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Analysis of Low Power LED Units for Power Quality Requirements

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ABSTRACT

Power quality requirements has several requirements that affect on the electric power network. Expansion of nonlinear loads in wide applications like LED unit's production especially lower power units encourage the researches to modify the technical characteristics of these units. The actual analyses of LED unit's performances is carried out to maximize their advantages to increase their applications in our life. So. This paper focus on internal performance of indoor LED units through experimental procedures using Ti200 thermography Fluke to measure the output heat from proposed samples of LEDs units. Power dissipated of tested units has been studied. Also, correlated color temperature of tested units have been evaluated. One sample of CFL tested unit is selected for comparison between LED's units. Tenmars Lux/FC light meter is used to measure the luminance of LEDs units that have different operating hours. The analysis results are discussed and concluded.

Keywords : CThermal characteristics, Low power LEDs, Junction temperature, Maximum temperature, Utilized light power, Thermal image.

1 INTRODUCTION

CURRENTLY, world has been interested by power quality of lighting units productions especially lighting emitted diodes LED units which is considered the best one for several advantages than the traditional lighting units and due to manufactures wide publicity. Harmonic current distortion waveforms and power factor are the essential requirements of LED unit performance which are being investigated practically from standards or published issues [1]. The lifespan time of the LEDs is affected by its thermal characteristic that have consumed most of LED input power. The behavior of P-N junction of LED unit changes with operating periods causes technical problems of LEDs such that increase of junction temperature [2], [3]. Visible light which have been generated from LEDs units are in the range 15% to 25 % of total input power while the remainder is dissipated as output heat through unit's body that has heat sink, unit interior area and unit frame [4]. Recessed indoor LEDs have higher temperature than others because of no ventilation that is rising the area surroundings. Various parameters may generate heat from the LED such that output power per dissipating surface area of unit, drive current, LED forward voltage, heat sink material, size of cooling area of LED unit …….*etc*. Increased temperature of unit junction leads to current decreasing of LEDs that leads the decrease in theoutput light [5], [6], [7]. The temperature of P-N junction must be in 25 °C according to standards but in actual applications, LED unit temperature is 60 °C or above that have adversely impact on LED performance and its lifespan. Due to the LED increasing temperature, color temperature of light wavelength is shifting gradually. Also, decreasing of light output has an impact of lumen maintenance of LEDs which is a percentage of the luminous flux output at specified operating time divided by the unit's luminous flux. Standards deduce lumen maintenance doesn't decrease than 0.7 at 70 % of LED lifespan [8]. Then, released over heat of LEDs, must be removed through an effective cooling system or redesigning the heat sink of LEDs or advanced luminaire shape which dissipates most output heat that cause serious problems [9].

Other requirements of power quality of LEDs have been affected by temperature increase like Correlated Color Temperature (CCT). It is defined as the color impression of a perfect black-body radiator at certain temperatures. This means that if material is heated gradually, its color appearance changes from red to yellow and then, white. Then, increased color temperature means cooler perception of the white light

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[10]. Shifting the wavelength and change the unit performance occur due to CCT changes when unit junction temperature increases as indicated in appendix [4], [11], [12], [13]. Most of commercial LED's color with performance is not guaranteed after 5000 operating hours. Also, more operating time of LEDs with constant load current causes CCT change for all units [14], [15].

2 INVESTIGATION OF POWER LOSSESBASED ON MANUFACTURES' OPERATING

In the first experiment, five types of low power LEDs and one unit of CFL are selected and sorted from type (1) to type (6) with its specifications in TABLE 1. Operating time of the experiment exceeds than three hours and the current of each tested unit circuit is measured at experiment time end where the LED junction temperature changes indifferent feature for each while the current must be constant [16]. The percentage of power that would be converted into light has been specified from manufacture's manual as explained below. Also, losses due to thermal power of LED unit has been studied and so, utilized power from the total input power of LED's circuit can be estimated based on manufacture concept. This analyses depends on the Junction power input $P_{junction}$, forward voltage and forward current of each unit. Manufacture's strategy presents the value of converted light power as a percentage of the total input power unit circuit which equals 25 % of total input power. This strategy depends on the forward voltage V_f, , forward current I_f of the unit junction and input LED power. P_{Input}, forward voltage and forward current of selected units are assumed according to its wattages the light color taken from standards as general cases since datasheets is not available [10], [11], [12], [13]. Then, Each tested unit has consumed power from the power network P_S that equals V (Network voltage) × I_L (consumed current or measured current).Therefore, the junction is consuming the electric power which equals the input power of LED, meaning that:

$$P_{Junction} = P_{LED} = I_f \times V_f \quad (1)$$

I_f = forward current to the LED (instantaneous measured current at operating period end).

V_f = forward voltage, (is taken as standard value based on unit light color).

Power loss in each unit drive

$$P_{Loss} = P_S - P_{LED} \quad (2)$$

And the power dissipated in unit junction equals to = Thermal power = $P_{thermal}$

$$= 0.75 I_f \times V_f \lll P_{Loss} \quad (3)$$

Then, the utilized light power

$$= 0.25 I_f \times V_f \quad (4)$$

Then, the LED unit efficiency can be identified as:

$$\therefore \textit{Utilized Power Unit} = \frac{\text{Utilized Output Light Power(UOLP)}}{P_S} \quad (5)$$

When the above algorithm is applied for each tested unit, the required power for each unit is very small if compared to its feeding power network P_S even in light power of some tested units are not arithmetically accurate and theoretically unacceptable. In general, the utilized light power is nil and the rest is missed as heavy lost in electric network as indicated in TABLE 1.

TABLE 1
FIRST EXPERIMENT RESULTS FOR TESTED TYPES

No.	Type	Current (mA)	P_S W	$P_{junction\ input}$	$P_{thermal}$	(UOLP) W	$\frac{\textit{Utilized Output Light Power}}{P_S}$ %
Type (1)	3 W white bulb	52	11.4	0.1976	0.1482	0.0494	0.43
Type (2)	3.5 W warm bulb	14	3.08	0.0448	0.0336	0.0112	0.36
Type (3)	4 W, white spot	14	3.08	0.0448	0.0336	0.0112	0.36
Type (4)	5.5 W, warm bulb	17	3.74	0.0544	0.0408	0.0136	0.36
Type (5)	9 W, warm bulb	36	7.92	0.1368	0.1026	0.0342	0.43
Type (6)	11 W, white CFL	43	9.46	0.1634	0.1226	0.0409	0.43

3 TEMPERATURE MEASUREMENT OF TESTED UNITS

3.1 Exerimental Precedure

Second experiment has been established by using Ti200 thermography to focus and measure the temperature of six units which are used in the first experiment. Fluke photography device has a sensitivity to detect the emitted heat from the tested unit recording the temperature at any choice point of the unit body. The experiment time is taken from 12:45 pm to 4 pm. The temperature is measured and recorded for each unit individually at three definite points on unit's body as shown in following figures. Let these points are unit drive, interior area of unit and junction location called by bottom of unit, unit area, and maximum temperature of unit respectively. Measured temperatures are taken for three times during the experimental period; the first at 1:30 pm, the second and the third are 3:00 pm and 4:00 pm respectively. The experiment is being started at mid-day time starting from 12:45 pm that is the highest temperature time. The maximum temperatures of the three measurements are recorded in TABLE 2.

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3.2 Analysis of Temperature Measurements

Thermal images for tested units are recorded on three points as explained above From Fig. 1 to Fig. 6. For one example, Fig. 1, picture 1 indicates the thermal image of type (1) taken at 12:45 pm that has a drive point temperature is 24.7 ºC, interior area temperature is 39.78 ºC and maximum temperature is 55.09 ºC. Fig. 1, picture 2 shows the thermal image is taken at 3:00 pm for the same three measures that are 33.37º ºC, 30.75 ºC and 60.30 ºC respectively. Fig. 1, picture 3 shows the thermal image of type (1) recorded at 4:00 pm with three measures; 43.45 ºC, 30.73 ºC and 61.09 ºC. Fig. 1, picture 4 indicates the temperature trend curves of the three unit points along the examined interval experimental time. The three curves show the same explained increasing rate of temperature. Curves of type (1) are characterizes the rising of temperature gradually with operating time extent.

Maximum temperature of all types is not constant but it changes actually in limits range of standards through the testing period except the recessed types - spots - like type (3) have no ventilation area around it. This may lead to maximize the unit temperature to be higher than acceptable operating temperature of standards causing serious problems on unit lifetime or the surroundings [16]. Type (6), CFL unit, has the highest temperature than others. Measured temperature for most units is being increase than for own operating temperatures.

TABLE 2
UNITS FORTEMERATURE MEASUREMENT IN SECOND EXPERIMENT

Unit Type No.	LED unit Type, Operating Temp ºC.	Max. Temp ºC at 1:300 pm Time (1)	Max. Temp ºC at 3:00 pm Time (2)	Max. Temp ºC at 4:00 p:m Time (3)	Average Max. Temp ºC.
Type (1)	3 W, white bulb, 43 ºC	55.09	61.09	60.50	58.9
Type (2)	3.5 W warm bulb, N/A	51.22	50.9	47.4	49.84
Type (3)	4 W, white spot 25 ºC	60.53	58.99	61.16	60.23
Type (4)	5.5 W, warm bulb, 80 ºC	48.18	48.43	52.08	49.65
Type (5)	9 W, warm bulb, 25-45 ºC	65.15	77.49	79.37	74.00
Type (6)	11 W, white CFL, N/A	129.49	129.04	125.81	128.11

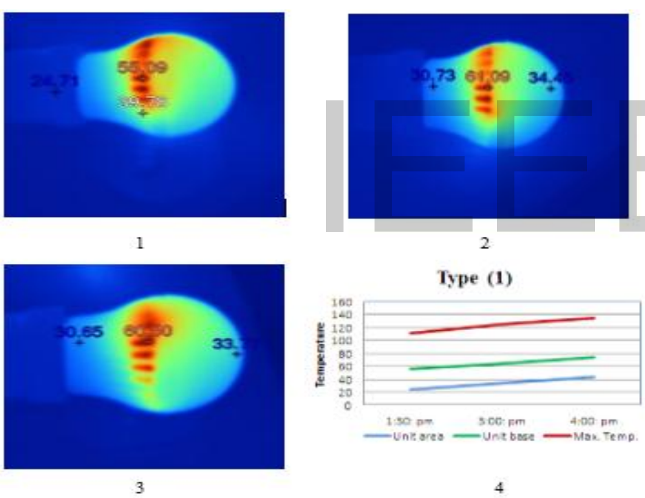

Fig. 2 Temperature measurements of type (1)
Picture 1, Temp. Measure at 12:45 pm, picture 2, temp. Measure at 3:00 pm, picture 3, Temp. Measure at 4:00 pm and picture 4 Temp. Curves of three parts of type 1

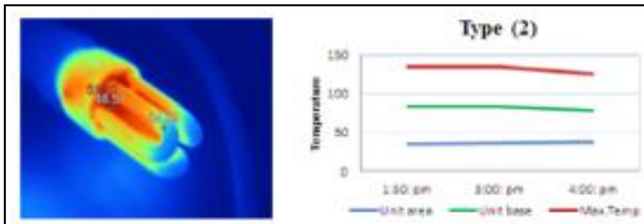

Fig.2 Temperature measurements of type 2
Picture 1 is the maximum temp.and picture 2 Temp. Curves of three parts of type2

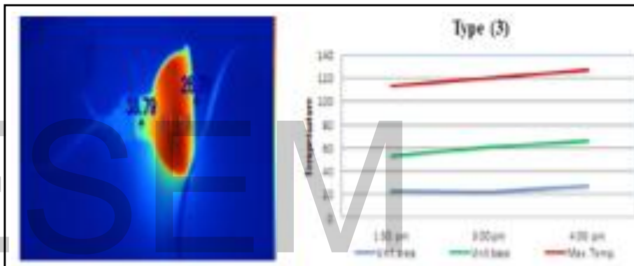

Fig. 3 Temperature measurements of type3
Picture 1 is the maximum temp.and picture 2 Temp. Curves of three parts of type 3

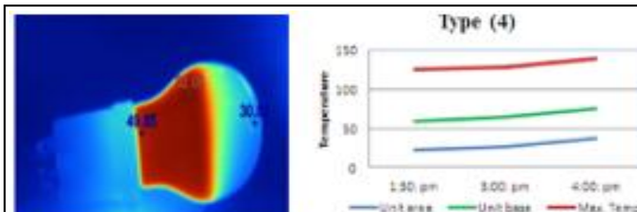

Fig 4 Temperature measurements of type 4
Picture 1 is the maximum temp.and picture 2 Temp. Curves of three parts of type 4

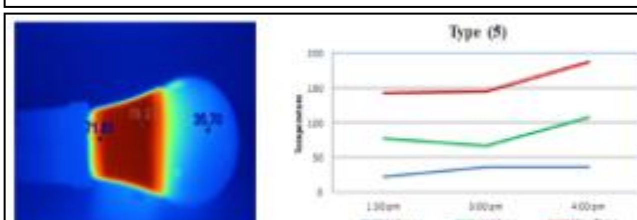

Fig. 5 Temperature measurements of type 5
Picture 1 is the maximum temp.and picture 2 Temp. Curves of three parts of type 5

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Unit base temperature - drive location- of most units ranges from 30ºC to 50ºC except type (5) and type (6) which have a temperature of 80 ºC and129 ºC respectively that may increase than the acceptable range. Then, drive's components of type (5) or the ballast of CFL must be reviewed to reduce the output heat. Most tested types have the maximum temperature in junction points especially for the units having more brightness - higher power rating and so more dissipated power emitted from them [7].
Increase the maximum temperature with operating time as shown in Fig. 2 picture 4, Fig 3 picture 2, Fig. 4 picture 2, and Fig 6 picture 4 may lead to unit overheating causing in turn the change in unit performance like unit life span and its power consumption. Regarding the maximum temperature of tested types units, type (3) and type (6) have the lowest temperature of interior area which diffuse the output light rays from the unit although its temperature has the largest because of its ballast. Base unit temperature of tested type (2) and type (4) records the highest temperature than others and so its unit drive must be redesigned. Maximum temperature of these units are concentrated in the unit junction and its temperature exceeded than allowable limits of standard specifications [10], [12], [13].

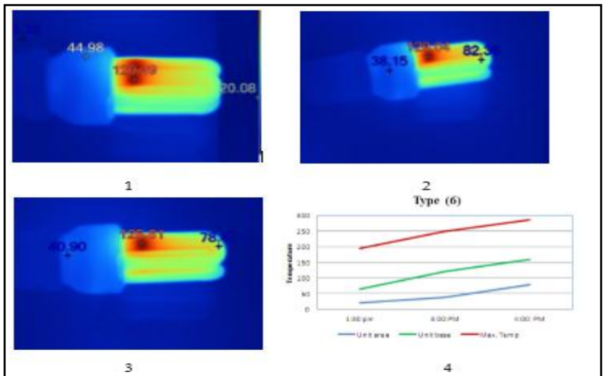

Fig. 6 Temperature measurements of type (6)
Picture 1, Temp. Measure at 12:45 pm, picture 2, temp. Measure at 3:00 pm, picture 3, Temp. Measure at 4:00 pm and picture 4 Temp. Curves of three parts of type 6

4 PERFORMANCE OF OPERATIMG HOURS LEDS

The third experiment aims to study the performance of LED's unit with the increase of its operating time and the unit temperature effect on LED quality requirements. Two sets (1) and (2) are selected where each one is composed of two identical unit bulbs but one unit has never operated previously and the other has consumed operating hours more than thousand hours. Tenmars (Lux meter device) measures light rays intensity Lux/FC emitted from LEDs of the two sets which have variable operation hours.

Set (1) is composed of two identical LED bulbs 4.7 W, one bulb is a new unit, not operated before, and the second bulb is turned on more than 1000 hours that is identified by overtime unit. The second set have two similar bulbs 8.6 W which have the same characteristics as the first set bulbs recorded in TABLE 3.

TABLE 3
MEARUED TEMPERATURE OF TESTED UNIITD IN THIRD EXPERIMENT

LED Tested Type	Light Color	Code No.	Nominal Lumen	Max. Temp. °C after 1hour		Max. Temp. °C after 4 hour		Measured Lux	
Set (1) Bulb 4.7 W	3000 K Yellow	E14 Guarrantee 20160607	400	N.	82.6	N.	85	N.	1920
				O.	78.7	O.	82	O.	1590
Set (2) Bulb 8.6 W	6500 K White	E27 865779	880	N.	78.9	N.	78.9	N.	3380
				O.	68.9	O.	67.1	O.	2700

The temperatures of four LEDs are measured twice; after one hour and after four hours of operating time and the readings are recorded in TABLE 3; N. unit is the new one while O. unit is the overtime unit. the light rays intensity or output luminance from LEDs are measured when the distance between Lux meter and LED unit is equal to 200 mm in X-Y plane based on IEC 62471 [16,17]. These readings identify the performance difference of new LEDs and overtime LEDs shown in TABLE 3. Overtime LEDs' luminance decrease by17.2 % and 20.6 % than new similar units of set (1) and set (2) respectively and so, luminance levels of LEDs unis is affected by LED's power ratings with operating times. Obviously, overtime units becomes having lower brightness than the newest. The luminance difference decrement between overtime LEDs and the new units exceeds than the designer limit that clarifies the luminance becomes in seventy percent of total luminance at operating hours up to 50000 hours [18]. Thus nominal lifetime of these units may be not true and it must be reviewed from manufacturers.

From TABLE 3, it can be concluded that temperature of LEDs increases with operating hours for low power units (4.7 W) whether the unit is new LED or overtime LED. Contrariwise, new LED of set (2) has constant temperature measurements while temperature of overtime unit decreases slightly with operating time extent. After one hour, overtime LED temperature decreases by 4.7% than new one of set (1) while overtime decreases by 12.7% than the new similarity LED unit in set (2). After four hours, overtime LED temperature decreases by 3.5% than

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the new one in set (1) while over time LED decreases nearly 15% than the new LED in the set (2). It is summarized that the output heat increases with ascending rate of LED's power units. Also, overtime LEDs units have lower output heat than the new units. It may return to the quality of junction semi-conductor material nature.

5 Evaluation of Correlated Color Temperature of Tested LED's Units

In TABLE 4, CCT for six units, used in first and second experiments, and its average temperature measurements are recorded. CCT of tested units is not satisfied if compared with standards. It should be reviewed from manufacturers. Evaluating the tested types deduce CCT doesn't match with similar standard type, such that type (2). It has warm color in its nature and its CCT ranges are from 3400 K to 3500 K while standard type color starts from 4000 K. Also, some of tested types have larger CCT than the standard's category like type (6). By reviewing the relation between CCT and junction temperature of tested types, measured temperature for the some are larger than the acceptable value like type (4). In general, CCT increases gradually with the operating temperature of tested types.

TABLE 4
CCT AND AVERAGE JUNCTION TEMPERATURED OF TESTED UNITD

No. of Unit Type	Type (1)	Type (2)	Type (3)	Type (4)	Type (5)	Type (6)
CCT (K)	N/A	3400-3500	6804	2700	4000-5000	6500
Aver. Jun. Temp. °C	58.89	49.84	60.23	49.56	74.00	128.11

6 Conclusions

- Analysis of results and requirements deduce that huge power dissipated in LEDs drives that must be reviewed from manufacturers.
- Negatively effects due to thermal characteristics of LEDs units causes potential problems on its lifetime or in its surroundings.
- Increase the operating time of LEDs leads to output light rays decrement than that calibrated from standards evaluation. So, nominal life time for most low power LEDs are not true and so, the balance between quality criteria requirements of and the predicting lifespan of LEDs must be studied carefully.
- Heat sink of most recessed LED units (spots) must be redesigned since there is no ventilation around unit area which leads to increase the unit temperature and power losses during operating times. Also, nature of heat sink material and its design must be taken into account. Since CFLs units have gradually ascending temperature, suspension fixtures for them are preferred.
- Completed technical datasheets must be provided attached the LED unit production to produce precise evaluation.

7 Appendix

It has four figures, Fig. APP.1 presents the graduation of CCT change from warm to true white color of LEDs. Fig. APP. 2 indicates the relative light color output with junction temperatures of LEDs which changes with variant color temperature (K) that is in range from 5000 K to 5350 K only as shown in Fig. APP 3. Peaks of light visible wavelengths differ with temperature degree values.

Fig. APP 1 Corrlated Color Temperature of warm, natural or true white.

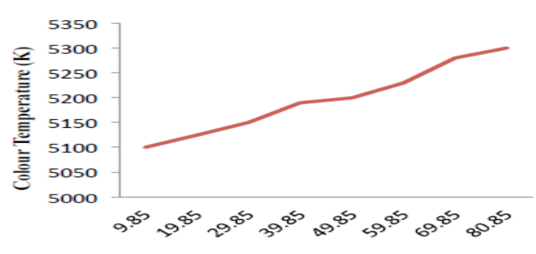

Fig. APP 2 Relation between relative light output and junction temperature

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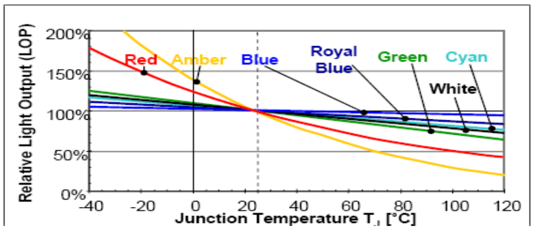

Fig. APP 3 Relation between junction temperature and various light color

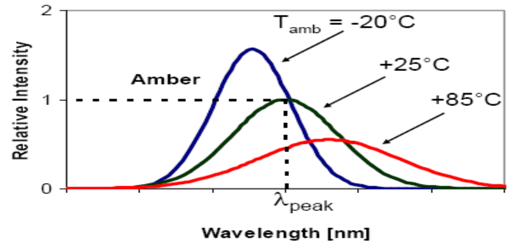

Fig.APP 4 Wavelenghts at different ambient temperaturs of

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