catalogue

Below is the Artemide online catalogue page which supports for Dialux.From this cataogue the relevent luminair types were selected and sumulated for the relevent application.This calalogue is very easy to use and can quickly find a bulb from each category .

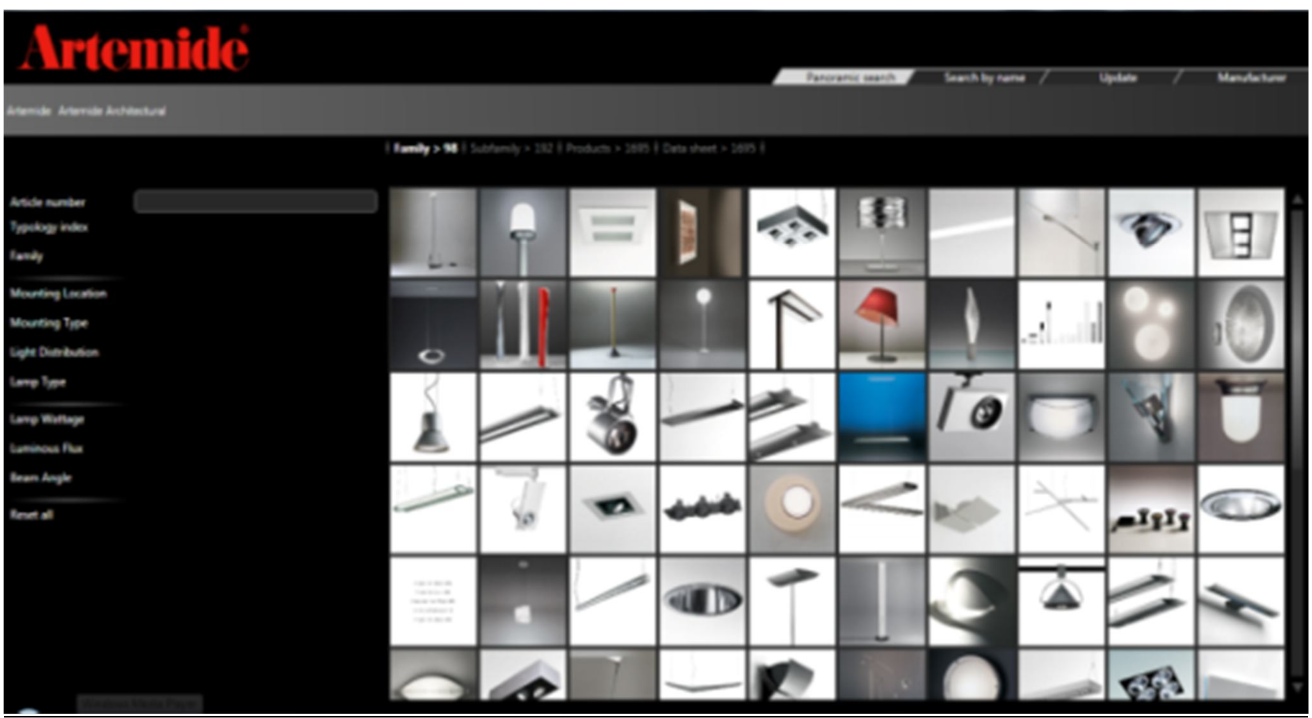


Figure 7.7 Artimide light catalogue (Ref.[1])

7.4.2 Selecting LED Luminair from Artemide Catalogue

Below were the perticulars of selected LED luminair from Artemide catalogue.

Product – JAVA 158 SQUARE 1XLED (GU10) 230-240V

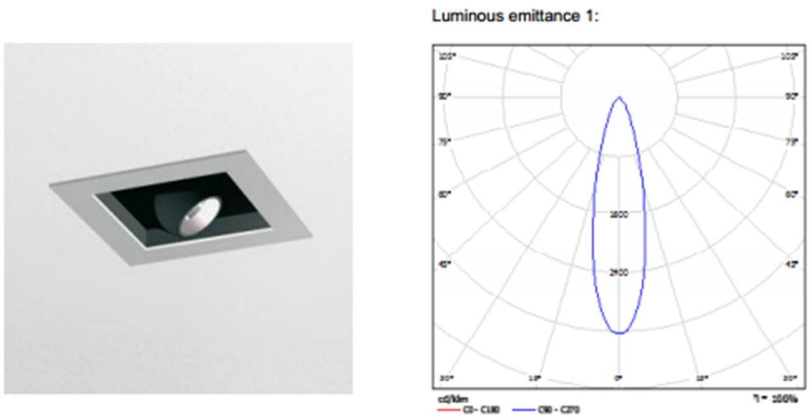


Figure 7.8 Product selected from Artemide catalogue

Table 7.1 Manufacturer Specifications of Artemide LED product

Characteristics	
Article number	M043115
Typology index	Recessed luminaires
Family	Java
Mounting Location	Ceiling
Mounting Type	Recessed
Colour	Grey
Optical	
Light Distribution	Spot
Luminouse Flux	155lm
Dimension	
length	0.161m
Width	0.158m
Height	0.117m
Lamps	
Lamp Type	LED
Lamp Wattage	7w

source: www.artemide.com

7.4.3 Adding luminairs for the selected Room

For the application, expected illuminance level was 38fc [410Lux] .The luminairs have been selected according to emmiting tothe required illuminance level.

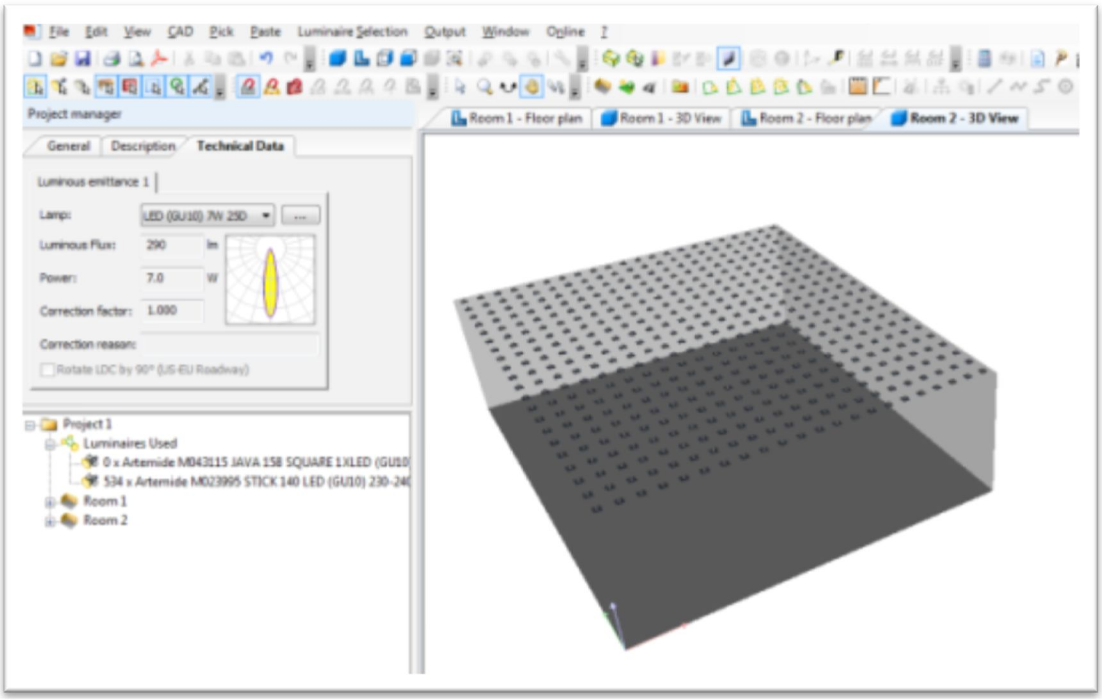
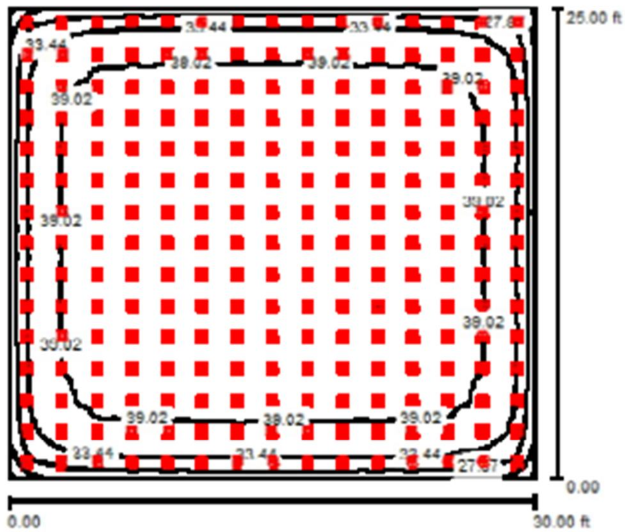


Figure 7.9 Artemide LED luminair added to the selected room

7.4.4Results and Calculations

Below are the software generated result sheet and the calculations were done to find the power which needs to light up the space to a fix light level.This calculation was done for 15 number of LED products,15 number of CFL products & 13 number of conventional prodcuts in this study.

Room 1 / Single Sheet Output



Height of Room: 9.000 ft, Mounting Height: 9.000 ft, Light loss factor: 0.80 — Values in Footcandles, Scale 1:98

Surface	ρ [%]	E_{av} [fc]	E_{min} [fc]	E_{max} [fc]	u0
Workplane	/	38	16	42	0.426
Floor	20	36	16	42	0.453
Ceiling	80	5.63	4.08	6.60	0.726
Walls (4)	50	9.35	4.48	12	/

Workplane:		UGR	Lengthways-	Across	to luminaire axis
Height:	2.493 ft	Left Wall	15	15	
Grid:	128 x 128 Points	Lower Wall	15	15	
Boundary Zone:	0.000 ft	(CIE, SHR = 0.25.)			

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.242, Ceiling / Working Plane: 0.148.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ [lm]	P [W]
1	225	Artemide M043115 JAVA 158 SQUARE 1XLED (GU10) 230-240V (1.000)	155	7.0
		Total:	34875	1575.0

Specific connected load: 2.10 W/sq ft = 0.55 W/sq ft/10 fc (Ground area: 750.02 sq ft)

Figure 7.10 Results of Artimide LED product simulated with Dialux

Above room should be contained with 225 individual lumiairs to achieve the required illuminance level of 38fc as shown in the above results sheet. So total load(kw) requirement was calculated for the above room to keep the light level of 38fc and there by the total load requirement for the building and the whole zone was found as below.

7.4.5 Calculation

Below are the total power calculation for different luminair types to emit same light level inside the selected building(to have 38fc on working plane).the building was assumed as 18 partion of 25ftx30ft.

7.4.5.1 LED Product (7w)

For a 25ftx30ft Partition ,Selected product was 7W luminair

Total Power = 7W/pcsx225pcs

=1,575W

For a 225ftx60ft building,

Total luminairs requirement to have the 409 lux level(Eav[fc] 38) is

225pcs/partition x18partition=4,050pcs

Total power =7W x 4,050

=2,8350W

=28.5 kW

So the electricity demand for light up a 1 buiding with selected LED type for this application was 28.5 kW.In the above individual luminair type it was obviouse that difficult to mount on the ceiling because this type is needed 225pcs to give 38 fc light level on to the working plane which is a bignumber so another compact type luminairs were used with the same luminair type from the Artimide catralogue.

7.4.5.2 28W LED Product

For a 25ftx30ft Partition, selected product is 28W lamp

Total Power = 28W/pcsx56pcs

=1,568W

For a 225ftx60ft building,

Total luminaire requirement to have the 409 lux level (Eav[fc] 38) is

56pcs/partition x18partition=1,008pcs

Total power =28W x 1008

=2,8224W

=28.2 kW

Then for the whole industrial zone (which include 8 buildings), the load required to light up was , 8 *28.2kW.

This load calculation for 15 number of diffferent LED types were done and thereby the total lighting load(kw) for each type was also calculated.

7.5CFL Lamp Selection

As it was done for the LED type here it was done for a CFL product from the same manufacture catalogue as below.This selected lamp includes 2 luminairs (26Wx2) and Emergency

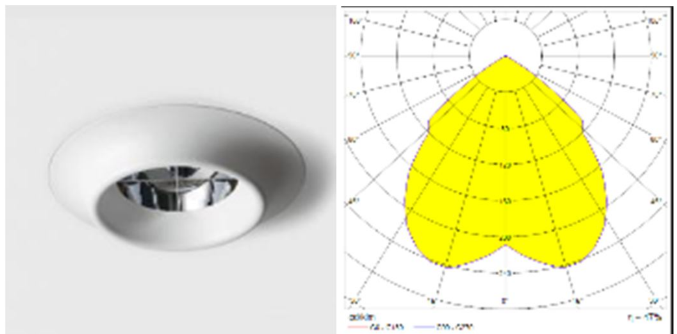


Figure 7.11 Artimide CFL Product with light distribution curve

Below table shows the product features of the selected CFL product from the Artemide catalogue as below.

Table 7.2Manufacturer Specifications of Artemide CFL product

Characteristics	
Article number	M106527
Typology index	Recessed luminaires
Family	Vulcania
Mounting Location	Ceiling
Mounting Type	Recessed
Colour	white
Optical	
Light Distribution	Spot
Luminouse Flux	1800lm
Dimension	
length	0.375m
Width	0.375m
Height	0.17m
Lamps	
Lamp Type	Compact flurocent lamp
Lamp Wattage	26W

7.5.1Adding CFL Luminair

This stagefollows adding relevent bulbs in a selective manner.Therefore this field arrangement was selected to arranging luminaires. It was required 5 Luminairs/raw and 4 raws/partition and 1 single luminair was also added and all togther 21 number of luminairs per one partition have been added to have 38fc light level on the working plane.

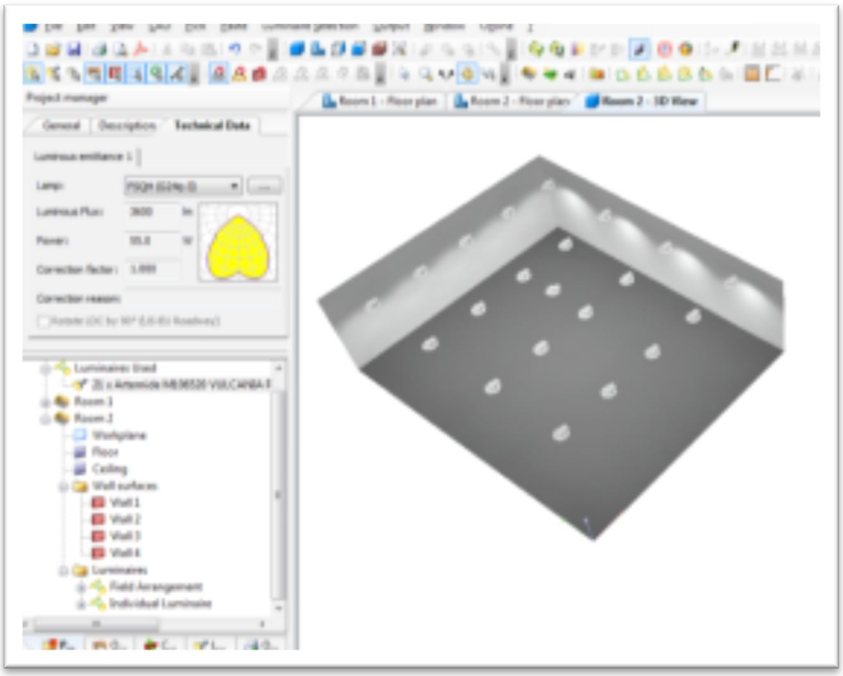


Figure 7.12 Artimide CFL luminair adding

7.5.2 Results and Calculation

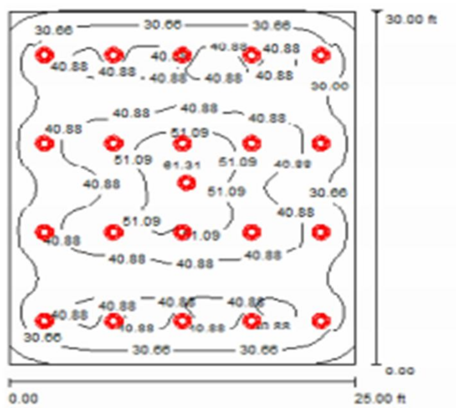
Project 1

DIALux

04 / 25 / 2013

Operator
Telephone
Fax
e-Mail

Room 2 / Summary



Height of Room: 9.000 ft, Mounting Height: 8.500 ft, Light loss factor: 0.80 Values in Footcandles, Scale 1:118

Surface	ρ [%]	E_{av} [fc]	E_{min} [fc]	E_{max} [fc]	u0
Workplane	/	38	15	62	0.398
Floor	20	35	17	51	0.487
Ceiling	80	6.08	4.20	7.02	0.690
Walls (4)	50	12	4.67	27	/

Workplane:
Height: 2.493 ft
Grid: 128 x 128 Points
Boundary Zone: 0.000 ft
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.279, Ceiling / Working Plane: 0.161.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ [lm]	P [W]
1	21	Artemide M106520 VULCANIA RECESSED Ø375MM FIX TC-DEL 2X26W (1.000)	3600	55.0
		Total:	75600	1155.0

Specific connected load: 1.54 W/sq ft = 0.41 W/sq ft/10 fc (Ground area: 750.02 sq ft)

DIALux 4.9 by DIAL GmbH Page 4

7.5.3 Calculation

Number of luminares used to get the average illuminance level to 38fc was 21. Here it has been used 20 numberof luminairs in filed arrangement and 1 luminaire in an isolated manner.

For a 25ftx30ft Partition,

Total Power = 55W/pcs x21pcs

=1,155W

For a 225ftx60ft building,

Total luminare requirement to have the 409 lux level(Eav[fc] 38) is;

21pcs/partition x18partition=378 pcs

Total power=55W x 378

=2,079W

=20.7kW

Then for the whole industrial zone (which include 8 buildings), the load required to light up was ,

8 *20.79Kw=166.32Kw.This load calculation for 15 number of diffferent CFL types were done and thereby the total lighting load(Kw) for each type was also calculated

7.6Incandecent Lamp Selection

An incandescent luminair was selected from the same manufacturer whose products were selected for LED and CFL as well.Below is the selected incandescent lamp from the catalogue.

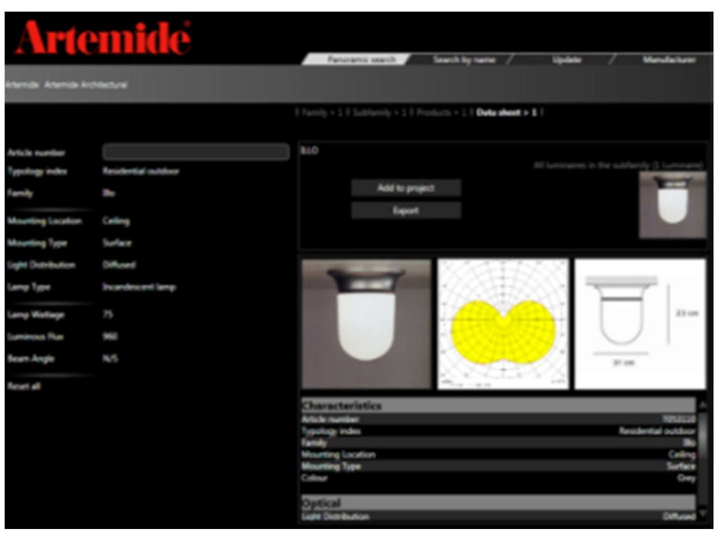


Figure 7.13 Artimide incandescent Catalogue

7.6.1Product Details

Below are the specification of the selected incandescent product from the catalogue.

Selected Product :Artemide T053110 ILLO

Article No.: T053110

Luminaire Luminous Flux: 960 lm

Luminaire Wattage: 75.0 W

Luminaire classification according to CIE: 64

CIE flux code: 23 49 75 64 61

Fitting: 1 x IAA60 (E27) (Correction Factor 1.000).

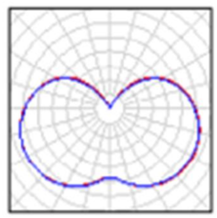
 

Figure 7.14 ArtimideT053110 ILLO(incandescent)lamp &light distribution curve

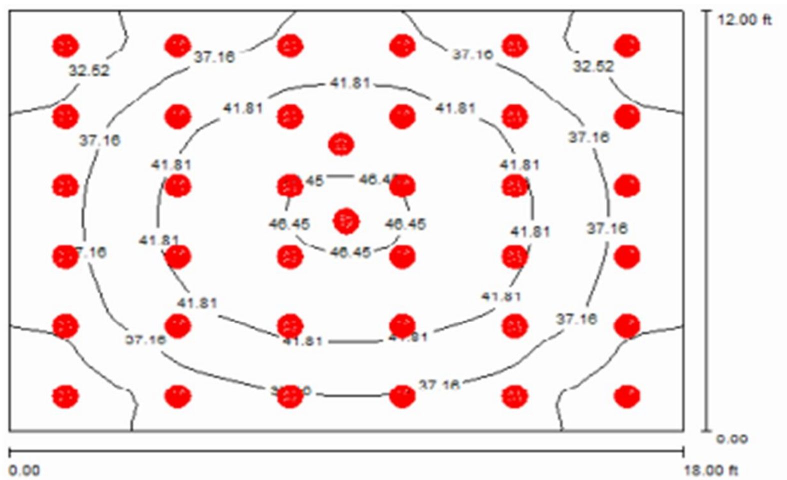
7.6.2Results

Project 2

DIALux
05 / 03 / 2013

Operator
Telephone
Fax
e-Mail

Room 1 / Summary



Height of Room: 9.000 ft, Mounting Height: 8.500 ft, Light loss factor: 0.80 Values in Footcandles, Scale 1:47

Surface	ρ [%]	E_{av} [fc]	E_{min} [fc]	E_{max} [fc]	u0
Workplane	/	38	28	47	0.725
Floor	20	30	22	36	0.732
Ceiling	80	33	19	48	0.584
Walls (4)	50	35	16	81	/

Workplane:

Height:	2.493 ft
Grid:	32 x 32 Points
Boundary Zone:	0.000 ft

Illuminance Quotient (according to LG7): Walls / Working Plane: 1.050, Ceiling / Working Plane: 0.858.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ [lm]	P [W]
1	38	Artemide T053110 ILLO (1.000)	960	75.0
		Total:	36480	2850.0

Specific connected load: 13.20 W/sq ft = 3.45 W/sq ft/10 fc (Ground area: 215.99 sq ft)

7.6.3 Calculation

Number of luminares were used to get the average illuminance level to 38fc was 38 numbers.Here 36 pcs have been used in field arrangement and 2 luminair were also added to achive 38fc in single luminair adding mode.

For a 25ftx30ft Partition,
Total Power = 75W/pcs x 38pcs
=2,850W

For a 225ftx60ft building,
Total luminare requirement to have the 409 lux level(Eav[fc] 38) is;
38pcs/partition x18partition=684 pcs
Total power =75W x 684
=5,130W
=51.3kW

Then for the whole industrial zone (which include 8 buildings), the load required to light up was ,

8 *51.3kW=410.4kW

This load calculation for 12 number of diffferent conventional types were done and thereby the total lighting load(kW) for each type was also calculated.

So for total of 42 luminair types were simulated individually for this building and the load(kW) values were seperatly noted to spread sheets and then the data's gathered from Dialux simulation and from the RCL were used to the doenergy analysis part considering power factors of each preliminary categorized P.F groups.

7.6.3.1 Apperent Power Calculation

Apperent power is the portion which we have to pay in monthly basis to the electricity provider,which is call as **kvar** in units.With the use of power triangle the apperent power was calculated as below

Apparent Power(S) =Active Power (P) /cos(theta)

Cos(thera) is the p.f for the light bulbs.

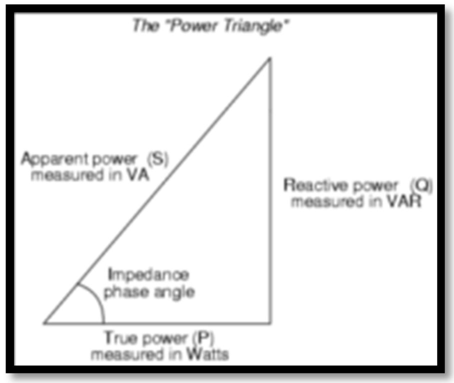


Figure 7.15 Power triangle

7.7 Test Results Summery

Below tables show the calculated power values individually for certain types of luminaires simulated with Dialux for different power factors which may available in the market. By analyzing this kind of a table it is very easy to select which luminar type seems good for lighting the building and which one seems bad and consuming more energy under their power factors. Below 2 tables show how the apparent power were calculated for one LED type and for one CFL type and then the other tables show the apparent power for all the luminairs simulated with Dialux.

Table 7.3 OMS LED PRODUCT (TUBUS CYGNUS LED 10W 700lm 2700K 90Ra)

Active power(kW)	10.44					
PF	0.4	0.5	0.6	0.7	0.8	0.9
Apparent Power(kVA)	26.10	20.88	17.40	14.91	13.05	11.60
Reactive Power(kVAr)	23.92	18.08	13.92	10.65	7.83	5.06

Table7.4 OMS CFL PRODUCT (UX-TUBUS 292 POLISHED 1x18W)

Active power(kW)	17.748					
PF	0.4	0.5	0.6	0.7	0.8	0.9
Apparent Power(kVA)	44.37	35.50	29.58	25.35	22.19	19.72
Reactive Power(kVAr)	40.67	30.74	23.66	18.11	13.31	8.60

According to the above tables it can be clearly seen that how apparent power changes with power factors.

So here total resultsfor all LED (15 products) ,CFL (15 products) and for conventional (13 products) have been summarized,reffer Annexture III .

7.8 Apparent power comparison for different power factors of LED,CFL and Conventional Bulbs

Below is the summery in which it is easy to compare each type of bulb for different power factors.(the range of power factors for LED and CFL which were categorized to 4 groups considering RCL test data's has been used here for the analysis). In this figure it is apparent that some types of LEDs are consuming more energy than the CFL or conventional bulbs under certain power factors. Below comparison tables can be used to find exactly suitable bulb for an application.

LED

	Details of Bulb	Apperent Power(KVA)			
		PF=0.4	PF=0.5	PF=0.8	PF=0.9
1	PHILIPS BCS640 W21L125 1xLED48/840 LIN-PC	19.04	15.23	9.5175	8.46
2	PHILIPS BCS680 W17L122 1xLED48/840 LIN-PC	20.25	16.2	10.125	9
3	OMS TORNADO PC LED 27W 2700lm 4000K 80Ra	20.66	16.52	10.328	9.18
4	OMS TORNADO PC LED 27W 2700lm 4000K 80Ra	20.66	16.52	10.328	9.18
5	DS7-W1-LWMB+LE DS7 FLAT LED MEDIUM BEAM	23.4	18.72	11.7	10.4
6	TUBUS CYGNUS LED 10W 700lm 2700K 90Ra	26.1	20.88	13.05	11.6
7	PHILIPS BCS680 W7L122 1xLED24/830 MLO-PC	26.73	21.38	13.365	11.88
8	OMS UX-PLASTIC PLAST 2 LED OPAL 13W	28.67	22.93	14.333	12.74
9	ALTO 11300 A60 830 O3 Downlight	46.8	37.44	23.4	20.8
10	BEGA 6826 LED 16W	48.96	39.17	24.48	21.76
11	DOS/LWNA BIT LED ACID ECHED GLASS	49.14	39.31	24.57	21.84
12	ALTO 11301 D30 830 O3 Directional luminaire	51.3	41.04	25.65	22.8
13	PHILIPS BCS401 9xLED-HB-2700 30	54.68	43.74	27.338	24.3
14	TAGORA 80 LED (GU10) 230-240V 7W	70.88	56.7	35.438	31.5
15	JAVA 158 SQUARE 1XLED (GU10) 230-240V	70.88	56.7	35.438	31.5

CFL

Details of Bulb	Apperent Power(KVA)			
	PF=0.55	PF=0.6	PF=0.8	PF=0.9
OMS UX-PLASTIC PLAST 3 OPAL 1X38W	31.42	28.80	26.58	19.20
FILIP 4 E27 23W (1.35.04.A.01)	31.42	28.80	26.58	19.20
BEGA 6796 1 TC-TELI(42W)	31.61	28.98	26.75	19.32
UX-TUBUS 292 POLISHED 1x18W(CFL Lamp)	32.27	29.58	27.30	19.72
BEGA 6797 2 TC-TELI(32W)	34.36	31.50	29.08	21.00
OMS UX-PLASTIC PLAST 4 PRISMA 1X38W	36.23	33.21	30.66	22.14
Artemide LS90300 LUCERI 150 TC-DEL 1x13W NON DIMMABLE	37.31	34.20	31.57	22.80
VULCANIA RECESSED Ø375MM FIX TC-DEL	37.80	34.65	31.98	23.10
Artemide LS96300 LUCERI 220 WW TC-DEL 2x13W NON	38.29	35.10	32.40	23.40
BEGA 6786 1 TC-TELI(26W)	40.32	36.96	34.12	24.64
MINI SIMPLE 01 15W E27	41.73	38.25	35.31	25.50
SIMPLE MOB 01 15W E27	48.44	44.40	40.98	29.60
BEGA 6907 1 TC-TEL 13W	49.09	45.00	41.54	30.00
SIMPLE S O4 15W	57.27	52.50	48.46	35.00
D60R/F32E+D60R/RM DUPLO COMPACT FLUORESCENT	72.33	66.30	61.20	44.20

CONVENTIONAL BULBS

Type	Details of Bulb	Active power (KW)	Apperent Power (KVA)	Reactive Power (Kvar)
incand	OMS DOWN LIGHT PRO HID 1X35W	11.7	11.7	0.00
FTL	DOUBLE LOUVRE 14X18W (160.2055)	16.2	27.00	21.72
FTL	Artemide M105101 INFINI T16 2X28W	16.47	20.59	22.08
Florocent	SILVA GLASS 2 METAL HALIED G12 35W	18.144	30.24	24.33
METAL HALIED	BEGA 4667 2 T26 36W	24.84	31.05	33.31
FTL	Artemide M170300 JAVA LINEAR SYSTEM DIFFUSER	43.74	54.68	58.65
incand	Artemide T053110 ILLO (incandecent lamp)	51.3	51.3	0.00
incand	BEGA 6830 1 QT14 33W	71.28	71.28	0.00
incand	Artemide A048120 TETI	86.4	86.4	0.00
incand	LOGICO SOFFITTO MICRO SINGOLA	91.8	91.8	0.00
incand	OMS UX-DOWN LIGHT 241 FACET 1X60W	99.792	99.792	0.00
incand	D14/E27 TOP INCANDESCENT	130.68	130.68	0.00
HALOGEN	SILVA 8 E27 (1.33.08.A.01)	151.2	252.00	202.74

Figure 7.16 Apparent power comparison against power factors of different bulbs

Observations of above comparison are as below,

11 CFL bulbs (dark blue highlighted) under PF=0.55 are better than 7 LED bulbs (dark blue highlighted) under PF=0.4

6 CFL bulbs (blue highlighted with yellow text) under PF=0.55 are better than 7 LED bulbs(orange color highlighted) under PF=0.5 in above tables

4CFL bulbs(light blue highlighted) with P.F= 0.8 are better than 3 LED bulbs(light blue highlighted) with P.F=0.8

4 CFL bulbs(purple color highlighted) with P.F=0.9 are better than 7 LED bulbs(purple color highlighted) with P.F=0.9

5 conventional bulbs(dark blue highlighted)are better than 7 LED bulbs(dark blue highlighted) with P.F=0.4 & 7 LED bulbs(Orange colour highlighted) with P.F= 0.5

7.9 Comparison of luminaire types against apparent power

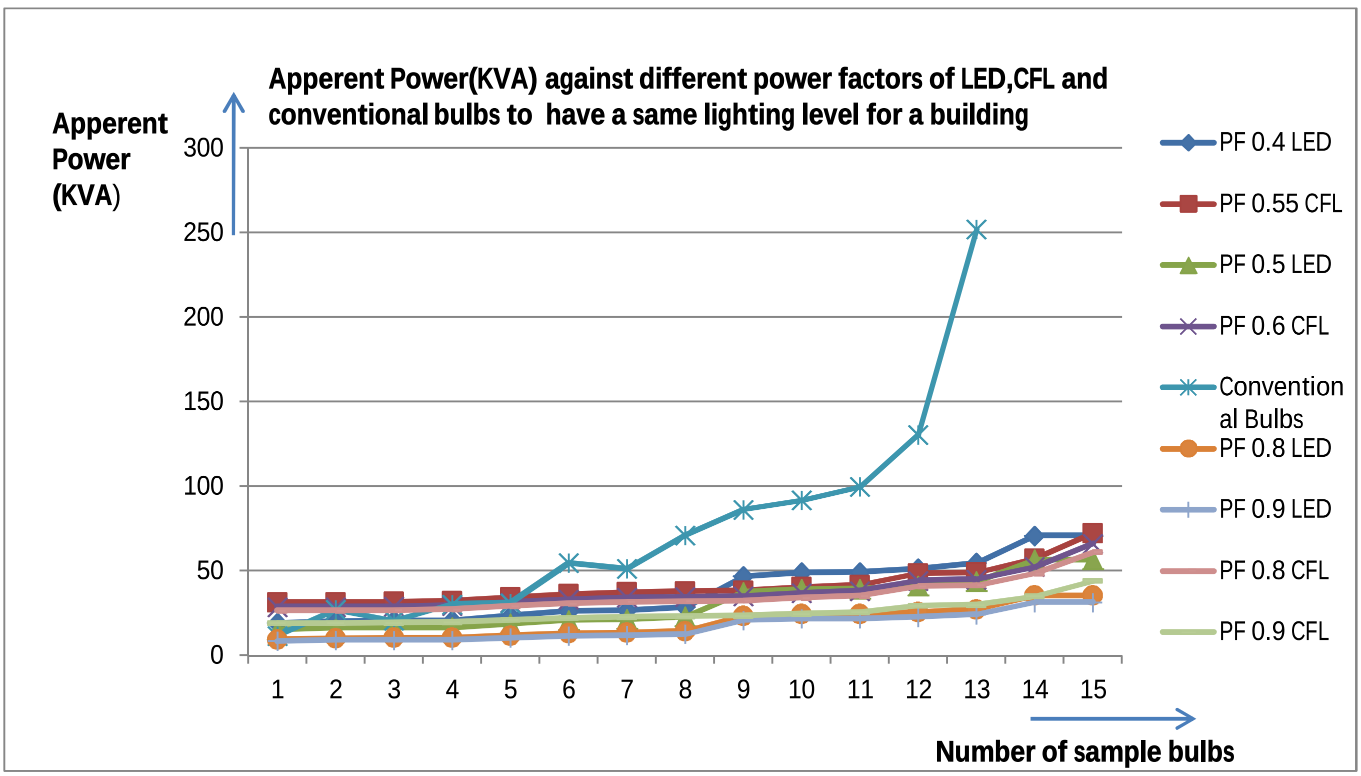


Figure 7.17 Apparent power comparison chart

It can be seen that the apparent power of the conventional bulbs are considerably higher than the LED and CFL bulbs for majority of the sample elements and the apparent power of the LED sample is better than the apparent power of the CFL sample when it considered above graph.

7.10Apparent Power of P.F=0.4 LED against different power factors of CFL bulbs

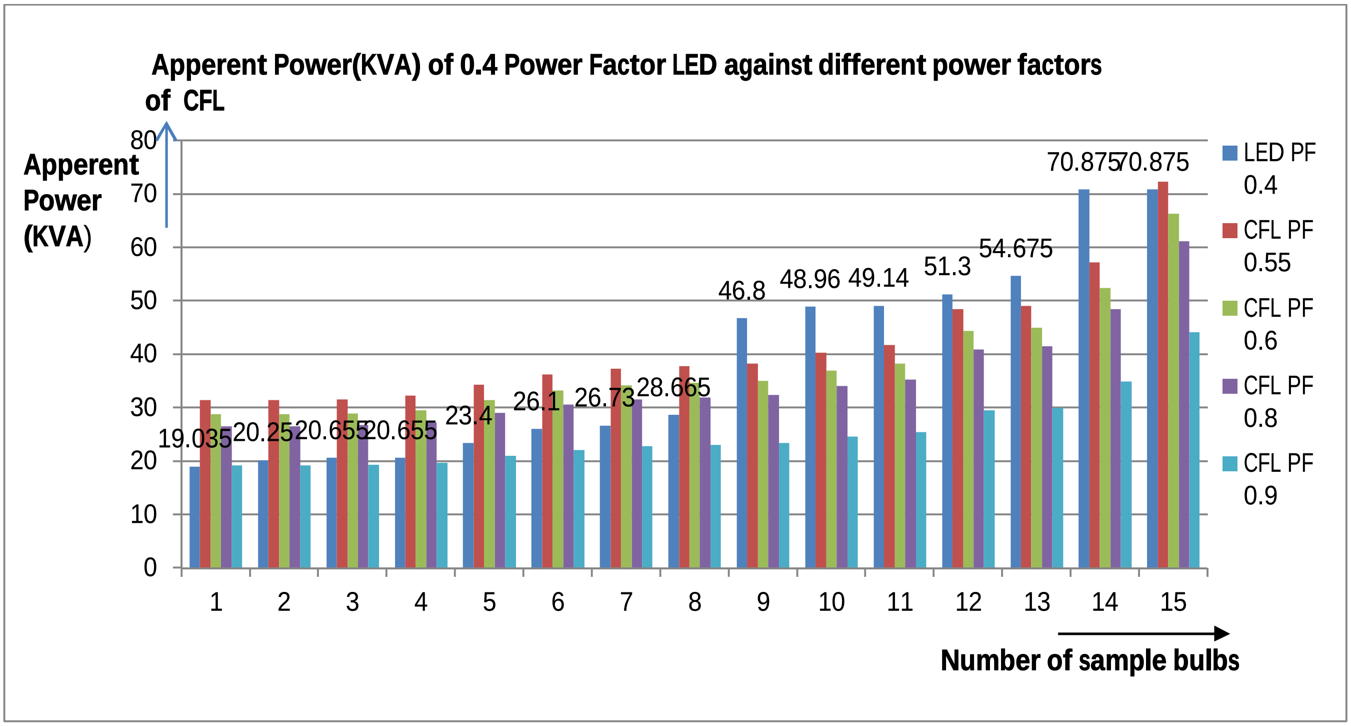


Figure7.18 Apparent power comparison for P.F=0.4 LED lamp

Above graph shows the apparent power change with the power factor of each P.F category of CFL compared to 0.4 P.F of LED bulb. It is obvious that 8 LED bulbs are better than the CFL when it is considered 0.4 P.F LED. This means that, it is around 53% of LED with 0.4 PF in the market are still better than CFL bulbs with P.F 0.8 or less, available in the market.

7.11Dialux simulation results analysis

Below tables show the Median, Minimum, Maximum and Average power consumption of the LED and CFL samples which were simulated with Dialux shows reactive and apparent power for each power factor categories.

7.11.1Comparison of Median of the sample

CFL

	PF			
load	**0.55**	**0.6**	**0.65**	**0.9**
P(kW)	21	21	21	21
Q(kVAr)	32	28	24	10
A(kVA)	38	35	32	23

LED

	PF			
load	**0.4**	**0.5**	**0.8**	**0.9**
P(kW)	11.5	11.5	11.5	11.5
Q(kVAr)	26	20	8.5	5.5
A(kVA)	29	20	14	13

Reactive power and apparent power of the median of the sample for CFL is greater than the median of the sample of LED. Comparison of the sample median shows that LED is better than the CFL.

7.11.2 Comparison of Minimum of the sample

CFL

	PF			
load	**0.55**	**0.6**	**0.65**	**0.9**
P(kW)	17	17	17	17
Q(kVAr)	26	23	20	8
A(kVA)	31	29	27	19

LED

	PF			
load	**0.4**	**0.5**	**0.8**	**0.9**
P(kW)	8	8	8	8
Q(kVAr)	17	13	6	4
A(kVA)	19	15	10	8

Reactive power and apparent power of the minimum of the sample for CFL is greater than the minimum of the sample of LED. Comparison of the sample minimum shows that LED is better than the CFL.

7.11.3 Comparison of Maximum of the sample

CFL

	PF			
load	**0.55**	**0.6**	**0.65**	**0.9**
P(kW)	40	40	40	40
Q(kVAr)	61	53	46	19
A(kVA)	72	66	61	44

LED

	PF			
load	**0.4**	**0.5**	**0.8**	**0.9**
P(kW)	28	28	28	28
Q(kVAr)	65	49	21	14
A(kVA)	71	57	35	31

Reactive power and apparent power of the maximum of the sample for CFL is greater than the maximum of the sample of LED. Comparison of the sample minimum shows that LED is better than the CFL.

7.11.4 Comparison of Average of the sample

CFL

	PF			
load	**0.55**	**0.6**	**0.65**	**0.9**
P(KW)	23	23	23	23
Q(Kvar)	35	30	26	11
A(kVA)	41	38	35	25

LED

	PF			
load	**0.4**	**0.5**	**0.8**	**0.9**
P(KW)	15	15	15	15
Q(Kvar)	35	27	11	7
A(kVA)	39	31	19	17

Reactive power and apparent power of the average of the sample for CFL is greater than the average of the sample of LED. Comparison of the sample average shows that LED is better than the CFL.

So this analysis of median, minimum, maximum and average values of the studied sample showed LED was better than CFL. But when the whole sample was considered it witnessed that there were some individual types of CFL and Incandescent which were better than LED. Reasons for these results may be different types of light distribution curves of each type of bulbs as see below figure and manufacturing issues and also the environment factors etc.

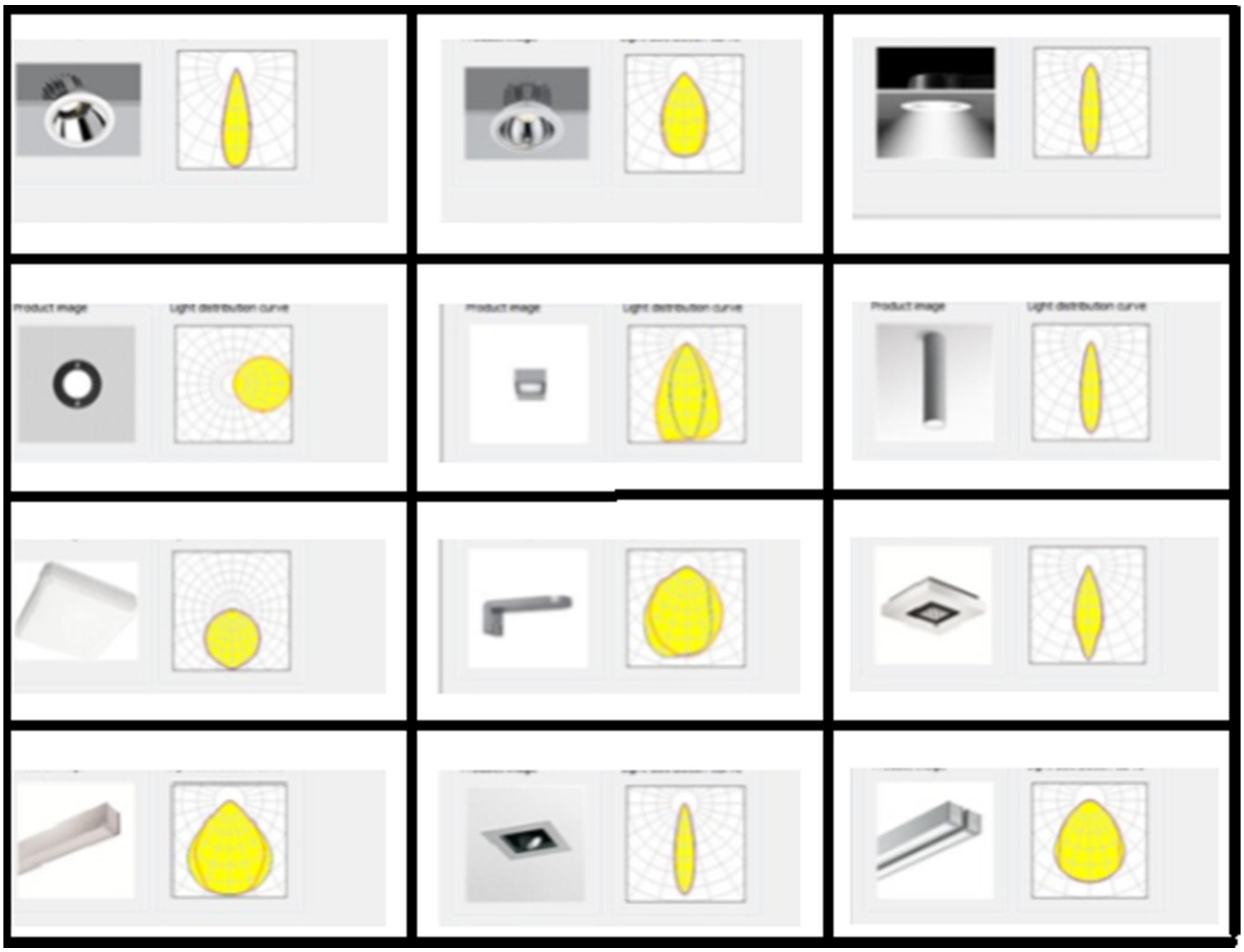


Figure7.19 Light distribution curves for different bulbs

8.0 Manufacturing Phase Energy Assessment

U.S Department of Energy (DOE) has done a life cycle energy assessment for LED,CFL and for incandescent and they have used over 10 research papers as their literature. Since this report has reliable data on manufacturing, packaging and transportation, DOE report data has been used to determine the manufacturing energy of different types of bulbs.

The Processing steps of the typical bulb unit can be simplified in to below phases

- Primary resource collection
- Raw material acquisition
- Manufacturing / assembly
- Usage, and the end-of-life phase
- Transportation is often included between each phase

Below study has done to finding the manufacturing phase primary energy MJ/20 million lumen hours

Table8.1 Performance of Conventional and LED lighting Technologies

Lamp Type	Watts	Lumens	Operating Lifetime (hrs)
Incandescent	60	900	1,000
CFL	15	900	8,500
LED (2011)	12.5	800	25,000
LED - future (2015)	5.8	800	40,000

The entire component related to manufacture LED lamp has been listed and weight of each component is calculated in grams and it has been summarized as a percentage value to the total mass of completed LED lamp in below table. It can be taken as the bill of material(BOM) for manufacturing a LED lamp.

Table 8.2 Example of LED Lamp Component

Name	Material	Mass (g)	Mass %
Glass bulb	Glass	10.7	13.0%
LED board connectors	Gold plated copper	0.5	0.60%
Array (9 LEDs in 1 array)		1.5	1.80%
Local heat sink ring	Aluminum	5.7	6.90%
Heat sink outer cone	Aluminum	18.1	22.0%
Heat sink inner cylinder	Aluminum	13.1	15.8%
Edison base insulator	Acrylic, polycarbonate	4.2	5.10%
Inner insulator and adhesive connections	Acrylic, polycarbonate	6.6	8.00%
Printed circuit board, capacitors, resistors, transistors, diodes		10.1	12.2%
Edison base and leads	Tin plated steel	12.2	14.8%
	Total =	**82.7**	**100%**

Source:(Hendrickson,2012)

DOE report has used several assumption as below in there study,

First, it is assumed that the energy consumption to manufacture an LED lamp is the summation of the energy concomitant with manufacturing the bulk lamp materials plus the energy require to manufacture a single LED package in to the number of packages. Thus, assuming that the packages have integrated equivalent die areas, a LED lamp that uses five packages has a lower embodied energy ingestion compared to an LED lamp that uses sixteen packages.

The second assumption considered was that the manufacturing energy ingesting of a single LED package is not related to efficacy, until total die area keep on constant. For example, an LED package of 50 lm/W has the same embodied energy ingesting as an LED package of 60 lm/W. This postulation allows for the package manufacturing energy approximations from the existing LCA studies to be utilized in characterizing 2011 LED packages, which may have developed efficacies.

The third assumption considered was that manufacturing energy ingesting of the LED bulk lamp materials remains constant if wattage does not alter. Nevertheless, changes in wattage may affect the thermal controlling for the lamp causing a change in product design and material use.

The energy ingesting range for the manufacturing phase of an incandescent, CFL and LED lamp is presented below in table. The minimum manufacturing energy estimation embodies the lowest derived from the previous LCA studies, while maximum embodies the greatest. The average or mean manufacturing energy approximation is an average of all derived values. The energy ingesting values are all normalized to the functional unit of 20 million lumen-hours, thus the different lifetimes of the 2011 LED and 2015 LED lamp products cause their energy ingesting to fluctuate.

Table 8.3 Manufacturing Phase Primary Energy (MJ/20 million lumen-hours)

Manufacturing Process	Incandescent			CFL			2011 LED (16 LED Packages)			Future 2015 LED (5 LED Packages)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Bulk Lamp Material	10.1	42.2	106	11.3	170	521	38	87.3	154	25.4	58.5	103
1 LED Package[1]	N/A	N/A	N/A	N/A	N/A	N/A	0.12	16	83.5	0.11	14.6	76.2
Total LED Packages contribution	N/A	N/A	N/A	N/A	N/A	N/A	1.9	256	1,336	0.54	73	381
Total	**10.1**	**42.2**	**106**	**11.3**	**170**	**521**	**39.9**	**343**	**1,490**	**25.9**	**132**	**484**

1. This value is not included in the total sum, but is presented to show the manufacturing energy contribution from one LED package.

The mean values for total manufacturing energy of incandescent, CFL and LED lamps are 42.9 MJ, 183 MJ, and 343 MJ per functional unit respectively. Consequently, on average CFL manufacturing is over four times and LED manufacturing is eight times more energy exhaustive than incandescent lamp manufacturing. Captivatingly, the mean approximation for the LED lamp designates that the LED bulk lamp materials represent about 25 percent of the total LED lamp manufacturing; with the residual 75 percent from manufacturing the LED package.

According to the above collected works, manufacturing energy of LED : CFL : Incandescent are in ratio of 8:4:1 ,where it has found the manufacturing energy equivalent to produce a functional unit of LED ,CFL and Incandescent can be taken as 343MJ,183MJ and 42.9MJ correspondingly.

The above ratio of energy found in the DOE report has been used to calculate the manufacturing phase energy for the sample bulbs considered for this study, i.e it has been calculated MJ/20million lumen -hours for each and every bulb used in this study. Below is the manufacturing energy for each type

8.1Energy required to manufacture LED,CFL and Conventional bulbs selected from Dialux catalogues relative to the above literature of DOE

Energy equivalent to produce a LED functional unit is 343MJ from the above study and the required energy to manufacture each type of LED was calculated as below in the table. This was helpful to find the best product in manufacturing energy point of view from the current market and specially a great tool for the academic point of view as well to compare energy consumption of manufacturing phase .

Bulbs required to produce 20-million lumen hours=20000000/(lumen)*(life time hours)

Energy required to manuf. a LED package= no of bulbs*343MJ (one bulb is assumed as one package)

Table 8.4 number of LED bulbs required to produce 20-million lumen hours

Product Name	Wattage (W)	Lumen (lm)	Life time hours	bulbs required to produce 20 million lumen hrs	round up value(bulbs required)	Energy required to manufacturing a LED Package(MJ)
JAVA 158 SQUARE 1XLED (GU10) 230-240V	7.0	155.0	25000	5.16	6	2058
TAGORA 80 LED (GU10) 230-240V 7W 25° 3100K GREY/WHITE	7.0	155.0	25000	5.16	6	2058
TUBUS CYGNUS LED 10W 700lm 2700K 90Ra	10.0	618.0	25000	1.29	2	686
OMS UX-PLASTIC PLAST 2 LED OPAL 13W	13.0	900.0	25000	0.89	1	343
OMS TORNADO PC LED 27W 2700lm 4000K 80Ra	27.0	2691.0	25000	0.30	1	343
PHILIPS BCS401 9xLED-HB-2700 30	15.0	414.0	25000	1.93	2	686
PHILIPS BCS680 W17L122 1xLED48/840 LIN-PC	50.0	4050.0	25000	0.20	1	343
PHILIPS BCS640 W21L125 1xLED48/840 LIN-PC	47.0	4250.0	25000	0.19	1	343
PHILIPS BCS680 W7L122 1xLED24/830 MLO-PC	27.0	1650.0	25000	0.48	1	343
ALTO 11301 D30 830 O3 Directional luminaire	10.0	685.0	25000	1.17	2	686
ALTO 11300 A60 830 O3 Downlight	10.0	685.0	25000	1.17	2	686
BEGA 6826 LED 16W	16.0	900.0	25000	0.89	1	343
DO5/LWNA BIT LED ACID ECHED GLASS	26.0	1800.0	25000	0.44	1	343
D57-W1-LWMB+LE D57 FLAT LED MEDIUM BEAM	13.0	1335.0	25000	0.60	1	343

In above table, calculated number of “bulbs required” column means the equivalent number to gain 20-million lumen hours and the “energy required to manufacturing a LED package” means the useful energy (MJ) to produce/manufacture these number of LED bulbs to the defined application. Here it can be found that manufacturing energy for each type of LED used in this study to light up the defined building. In above table there are two type of LEDs which are not that good. they are needed 6 bulbs to produce 20million lumen hours where rest of the types need 1 or 2 bulbs. High number of bulbs need to produce 20million lumen hours means that bulb type is worse.

8.2 Energy required to manufacture CFL bulbs

Energy equivalent to produce a CFL functional unit is 183MJ.so the energy required to manufacture each type of CFL is calculated in below table. Bulbs required to produce 20-million lumen hours=20000000/(lumen)*(life time hours)

Energy required to manuf. a CFL package= no of bulbs*183MJ (one bulb is assumed as one package)

Table 8.5number of CFL bulbs required to produce 20-million lumen hours

Product Name	Wattage (W)	Lumen (lm)	Life time hours	bulbs required to produce 20 million lumen hrs	round up value(bulbs required)	Energy required to manufacturing a CFLPackage(MJ)
Artemide L596300 LUCERI 220 WW TC-DEL 2x13W NON DIMMABLE	28	1800	8500	1.31	2	366
Artemide L590300 LUCERI 150 TC-DEL 1x13W NON DIMMABLE	15	900	8500	2.61	3	549
VULCANIA RECESSED Ø375MM FIX TC-DEL 2X26W+EMERGENCY	55	3600	8500	0.65	1	183
UX-TUBUS 292 POLISHED 1x18W(CFL Lamp)	17	1200	8500	1.96	2	366
OMS UX-PLASTIC PLAST 3 OPAL 1X38W	30	2700	8500	0.87	1	183
OMS UX-PLASTIC PLAST 4 PRISMA 1X38W	41	2700	8500	0.87	1	183
BEGA 6907 1 TC-TEL 13W	15	850	8500	2.77	3	549
BEGA 6786 1 TC-TELI(26W)	28	1750	8500	1.34	2	366
BEGA 6796 1 TC-TELI(42W)	46	3200	8500	0.74	1	183
MINI SIMPLE 01 15W E27	15	900	8500	2.61	3	549
SIMPLE MOB 01 15W E27	16	900	8500	2.61	3	549
SIMPLE S O4 15W	15	900	8500	2.61	3	549
FILIP 4 E27 23W (1.35.04.A.01)	23	1500	8500	1.57	2	366
D60R/F32E+D60R/RM DUPLO COMPACT FLUORESCENT	32	3200	8500	0.74	1	183

In above table, calculated number of "bulbs required" column means the equivalent number to gain 20-million lumen hours and the "energy required to manufacturing a CFL package" means the useful energy (MJ) to produce/manufacture these number of CFL bulbs to the defined application. Here it can be found the manufacturing energy for each type of CFL used in this study to light up the defined building. When CFL table is compared to LED table it can be seen, none of CFL need 6 bulbs to produce 20million lumen hours.so that means there are some LEDs which are worse than CFL, but when average is compared LED is better than CFL

8.3Energy required to manufacture conventional bulbs

Energy equivalent to produce an incandescent functional unit is 42.9MJ.so the energy required to manufacture each type of conventional bulb is calculated as below table, here FTL and metal halide are also assumed as to this category.

Bulbs required to produce 20-million lumen hours=20000000/(lumen)*(life time hours)

Energy required to manuf. a conventional bulb package= no of bulbs*42.9 MJ (one bulb is assumed as one package)

Table 8.6number of Conventional bulbs required to produce 20million lumen hours.

Product	Wattage (W)	Lumen (lm)	Life Time hrs	Bulbs require to produce 20 million lumen hrs	round up value(bulbs required)	energy required to manufacturing an incandecent package (MJ)
Artemide T053110 ILLO (incandecent lamp)	75	960	1000	20.83	21	900.9
Artemide A048120 TETI	40	430	1000	46.51	47	2016.3
LOGICO SOFFITTO MICRO SINGOLA	60	660	1000	30.3	31	1329.9
OMS UX-DOWN LIGHT 241 FACET 1X60W	56	710	1000	28.17	29	1244.1
OMS DOWN LIGHT PRO HID 1X35W	42	2800	1000	7.14	8	343.2
BEGA 6830 1 QT14 33W	33	460	1000	43.48	44	1887.6
DOUBLE LOUVRE 14X18W (160.2055)	74	4800	1000	4.17	5	214.5
SILVA 8 E27 (1.33.08.A.01)	150	2500	1000	8	8	343.2
SILVA GLASS 2 METAL HALIED G12 35W	48	3300	1000	6.06	7	300.3
D14/E27 TOP INCANDESCENT	60	660	1000	30.3	31	1329.9
Artemide M105101 INFINI T16 2X28W DIMMABLE	61	5200	1000	3.85	4	171.6
Artemide M170300 JAVA LINEAR SYSTEM DIFFUSER	27	1750	1000	11.43	12	514.8
BEGA 4667 2 T26 36W	92	1380	1000	14.49	15	643.5

In above table, calculated number of "bulbs required" column means the equivalent number to gain 20-million lumen hours and the "energy required to manufacturing a conventional bulb package" means the useful energy (MJ) to produce/manufacture these number of conventional bulbs to the defined application. Here it can be found the manufacturing energy for each type of conventional bulbs used in this study to light up the defined building.

All above 3 tables shows the manufacturing phase energy required to produce each type of light bulbs to light up the defined building relative to the DOE analysis.

9.0 Power Simulation Software for Engineers [PSS®E] Modeling

PSS®E is the foremost software tool used by electrical transmission designers/users world-wide. The probabilistic examines and advanced dynamics modeling competencies included in PSS®E provide transmission preparation and operations engineers a wide range of methodologies for use in the design and operation of trustworthy networks. PSS®E is the typical Siemens offering for electrical transmission analysis which continues to be the technology of choice in an growing market that exceeds 120 countries. PSS®E was introduced in 1976.

PSS®E is an cohesive, interactive program for simulating, analysing, and optimizing power system performance. It provides the user with the most progressive and proven methods in many technical capacities, including:

- Power Flow
- Optimal Power Flow
- Balanced or Unbalanced Fault Analysis
- Dynamic Simulation
- Extended Term Dynamic Simulation
- Open Access and Pricing
- Transfer Limit Analysis
- Network Reduction

In this study PSS®E was used to calculate power flow through the transmission lines, transmission line over loadings, generation and transmission losses of the considered IEEE 9 bus bar power system. This simulation has been done for several categories as described below.

1. Simulation of Compact Florescent Lamp with P.F=0.55
2. Simulation of Compact Florescent Lamp with P.F=0.9
3. Simulation of LED Lamp with P.F=0.5
4. Simulation of LED Lamp with P.F=0.9
5. Simulation of Incandescent Lamp
6. Simulation of Florescent Tube Light with P.F=0.96

9.1 Information about IEEE Bus Bar power System

In this study IEEE 9 bus bar power system was used to find out the influence of the light bulb type into the power system. Therefore IEEE 9 bus bar was modeled using PSS®E with light bulb loading and find out power flow through the transmission lines, transmission line over loadings, generation & transmission losses.

Details of the IEEE 9 bus bar power system as below;

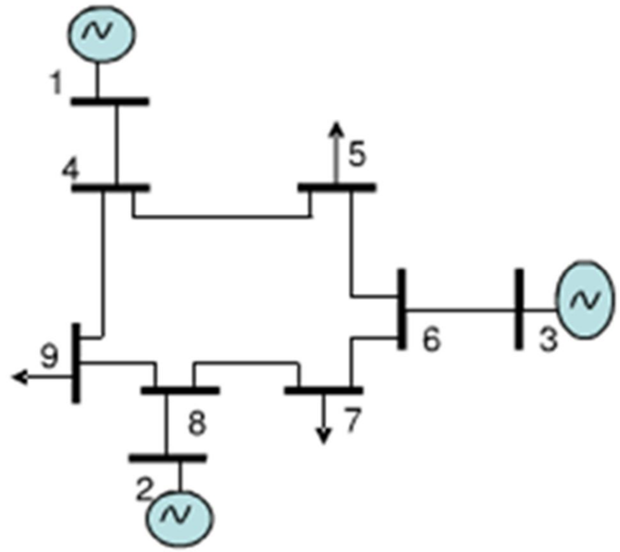


Figure 9.1 Schematic diagram of IEEE 9 bus bar system

1, 2 and 3 are the Generation Bus Bars where the generators are connected to the power system, 5, 7 and 9 are the Load Bus Bar where the loads are connected to the power system and 4, 6, 8 and the normal Bus Bars where the transmission lines are connected together and creates the power network.

```
baseMVA = 100;

% bus data
%   No.bus    type     Pd       Qd
bus = [
      1        3        0        0
      2        2        0        0
      3        2        0        0
      4        1        0        0
      5        1        90       30
      6        1        0        0
      7        1        100      35
      8        1        0        0
      9        1        125      50
];

%% generator data
%   bus  Pg   Qg     Qmax     Qmin       Pmax     Pmin
gen = [
    1    0    0      300      -300       250       10
    2    163  0      300      -300       300       10
    3    85   0      300      -300       270       10
];
```

No. 2, No. 3 are the Generator Bus Bars which notates by type 2 while No. 1 act as the Slack Bus Bar of the power system which notates by type 3. The Load Bus Bars are notates by type 1. The Pd is the active power generates or consumes by the bus and Qd is the reactive power generates or consumes by the bus. Active (Real or True) Power is measured in watts (W) and is the power drawn by the electrical resistance of a system doing useful work. Reactive power required by inductive loads increases the amount of apparent power - measured in kilovolt amps (kVA) - in the distribution system. Increasing the reactive and apparent power causes the power factor - *PF* - to decrease.

Pd and Qd are the active and reactive power quantities respectively. In this study these values were changed according to the light bulb types and their corresponding loading which gives the same light level the work plane.

```
%% branch data
%   fbus    tbus     r         x         b
branch = [
    1        4      0         0.0576    0
    4        5      0.017     0.092     0.158
    5        6      0.039     0.17      0.358
    3        6      0         0.0586    0
    6        7      0.0119    0.1008    0.209
    7        8      0.0085    0.072     0.149
    8        2      0         0.062     0   250
    8        9      0.032     0.161     0.306
    9        4      0.01      0.085     0.176
];
```

9.2 Summery of PSSE Results

Below is the summery of the results gained from PSSE Considering IEEE 9 Bus Bar system for above considered light bulbs types. For this simulation work ,12 equivalent buildings have been considered.

Table 9.1 Generation, loads and losses

Lamp Type	PF	Generation		Load		Losses	
		P(MW)	Q (kvar)	P(MW)	Q (kvar)	P(MW)	Q (kvar)
CFL	0.55	285.5	437.0	276.0	420.0	9.5	119.9
CFL	0.9	278.3	33.3	276.0	132.0	2.3	32.7
LED	0.5	185.7	260.1	181.0	324.0	4.7	50.7
LED	0.9	182.7	-35.7	181.0	84.0	1.7	16.8
Incandescent	1.0	978.3	348.0	936.0	0.0	42.3	465.2
FTL	0.96	344.4	354.9	336	351	8.4	112.8

Table 9.2 Line loading

Lamp Type	PF	Line Loading %								
		1-4	4-5	5-6	6-3	6-7	7-8	8-2	8-9	9-4
CFL	0.55	93	81	73	44	102	94	53	100	174
CFL	0.9	52	46	35	25	56	48	25	44	91
LED	0.5	48	46	63	32	71	65	38	81	104
LED	0.9	13	9	46	26	37	29	25	50	35
Incandescent	1.0	122	76	195	139	223	114	105	205	238
FTL	0.96	100	92	63	38	96	87	45	84	176

Table 9.3 Generator Loading

Lamp Type	PF	**Generator Loading**		
		Gene No 1 (Swing Bus)	Gene No 2	Gene No 3
CFL	0.55	232	160	131
CFL	0.9	130	75	76
LED	0.5	121	96	113
LED	0.9	33	78	76
Incandescent	1.0	306	316	418
FTL	0.96	251	135	115

10.Load Curve Analysis

According to the National Survey on Household Lighting Report composition of light types in peak time and the total peak demand from each consumer categories can be summarized as follows.

Table 10.1 Percentage of light consumption by different bulbs at peak time in Sri Lanka in 2011

Electricity Unit	Peak Lighting Load-Incandescent	Peak Lighting Load-CFL	Peak Lighting Load-FTL
	%	%	%
0-90	42	41	17
90-180	40	46	15
180<	37	45	18
Category	Peak Lighting Load		
	(MW)		
0-90	370		
90-180	90		
180<	21		
Total	481		

Source :(National survey on house hold lighting,Sri Lanka – Implementation of EE Policy Initiatives)

The following figure shows the total lighting load profile which is equal to the summation of above three figures from each consumer categories.

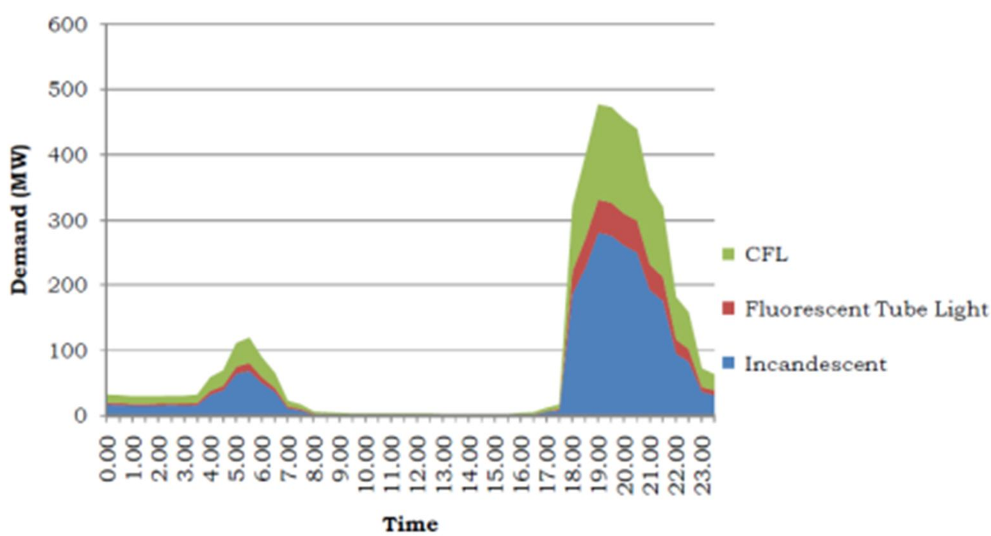


Figure 10.1: Total lighting load profile

The following table shows the energy consumed by each light type at peak demand period in MWh. The energy is obtained by calculating the area under the peak demand curve shown above in figure. The area under the curve is calculated using the Auto CAD as in below figures.

Area under the total curve including CFL, FTL and Incandesecnt bulb energy consumption

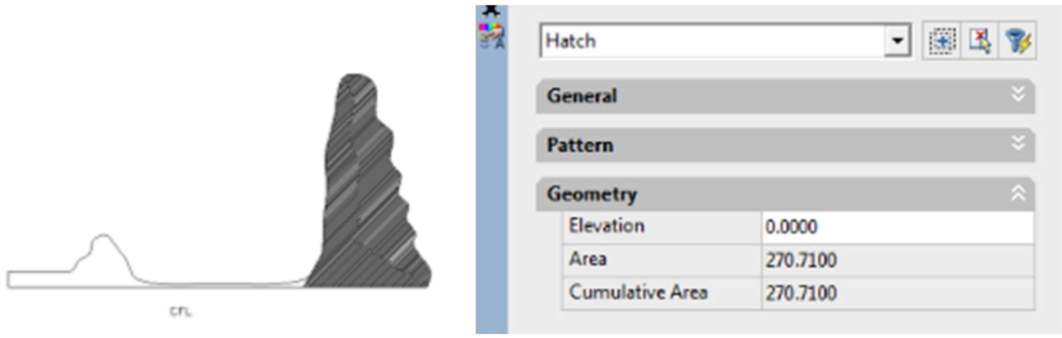


Figure 10.2 Energy consumption of CFL,FTL and Incandesent bulbs as curve area

Table 10.2 Energy consumption of CFL,FTL and Incandescent at peak time

Peak Lighting Load	Energy Consumption MWh
Incandescent	134
CFL	88
FTL	48
Total	270

This study has shown that following bulbs gives the same light levels in the working plane.

Table 10.3 Average wattage &Power factors of CFL,FTL ,Incandescent and LED

Light Type	Wattage (W)	Power Factor
Incandescent	78	1
CFL	23	0.55
FTL (with electronic blaster)	28	0.96
LED	15	0.5

Assuming all the incandescent, CFL and FTL bulbs will replaced by LED, we can reduce the peak lighting load nearly 1/3 of the present value. That can be shown as in the following table.

Table 10.4 Equivalent MWh to replace by LED

Bulb Type	Peak Lighting Load in MWh	Equivalent MWh if replaced by LED
Incandescent	134	26
CFL	88	48
FTL	48	26
Total	270	100

The equivalent peak light load if all other bulb types are replaced by LED is 100 MWh, i.e it has come down from 270 MWh to 100 MWh. The Saving 170 MWh.

10.2 Possibility of replacing high cost thermal generation by using LED bulbs

The figure below shows the shape of the load curve in Sri Lanka. The daily maximum demand (2163MW in 2011) occurs between 06.30pm to 10.00pm. The maximum demand is more than twice the lowest demand (950MW in 2011) which occurs between 00.30am to 04.30am. Further the maximum demand shows more than 25% growth when compared to the day peak demand (around 1500MW in 2011) which occurs between 11.00am to 05.00pm.

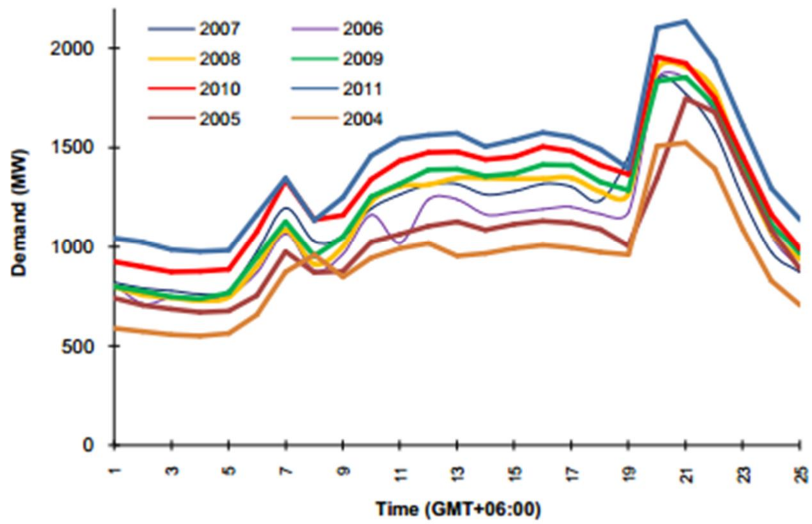


Figure 10.3 Sri Lanka-Load curve shape

(Source: Long Term Generation Plan 2013~2032, published by Ceylon Electricity Board)

10.3 Cost Analysis

The AES Kelanitissa thermal power plant is the most costly generation source. The generation cost (2011) is Rs.49.54 cost per kWh. The expected reduction in energy consumption is 170MWh. Then the power of the utility can be reduced with an equal amount of energy, thereby reducing the most costly thermal power generation such as AES Kelanitissa. The expected daily cost saving is Rs 8,421,800 and the expected annual cost saving is Rs. 3,073,957,000 .

11.0 Discussion

According to the above energy analysis done for selected sample of LED, CFL and Incandescent bulbs, the energy equivalent for each type at Manufacturing, Use, Generation & Distribution phases has been separately studied. Below is the ratio of energy at each stage for all 3 types summarized as to understand which portion of the energy at each step is higher or lower than the other type and thereby compared with each other. By evaluating energy at each of below steps, the total life cycle energy for each lamp category could be assumed.

Energy consumption ratio at manufacturing stage

LED : CFL : Conventional = 8 : 4.27 : 1

It requires 700% more energy to manufacture a LED lamp than an incandescent and 375% more energy than to manufacture a CFL . To produce a CFL, 327% more energy is needed than to manufacture an incandescent.

Energy Consumption ratio at Use stage

LED : CFL : Conventional = 1 : 1.32 : 2.74

During the use phase LED saves 32% energy than CFL and 174% energy than incandescent. This is a considerable saving by LED at use phase.

Energy Loss ratio at Generation and Transmission

LED : CFL : Conventional = 1 : 2.3 : 8.6

When generation & transmission losses are considered for LED compared to CFL and Conventional bulbs, it shows 130% excess losses by CFL and 760% excess losses by conventional bulbs.

According to the manufacturing phase, LED needs rather much energy compared to the other 2 types because the electronics, materials, technologies used for LED manufacturing are done by more advanced methods. They are needed more energy to produce these raw inputs has increased total energy than CFL and conventional types. So this has become the decisive fact that LED lamp expensive than 2 other types. But with the advanced energy efficient methods and new findings this may change by the time of 2017~2018 and will reduce energy required to manufacture LED by 50% ~60%. When the life time of incandescent is compared to LED is less than 1/8 and this means that if life time is considered LED does not seems worse than the 2 other type seven if it requires high manufacturing energy. When consider “Use phase”, LED is the best energy saver and CFL consumes 1.32 times higher energy than LED and conventional bulbs are worst, 2.74 times consumes than LED.

At the generation and distribution stages the losses were calculated by PSSE and there by the loss ratio was calculated, i.e if load was created by LED, then the reactive power generated was calculated and there by the apparent power calculations were done and same was done for CFL and Conventional bulbs considering separate loads.

According to the above loss ratio LED has shown less losses compared to other types. This means that if the buildings were lighted with LED then the generation and transmission losses could be minimized and save energy than other two types.

This gives a total picture of what luminaire type should be used to the buildings considering “Use” phase, gen & trans. phases to minimize energy wastage.

12.0 Conclusions

- LED lighting has the potential to save energy and improve lighting quality and performance beyond that of many conventional lighting technologies.
- This analysis shows that 53% of LED with P.F 0.4 in the market are better than CFL bulbs with P.F < 0.8, available in the same
- LED lighting reduces the loading of power system equipment’s. They can reduce transmission and distribution losses and can reduce required installed capacity. Increase durability of the electrical machines
- There are some LED types which are not better than the CFL bulbs when compare the apparent power and also some incandescent also found which are better than CFL or LED to make same lighting level on a working plane. But this is only the case for a few types and when it comes to average, min, max and median condition comparisons, LED is leading all others.
- The penetration of LED bulbs in Sri Lankan market is yet negligible, but shows a high potential.
- If CFL, incandescent and FTL can be replaced with LED lamps, the peak lighting load in Sri Lanka can be reduced more than 50%, can saving millions Rs. per day. That saving can be reinvested to reduce incandescent bulbs in the usage by giving subsidiary to buy LEDs to customer’s specially in the 0-90 kWh category.

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[19]Effects of Compact Fluorescence Light (Cfl) Bulbs on Power Quality*Charles Ndungu1* John Nderu1 Livingstone Ngoo1,2School of Engineering, Jomo Kenyatta University of Agriculture and Technology, PO box 62000, Nairobi,Kenya& School of Engineering, Multimedia University College of Kenya, PO box 62000, Nairobi, Kenya*

Annex I

Recommended illuminance for Different Applications

Area/Activity	*LUX*
Industrial assembly/Inspection	
Simple	*300*
Difficult(garment factory ect)	*1500*
Exact(lapidary-cutting shaping of jewellery	*7500*
Machine Shops	
Rough machining	*300*
Automatic machine,grinding,polishing,fine bench work	*750*
	3000
Material Handling	
Wrapping,packing,labeling	*300*
Stock taling,classifying	*300*
Loading , unloading	*150*
Reading printed matter	
6-point typeface	*750*
8 t0 10-point typeface	*300*
newsprint	*300*
telephone directory	*750*
Office space	
minor clerical work	*300 ~ 500*
computer/typing	*500 ~1000*
drawing/sketching	*1000 ~ 2000*

Annex II

General Comparison of LED, CFL and Incandescent

Energy Efficiency & Energy Costs	**LED**	**Incandescent**	**CFL**
Life Span (average)	50,000 hours	1,200 hours	8,000 hours
Watts of electricity used (equivalent to 60 watt bulb). LEDs use less power (watts) per unit of light generated (lumens). LEDs help reduce greenhouse gas emissions from power plants and lower electric bills	6 - 8 watts	60 watts	13-15 watts
Kilo-watts of Electricity used (30 Incandescent Bulbs per year equivalent)	329 KWh/yr.	3285 KWh/yr.	767 KWh/yr.
Annual Operating Cost (30 Incandescent Bulbs per year equivalent)	$32.85/year	$328.59/year	$76.65/year
Light Output			
Lumens	Watts	Watts	Watts
450	4-5	40	9-13
800	6-8	60	13-15
1,100	9-13	75	18-25
1,600	16-20	100	23-30
2,600	25-28	150	30-55
Environmental Impact			
Contains the TOXIC Mercury	no	No	Yes - Mercury is very toxic to your health and the environment
RoHS Compliant	Yes	Yes	No - contains 1mg-5mg of Mercury and is a major

			risk to the environment
Carbon Dioxide Emissions (30 bulbs per year) Lower energy consumption decreases: CO2 emissions, sulfur oxide, and high-level nuclear waste.	451 pounds/year	4500 pounds/year	1051 pounds/year
Important Facts			
Sensitivity to low temperatures	None	Some	Yes - may not work under negative 10 degrees Fahrenheit or over 120 degrees Fahrenheit
Sensitive to humidity	No	Some	Yes
On/off Cycling Switching a CFL on/off quickly, in a closet for instance, may decrease the lifespan of the bulb.	No Effect	Some	Yes - can reduce lifespan drastically
Turns on instantly	Yes	Yes	No - takes time to warm up
Durability	Very Durable - LEDs can handle jarring and bumping	Not Very Durable - glass or filament can break easily	Not Very Durable - glass can break easily
Heat Emitted	3.4 btu's/hour	85 btu's/hour	30 btu's/hour
Failure Modes	Not typical	Some	Yes - may catch on fire, smoke, or omit an odor

Annex III

Summary of apperent power value for LED Lamps

Details of Bulb	Apparent Power(Kvar)			
	PF=0.4	PF=0.5	PF=0.8	PF=0.9
PHILIPS BCS640 W21L125 1xLED48/840 LIN-PC	19.04	15.23	9.51	8.46
PHILIPS BCS680 W17L122 1xLED48/840 LIN-PC	20.25	16.20	10.13	9.00
OMS TORNADO PC LED 27W 2700lm 4000K 80Ra	20.66	16.52	10.33	9.18
OMS TORNADO PC LED 27W 2700lm 4000K 80Ra	20.66	16.52	10.33	9.18
D57-W1-LWMB+LE D57 FLAT LED MEDIUM BEAM	23.40	18.72	11.70	10.40
TUBUS CYGNUS LED 10W 700lm 2700K 90Ra	26.10	20.88	13.05	11.60
PHILIPS BCS680 W7L122 1xLED24/830 MLO-PC	26.73	21.38	13.37	11.88
OMS UX-PLASTIC PLAST 2 LED OPAL 13W	28.67	22.93	14.33	12.74
ALTO 11300 A60 830 O3 Down light	46.80	37.44	23.40	20.80
BEGA 6826 LED 16W	48.96	39.17	24.48	21.76
DO5/LWNA BIT LED ACID ECHED GLASS	49.14	39.31	24.57	21.84
ALTO 11301 D30 830 O3 Directional luminaire	51.30	41.04	25.65	22.80
PHILIPS BCS401 9xLED-HB-2700 30	54.68	43.74	27.34	24.30
TAGORA 80 LED (GU10) 230-240V 7W 25^0 3100K GREY/WHITE	70.88	56.70	35.44	31.50
JAVA 158 SQUARE 1XLED (GU10) 230-240V	70.88	56.70	35.44	31.50

Summery of apperent power value for CFL Lamps

Details of Bulb	Apparent Power(KVA)			
	PF=0.55	PF=0.6	PF=0.8	PF=0.9
OMS UX-PLASTIC PLAST 3 OPAL 1X38W	31.42	28.8	26.58	19.2
FILIP 4 E27 23W (1.35.04.A.01)	31.42	28.8	26.58	19.2
BEGA 6796 1 TC-TELI(42W)	31.61	28.98	26.75	19.32
UX-TUBUS 292 POLISHED 1x18W(CFL Lamp)	32.27	29.58	27.3	19.72
BEGA 6797 2 TC-TELI(32W)	34.36	31.5	29.08	21
OMS UX-PLASTIC PLAST 4 PRISMA 1X38W	36.23	33.21	30.66	22.14
Artemide L590300 LUCERI 150 TC-DEL 1x13W NON DIMMABLE	37.31	34.2	31.57	22.8
VULCANIA RECESSED Ø375MM FIX TC-DEL 2X26W+EMERGENCY	37.8	34.65	31.98	23.1
Artemide L596300 LUCERI 220 WW TC-DEL 2x13W NON DIMMABLE	38.29	35.1	32.4	23.4
BEGA 6786 1 TC-TELI(26W)	40.32	36.96	34.12	24.64

MINI SIMPLE 01 15W E27	41.73	38.25	35.31	25.5
SIMPLE MOB 01 15W E27	48.44	44.4	40.98	29.6
BEGA 6907 1 TC-TEL 13W	49.09	45	41.54	30
SIMPLE S O4 15W	57.27	52.5	48.46	35
D60R/F32E+D60R/RM DUPLO COMPACT FLUORESCENT	72.33	66.3	61.2	44.2

Summery of apperent power value for Conventional Lamps

Type	Details of Bulb	Active power (KW)	Apparent Power(KVA)
Florescent	DOUBLE LOUVRE 14X18W (160.2055)	16.20	20.25
FTL	Artemide M105101 INFINI T16 2X28W	16.47	20.59
Metal Halied	SILVA GLASS 2 METAL HALIED G12 35W	18.14	22.68
FTL	BEGA 4667 2 T26 36W	24.84	31.05
FTL	Artemide M170300 JAVA LINEAR SYSTEM DIFFUSER	43.74	54.68
Incandescent	Artemide T053110 ILLO (incandescent lamp)	51.30	51.30
Incandescent	BEGA 6830 1 QT14 33W	71.28	71.28
Incandescent	Artemide A048120 TETI	86.40	86.40
Incandescent	LOGICO SOFFITTO MICRO SINGOLA	91.80	91.80
Incandescent	OMS UX-DOWN LIGHT 241 FACET 1X60W	99.79	99.79
Incandescent	D14/E27 TOP INCANDESCENT	130.68	130.68
Halogen	SILVA 8 E27 (1.33.08.A.01)	151.20	189.00

Annex IV

Apparent power calculation

Apparent power (kVA)=sqt {(Reactive power^2(kVAr)+Active power^2(kW)}

Energy Ratio

Energy @ Manufacturing Stage

LED : CFL : CONVEN						
	343	183	42.9			LED:CFL:CONVEN
	8.00	4.27	1			8 : 4.27 : 1

Energy @ use phase

LED	**Apperent Power(KVA)**					
	PF=0.4	**PF=0.5**	**PF=0.8**	**PF=0.9**		**Average KVA of all PFs**
Average	38.54	30.83	19.27	17.13		26.44

CFL	**Apperent Power(KVA)**					
	PF=0.55	**PF=0.6**	**PF=0.8**	**PF=0.9**		
Average	41.33	37.88	34.97	25.25		34.86

Conventional	**KW**	**KVA**				
Average	**66.82**	**72.46**				72.46

conventional bulbs separated

others	**Kw**	**KVA**
Average	**45.10**	**56.37**

incandescent	**Kw**	**KVA**
Average	**88.54**	**88.54**

Energy consumption at use phase for LED,CFL,CONVEN

LED	CFL	CONVEN
26.44	34.86	72.46
1	1.32	2.74
	24%	**64%**

saving if LED is used = (CFL-LED)/CFL *100%

use phase energy ratio

LED:CFL:CONVEN
1 : 1.32 : 2.74

Losses at generation and transmission phases

Lamp Type	PF	Losses			Average
		P(MW)	Q (kVAr)	A(kVA)	
CFL	0.55	9.5	119.9	120.28	
CFL	0.9	2.3	32.7	32.78	76.53
LED	0.5	4.7	50.7	50.92	
LED	0.9	1.7	16.8	16.89	33.90
Incandescent	1	42.3	465.2	467.12	
FTL	0.96	8.4	112.8	113.11	290.12

average gen. & trans. losses
LED : CFL : Conventional **1 : 2.26 : 8.56**

LED Equivalent load calculation

Peak Lighting Load-Incand	(Peak Lighting Load-Incand)* average incand. wattage)	
Eqi. To LED (MW)	Average Incand. wattage	
	(155.4)*15	
	78	

Cost analysis

	Power Plant in merit order		
1	AESKelanitissa	163	MW
	units generated in peak time	652	MWh
	AESKelanitissa unit price	49.54	Rs.
2	AESKelanitissa	60	MW
	units generated in peak time	240000	
	AESKelanitissa unit price	25	Rs.
	saving due to LEDs daily	8,421,800.00	
	saving due to LEDs annually	3,073,957,000.00	

Annex V

PSSE Simulation Results

The PSS®E simulation for above mentioned light bulb categories gives the power flow through the transmission lines, transmission line over loadings, generation and transmission losses. The colored boxes shows the percentages of over loadings.

V.I Simulation of Compact Florescent Lamp with P.F=0.55

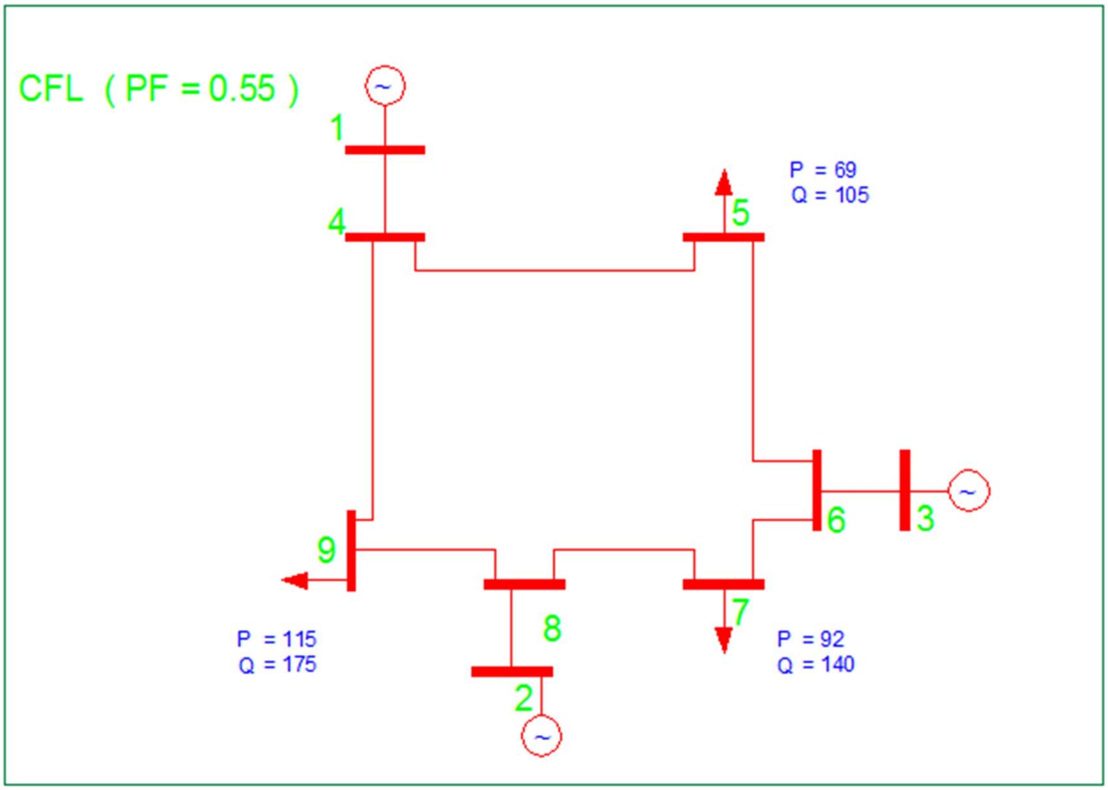

Figure V.I Schematic diagram of IEEE 9 bus bar system for CFL lamp with P.F=0.55

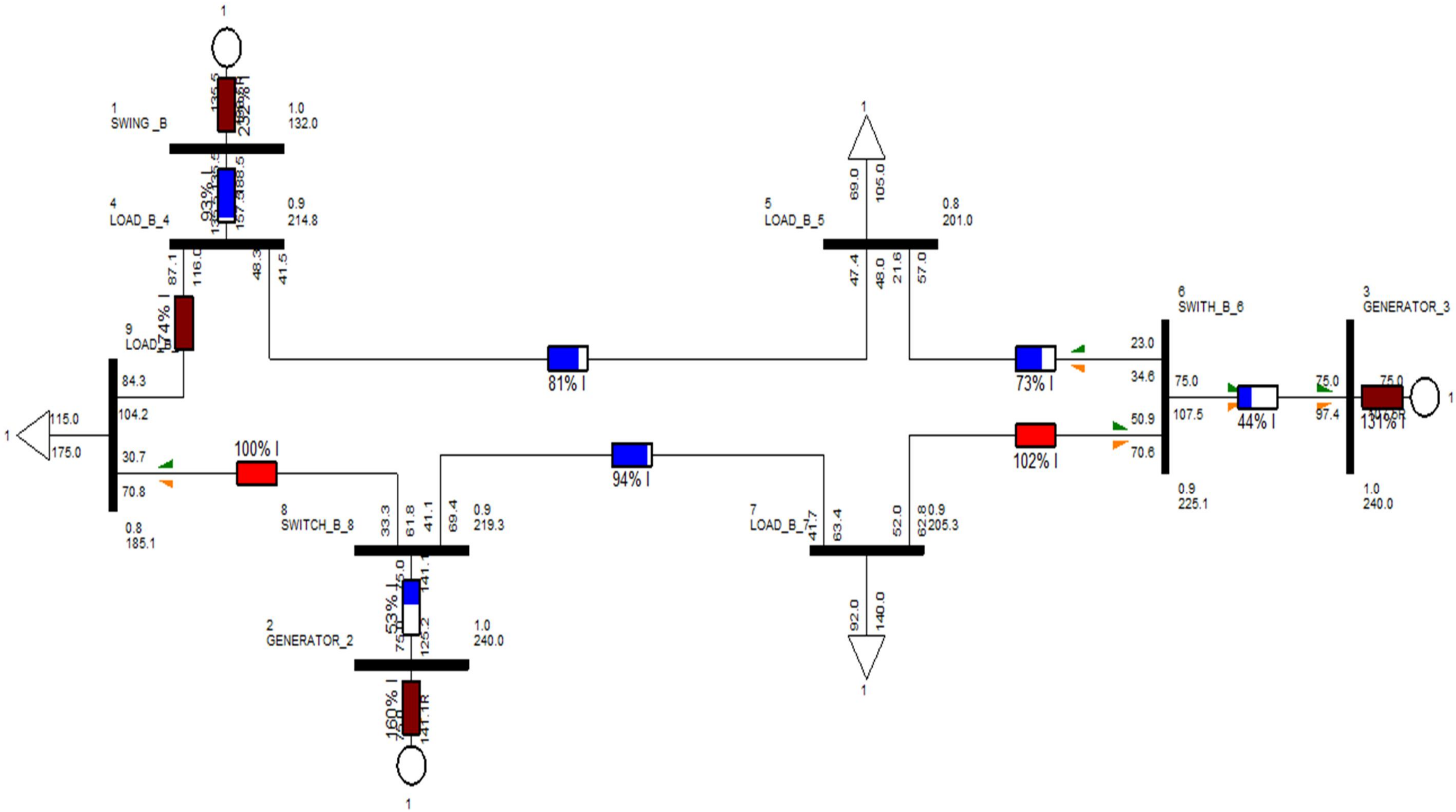

Figure V.II Power flow diagram of CFL Lamp with P.F=0.55

Results gained from PSSE Simulation for CFL with P.F=0.55

Report on Losses

IEEE 9 BB SYSTEM

AREA TOTALS IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	FROM IND GENERATN (AT AREA BUSES)	TO IND MOTORS (AT AREA BUSES)	TO LOAD (AT AREA BUSES)	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES (NET INTERCHANGE)	TO TIES + LOADS (NET INTERCHANGE)	DESIRED NET INT
1	285.5	0.0	0.0	276.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0	0.0
	437.0	0.0	0.0	420.0	0.0	0.0	0.0	102.8	119.9	0.0	0.0	
COLUMN	285.5	0.0	0.0	276.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0	0.0
TOTALS	437.0	0.0	0.0	420.0	0.0	0.0	0.0	102.8	119.9	0.0	0.0	

Report on Loadings

IEEE 9 BB SYSTEM

SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

FROM BUS#	FROM NAME	FROM BASKV	FROM AREA	TO BUS#	TO NAME	TO BASKV	TO AREA	CKT	LOADING	SET A RATING	SET A PERCENT	SET B RATING	SET B PERCENT	SET C RATING	SET C PERCENT
4	LOAD_B_4	240.00	1	9	LOAD_B_9	240.00*	1	1	173.7	100.0	173.7	100.0	173.7	100.0	173.7
6	SWITH_B_6	240.00	1	7	LOAD_B_7	240.00*	1	1	101.8	100.0	101.8	100.0	101.8	100.0	101.8
8	SWITCH_B_8	240.00	1	9	LOAD_B_9	240.00*	1	1	100.1	100.0	100.1	100.0	100.1	100.0	100.1

V.II Simulation of Compact Florescent Lamp with P.F=0.9

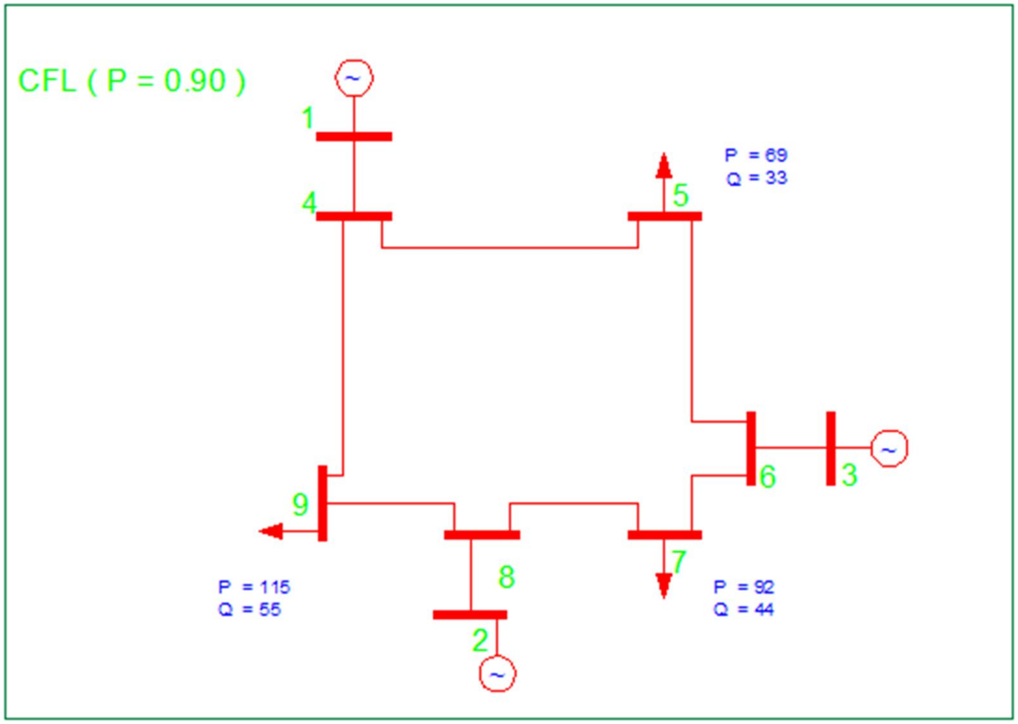

Figure V.III Schematic diagram of IEEE 9 bus bar system for CFL lamp with P.F=0.9

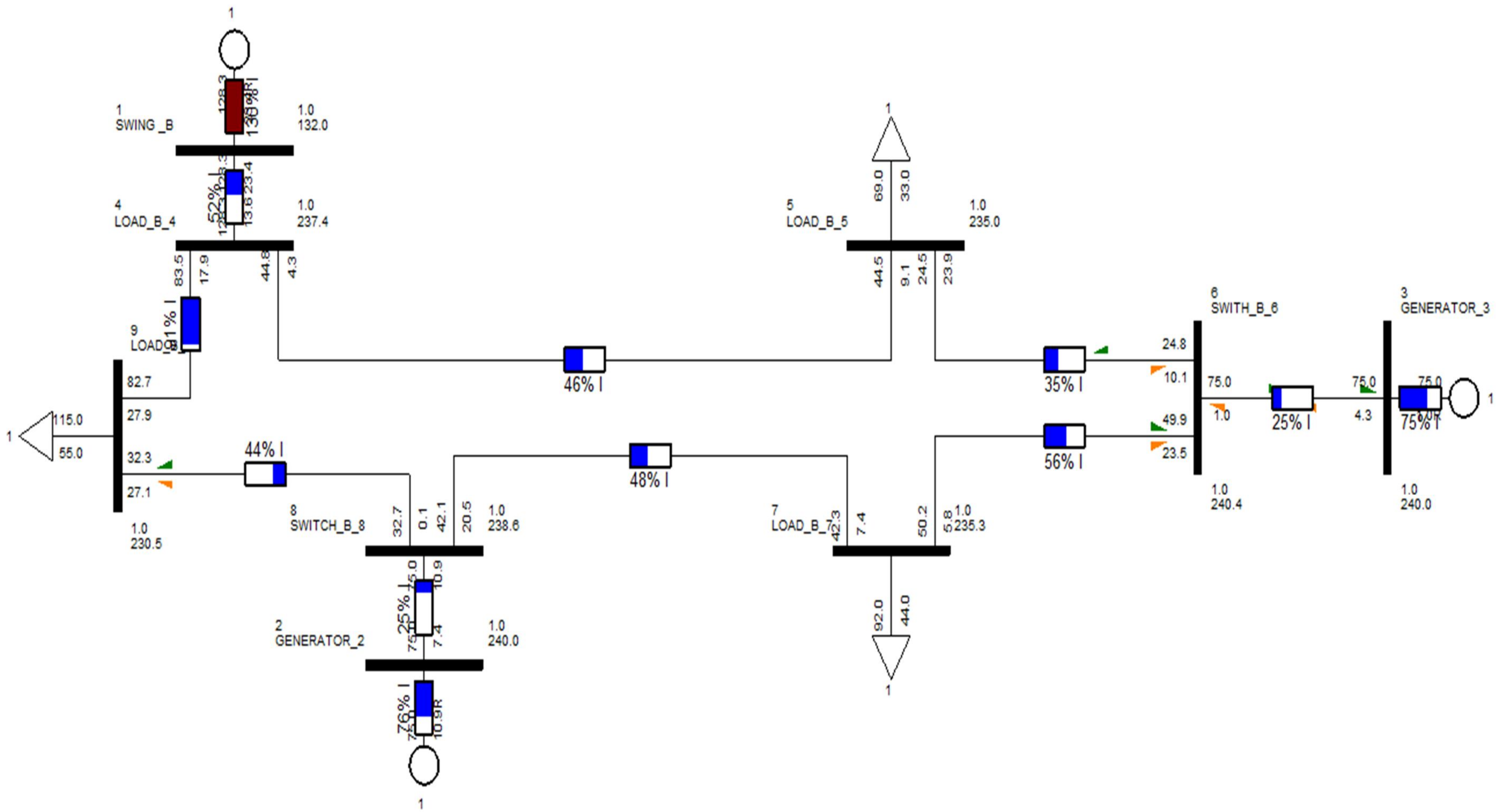

Figure V.V Power flow diagram of CFL Lamp with P.F=0.9

V.III Results Gained from PSSE Simulation for CFL with P.F=0.9

Report on Losses

IEEE 9 BB SYSTEM

AREA TOTALS
IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	AT AREA BUSES: FROM IND GENERATN	AT AREA BUSES: TO IND MOTORS	AT AREA BUSES: TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	NET INTERCHANGE: TO TIE LINES	NET INTERCHANGE: TO TIES + LOADS	DESIRED NET INT
1	278.3	0.0	0.0	276.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
	33.3	0.0	0.0	132.0	0.0	0.0	0.0	131.5	32.7	0.0	0.0	
COLUMN	278.3	0.0	0.0	276.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
TOTALS	33.3	0.0	0.0	132.0	0.0	0.0	0.0	131.5	32.7	0.0	0.0	

Report on Loadings

IEEE 9 BB SYSTEM

```
 SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
 LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

 X--------- FROM BUS ----------X X---------- TO BUS -----------X               RATING SET A    RATING SET B    RATING SET C
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT  RATING PERCENT  RATING PERCENT

                                  * NONE *
```

V.IV Simulation of LED Lamp with P.F=0.5

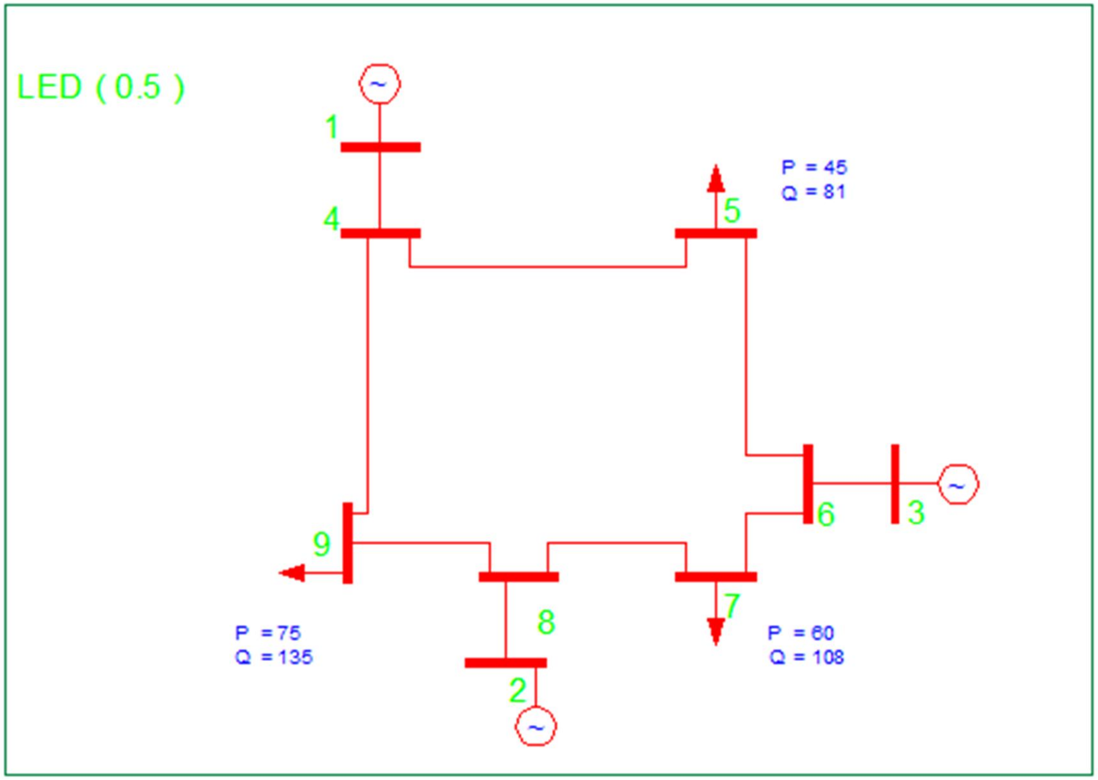

Figure V.VI Schematic diagram of IEEE 9 bus bar system for LED lamp with P.F=0.5

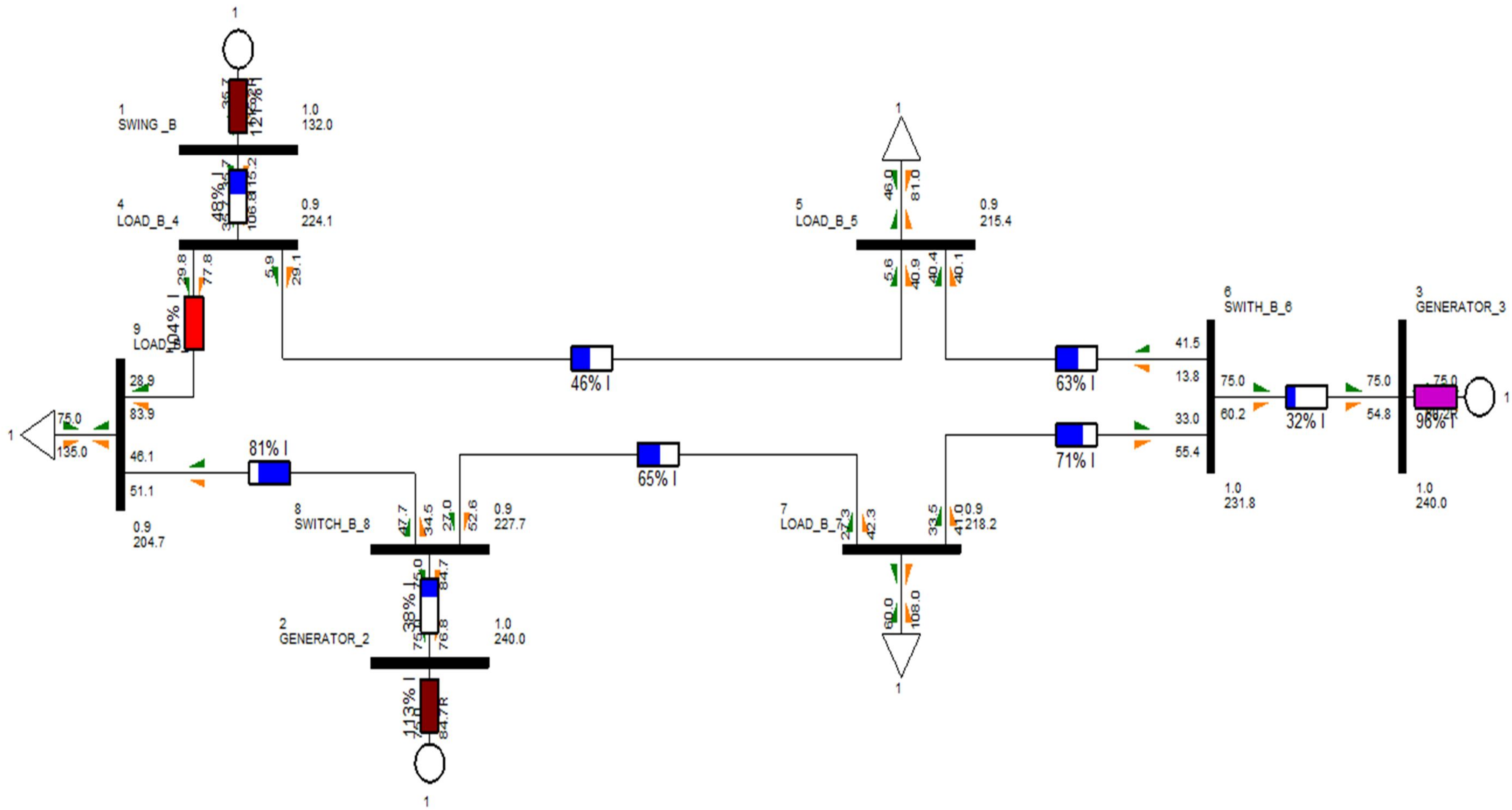

Fig V.VII Power flow diagram of LED Lamp with P.F=0.5

V.V Results Gained from PSSE Simulation for LED with P.F=0.5

Report on Losses

```
IEEE 9 BB SYSTEM                                                   AREA TOTALS
                                                                     IN MW/MVAR
                 FROM ------AT AREA BUSES-------             TO                                             -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

    1           185.7      0.0      0.0     181.0      0.0      0.0      0.0      0.0      4.7      0.0      0.0      0.0
                260.1      0.0      0.0     324.0      0.0      0.0      0.0    114.6     50.7      0.0      0.0

 COLUMN         185.7      0.0      0.0     181.0      0.0      0.0      0.0      0.0      4.7      0.0      0.0      0.0
 TOTALS         260.1      0.0      0.0     324.0      0.0      0.0      0.0    114.6     50.7      0.0      0.0
```

Report on Loadings

```
IEEE 9 BB SYSTEM


 SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
 LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

 X--------- FROM BUS ----------X X---------- TO BUS -----------X                RATING SET A    RATING SET B    RATING SET C
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT  RATING PERCENT  RATING PERCENT
      4 LOAD_B_4    240.00     1      9 LOAD_B_9    240.00*    1  1    104.0   100.0   104.0   100.0   104.0   100.0   104.0
```

V.VI Simulation of LED Lamp with P.F=0.9

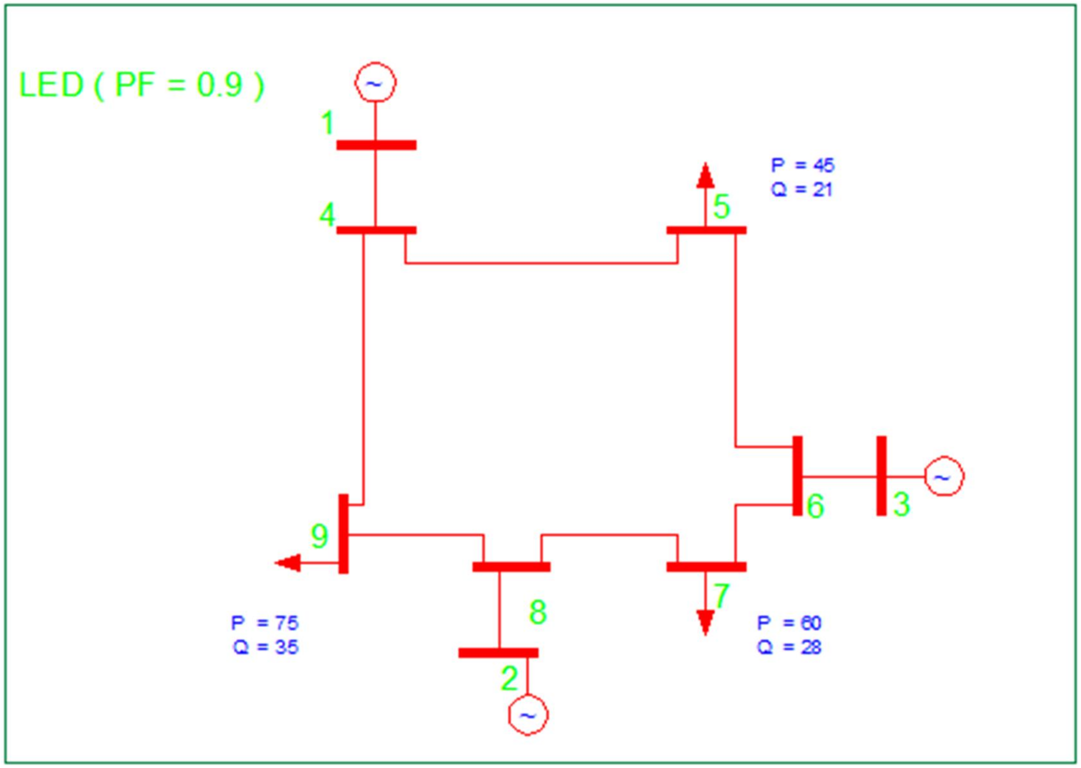

Figure V.VIII Schematic diagram of IEEE 9 bus bar system for LED lamp with P.F=0.9

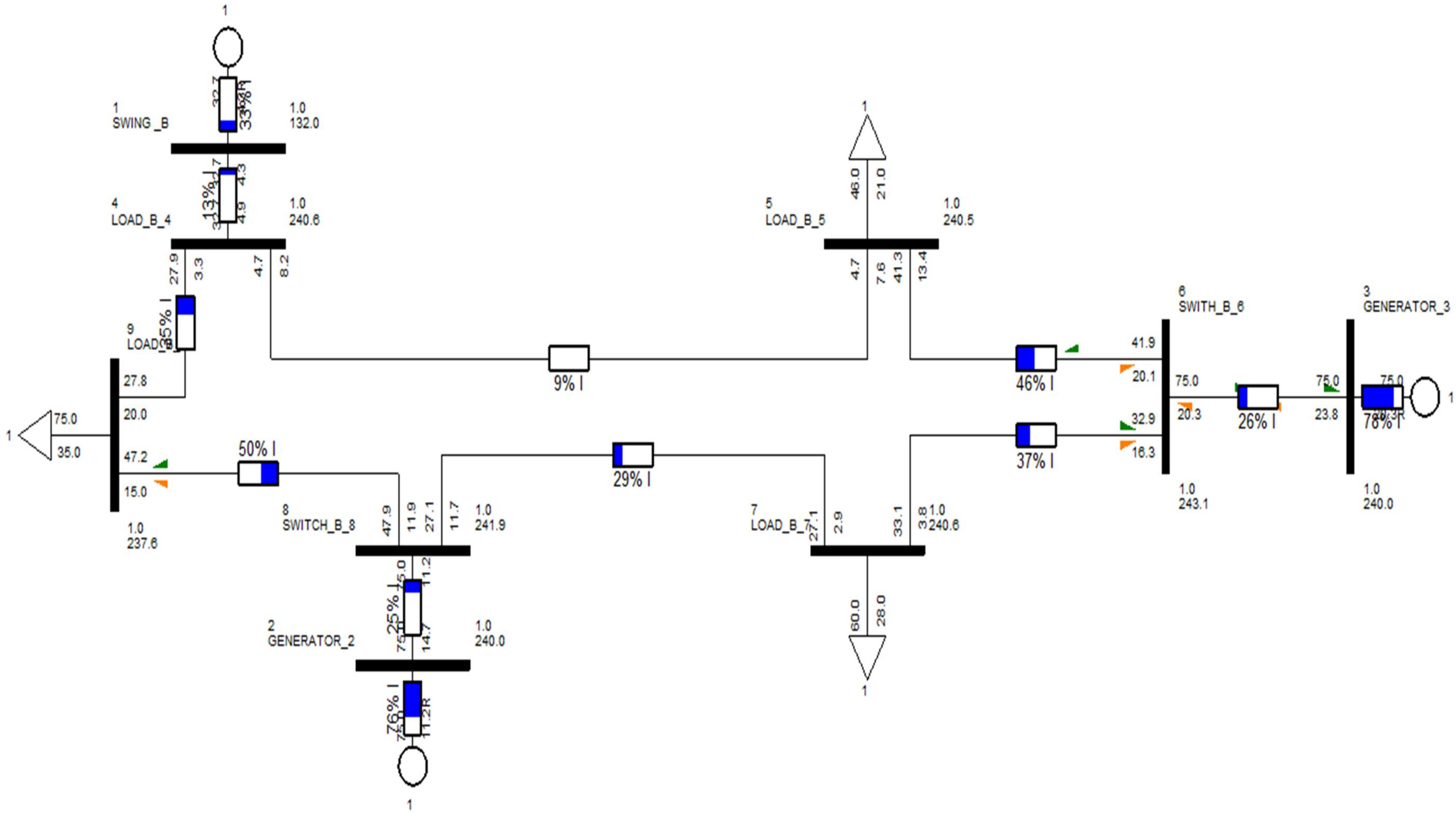

Fig V.IX Power flow diagram of LED Lamp with P.F=0.9

V.VII Results Gained from PSSE Simulation for LED with P.F=0.9

Report on Losses

IEEE 9 BB SYSTEM

AREA TOTALS IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	AT AREA BUSES: FROM IND GENERATN	AT AREA BUSES: TO IND MOTORS	AT AREA BUSES: TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	NET INTERCHANGE: TO TIE LINES	NET INTERCHANGE: TO TIES + LOADS	DESIRED NET INT
1	182.7	0.0	0.0	181.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0
	-35.7	0.0	0.0	84.0	0.0	0.0	0.0	136.5	16.8	0.0	0.0	
COLUMN	182.7	0.0	0.0	181.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0
TOTALS	-35.7	0.0	0.0	84.0	0.0	0.0	0.0	136.5	16.8	0.0	0.0	

Report on Loadings

IEEE 9 BB SYSTEM

SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

FROM BUS: BUS#	FROM BUS: X-- NAME --X	FROM BUS: BASKV	FROM BUS: AREA	TO BUS: BUS#	TO BUS: X-- NAME --X	TO BUS: BASKV	TO BUS: AREA	CKT	LOADING	RATING SET A: RATING	RATING SET A: PERCENT	RATING SET B: RATING	RATING SET B: PERCENT	RATING SET C: RATING	RATING SET C: PERCENT

* NONE *

V.VIII Simulation of Incandescent Lamp

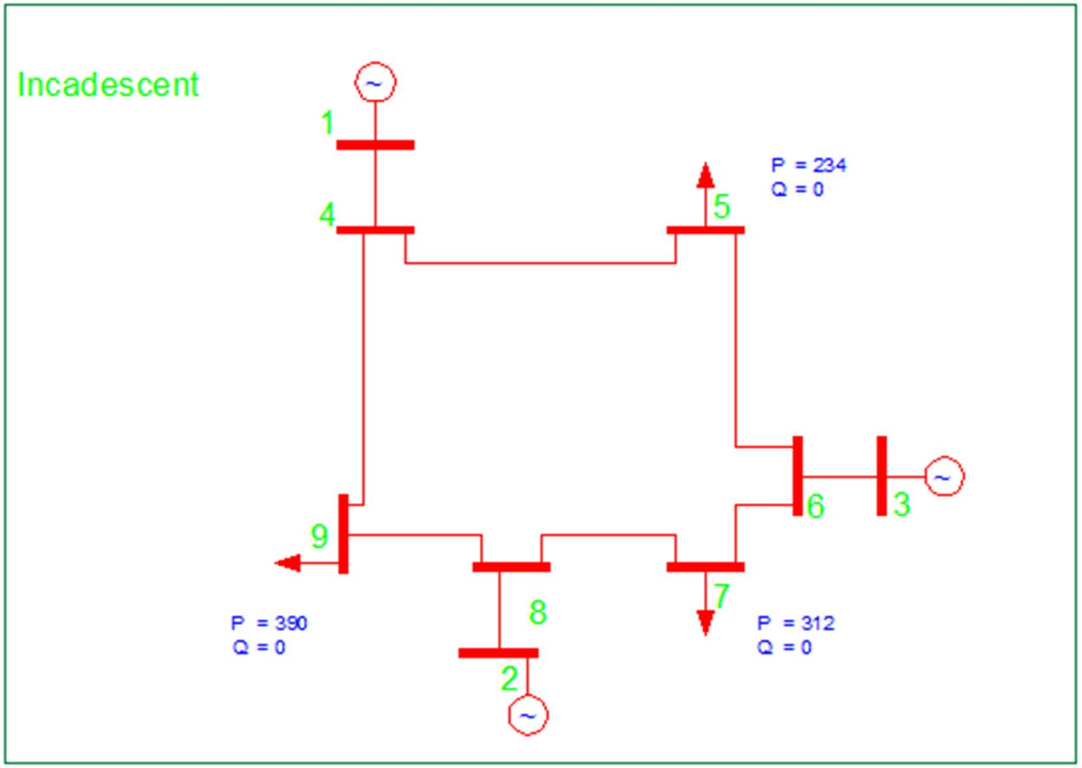

Figure V.X Schematic diagram of IEEE 9 bus bar system for incandescent

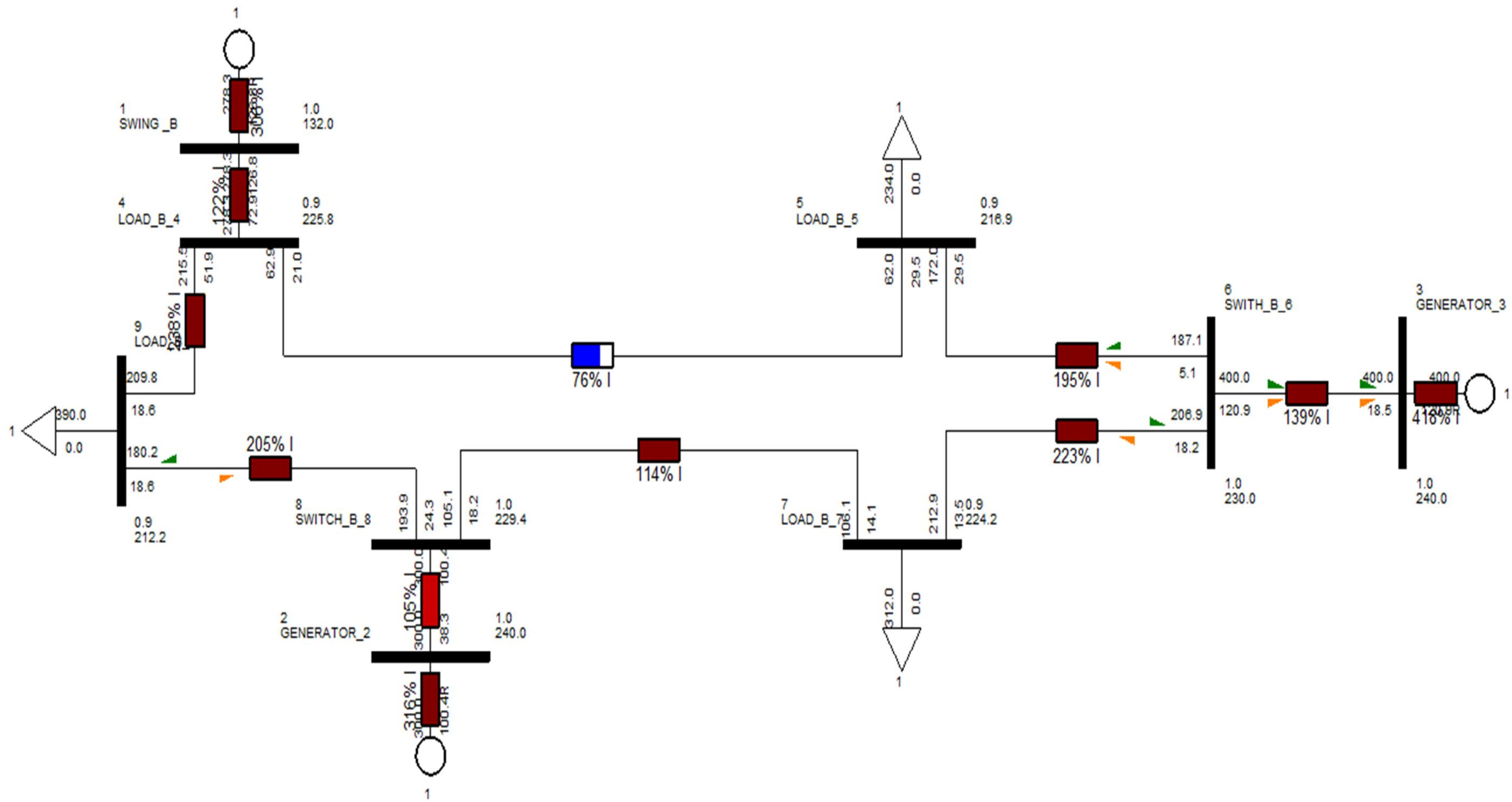

Figure X.XI Power flow diagram of incandescent Lamp

V.IX Results Gained from PSSE Simulation for incandescent lamp

Report on Losses

IEEE 9 BB SYSTEM

AREA TOTALS IN MW/MVAR

X-- AREA --X	FROM GENE- RATION	AT AREA BUSES: FROM IND GENERATN	AT AREA BUSES: TO IND MOTORS	AT AREA BUSES: TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	NET INTERCHANGE: TO TIE LINES	NET INTERCHANGE: TO TIES + LOADS	DESIRED NET INT
1	978.3	0.0	0.0	936.0	0.0	0.0	0.0	0.0	42.3	0.0	0.0	0.0
	348.0	0.0	0.0	0.0	0.0	0.0	0.0	117.1	465.2	0.0	0.0	
COLUMN	978.3	0.0	0.0	936.0	0.0	0.0	0.0	0.0	42.3	0.0	0.0	0.0
TOTALS	348.0	0.0	0.0	0.0	0.0	0.0	0.0	117.1	465.2	0.0	0.0	

Report on Loadings

IEEE 9 BB SYSTEM

SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

FROM BUS: BUS#	FROM BUS: X-- NAME --X	FROM BUS: BASKV	FROM BUS: AREA	TO BUS: BUS#	TO BUS: X-- NAME --X	TO BUS: BASKV	TO BUS: AREA	CKT	LOADING	RATING SET A: RATING	RATING SET A: PERCENT	RATING SET B: RATING	RATING SET B: PERCENT	RATING SET C: RATING	RATING SET C: PERCENT
1	SWING _B	132.00*	1	4	LOAD_B_4	240.00	1	1	305.8	250.0	122.3	250.0	122.3	250.0	122.3
2	GENERATOR_2	240.00	1	8	SWITCH_B_8	240.00*	1	1	316.4	300.0	105.5	300.0	105.5	300.0	105.5
3	GENERATOR_3	240.00	1	6	SWITH_B_6	240.00*	1	1	417.9	300.0	139.3	300.0	139.3	300.0	139.3
4	LOAD_B_4	240.00	1	9	LOAD_B_9	240.00*	1	1	238.2	100.0	238.2	100.0	238.2	100.0	238.2
5	LOAD_B_5	240.00	1	6	SWITH_B_6	240.00*	1	1	195.3	100.0	195.3	100.0	195.3	100.0	195.3
6	SWITH_B_6	240.00*	1	7	LOAD_B_7	240.00	1	1	222.6	100.0	222.6	100.0	222.6	100.0	222.6
7	LOAD_B_7	240.00*	1	8	SWITCH_B_8	240.00	1	1	114.1	100.0	114.1	100.0	114.1	100.0	114.1
8	SWITCH_B_8	240.00	1	9	LOAD_B_9	240.00*	1	1	204.9	100.0	204.9	100.0	204.9	100.0	204.9

V.X Simulation of Florescent Tube Light (T16) with P.F=0.96 (Electronics Balastar)

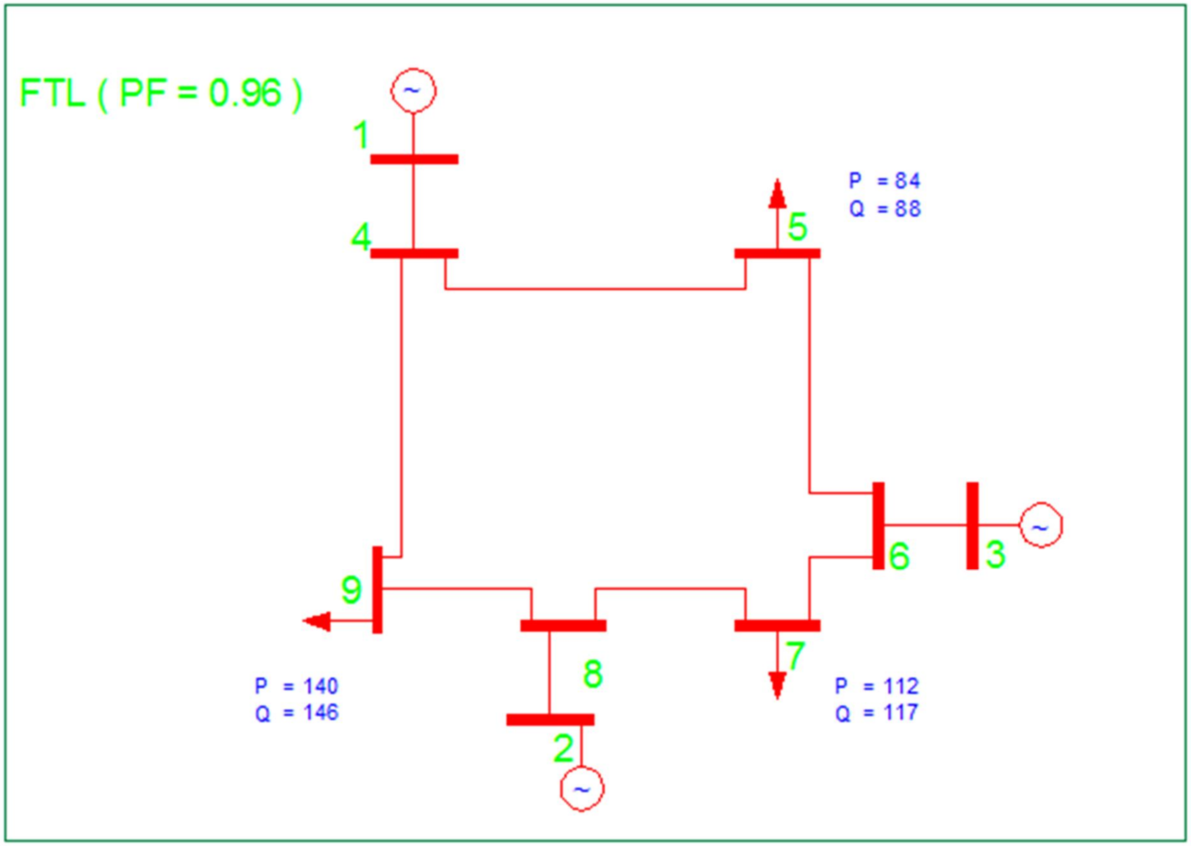

Figure X.XII Schematic diagram of IEEE 9 bus bar system for FTL lamp with P.F=0.96

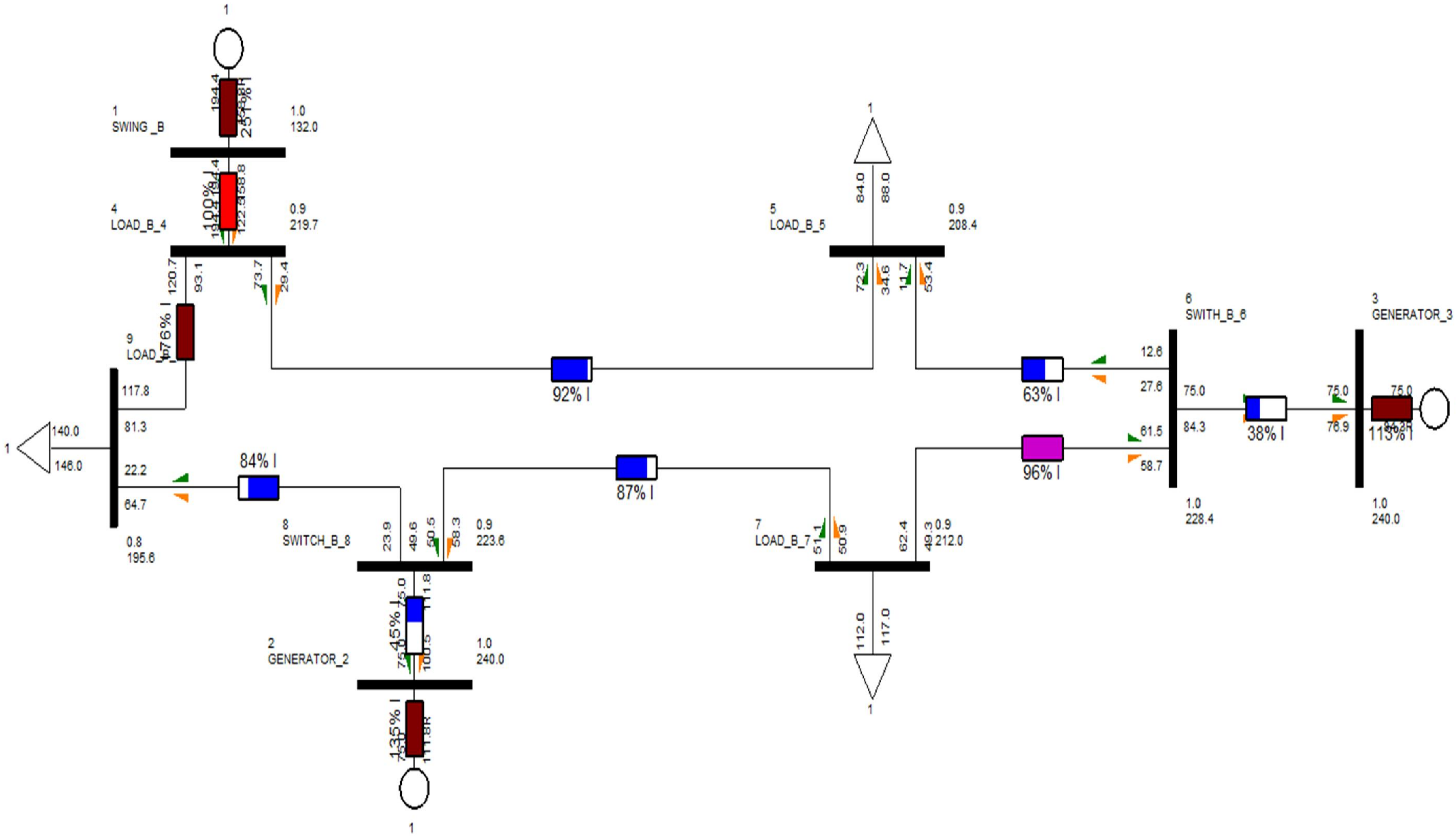

Figure X.XIII Power flow diagram of FTL Lamp with P.F=0.96

X.XI Results Gained from PSSE Simulation for FTL (T16) with P.F=0.96

Report on Losses

IEEE 9 BB SYSTEM

AREA TOTALS IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	AT AREA BUSES: FROM IND GENERATN	AT AREA BUSES: TO IND MOTORS	AT AREA BUSES: TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	NET INTERCHANGE: TO TIE LINES	NET INTERCHANGE: TO TIES + LOADS	DESIRED NET INT
1	344.4	0.0	0.0	336.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0
	354.9	0.0	0.0	351.0	0.0	0.0	0.0	108.9	112.8	0.0	0.0	
COLUMN TOTALS	344.4	0.0	0.0	336.0	0.0	0.0	0.0	0.0	8.4	0.0	0.0	0.0
	354.9	0.0	0.0	351.0	0.0	0.0	0.0	108.9	112.8	0.0	0.0	

Report on Loadings

IEEE 9 BB SYSTEM

SUBSYSTEM LOADING CHECK (INCLUDED: LINES; BREAKERS AND SWITCHES; TRANSFORMERS) (EXCLUDED: NONE)
LOADINGS ABOVE 100.0 % OF RATING (MVA FOR TRANSFORMERS, CURRENT FOR NON-TRANSFORMER BRANCHES):

FROM BUS: BUS#	FROM BUS: NAME	FROM BUS: BASKV	FROM BUS: AREA	TO BUS: BUS#	TO BUS: NAME	TO BUS: BASKV	TO BUS: AREA	CKT	LOADING	RATING SET A: RATING	RATING SET A: PERCENT	RATING SET B: RATING	RATING SET B: PERCENT	RATING SET C: RATING	RATING SET C: PERCENT
1	SWING _B	132.00	1	4	LOAD_B_4	240.00*	1	1	251.0	250.0	100.4	250.0	100.4	250.0	100.4
4	LOAD_B_4	240.00	1	9	LOAD_B_9	240.00*	1	1	175.6	100.0	175.6	100.0	175.6	100.0	175.6