A Novel Investigation of Road Lighting Under Voltage Variation

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Abstract- The road lights should provide good visibility condition and reduce potential hazards of accidents. Again the road lights glow from sunset to sunrise in all 24×7 days all through the year consuming remarkable amount of energy. Thus this study on road lighting was done to make it more visually acceptable and energy efficient one. So the analysis is mainly done on the visibility of object under different lamp lights. The lights are compared on the basis of their stability to provide lumen output during variation on voltage. Their spectral output is also analyzed during voltage variations on the basis of correlated color temperature (CCT) to get the information of appearance of the surrounding and on colour rendering index (CRI) which gives us information that how good we can perceive the colour of the object.

Keywords – Lumen, CCT, CRI, spectral output, voltage variation.

I. Introduction

The primary function of road lighting is to keep the safety of the people**.** The amount of useful lighting available for drivers and pedestrians from the road lighting not only depend on the illumination provided by the pole and head light of the vehicle but also on the weather condition [1-3]. So they are considered to be very dynamic in nature[4]. The use of full headlight is forbidden for the reduction of glare of the oncoming traffic of the other side of the road [5]. It is also forbidden to maintain luminance contrast when the road is fully illuminated with road lighting [6]. During night-time the purpose of road lighting lamp pole unit is mainly to illuminate the road surface i.e. horizontal illumination, while the headlights provide illumination of vertical surfaces, i.e. targets on the road. Studies show that the effect of horizontal illumination is more effective than vertical illumination [7]. It is argued that the visibility of a target located on the road or roadside is not only defined by its luminance contrast against the background but rather by the combination of its colour contrast and luminance contrast [8]. Measurements were made to study the use of road lighting and dipped vehicle headlights at the same time and whether this may have a conflicting effect on the luminance contrasts of various targets located on the road or at the side of the road. The measurements indicate that, in general, the use of dipped vehicle headlights in the presence of road lighting does not improve the visibility of various targets located on the road. In fact, in most cases when the targets appeared darker than the background dipped headlights reduced target contrasts and in some cases they made the target merge into the background [9-10].

II. BACKGROUND WORK

There are two measures of road lighting system performance have been employed: illuminance, i.e. the amount of light from luminaries incident upon a given road surface, and luminance, i.e. the amount of reflected light returned to the driver's eye from the road surface. Before 1940, road lighting design criteria were based mainly upon lighting levels expressed in terms of illuminance units. Around 1940 design, principles of photometry and geometry were followed by principles based on physiology. The design of road lighting installations was shifted towards the inclusion of visible quantities: target luminance, road surface luminance, uniformities, and glare [11].These basic ideas of visual performance were the key to the development of the luminance concept of road lighting which is still used today [12-13]. After various different visual tasks had been tried out, the one adopted most widely by the road lighting research communities was a square target 20 cm x 20 cm, with a contrast of C = 0.33 or C=0.2 with respect to the road surface, and placed on the road minimum 60 m and maximum 120m in front of the driver. This visual task was used in the development of recommendations for the current road lighting levels [13].Afterward road lighting research no longer concentrated only on the visibility of targets on illuminated roads, but started also to include visual comfort aspects. In the 1950s and 1960s, de Boer was one of the first researchers to add visual comfort to the pure visibility aspect of road lighting [14].

III. ABOUT THE VISION DURING DRIVING

The human eye contains two major light sensitive photoreceptors, namely cones and rods cell each with its own spectral sensitivity. Cone cell is for photopic sensitivity and rod cell for scotopic sensitivity. At night time under roadway lighting, both cones and rods are active. The twilight zone which lies between the photopic and scotopic regions is called mesopic. The gradual change from photopic to mesopic happens when the light level is reduced [15]. Normally road lighting is in the mesopic region where the spectral sensitivity of human eyes is somewhere between that of photopic and scotopic region [16]. With gradual decrease in light levels, the peak of visual sensitivity shift towards shorter wavelength known as Pukinjie shift.Purkinje shift caused by decreasing light level and increasing eccentricity should be considered when evaluating whether a light source is advantageous for the visual performance of humans for road lighting or not [17].

IV. ABOUT THE EXPERIMENT

The relative lumen of different lamps was measured in the integrating sphere. The change of the relative lumen output of the lamps with the change of the voltage was studied. As the line voltage can decrease up to 30%, so a voltage range from 240 volts to 165 volts are taken. The voltage was gradually decreased and the gradual changes of relative lumen of the lamps were calculated from their gradual change in illuminance in integrating sphere. The respective gradual change in illuminance of the respective standard lamp that is taken under same voltage variation. The whole pattern of the percentage variation of relative lumen of the lamps with percentage variation of voltage was studied with graphical plot model. Ratio of lux of the measured lamp to lux of the standard lamp is equal to lumen of the measured lamp to lumen of the standard lamp.

Their spectral output through spectroradiometer data analyzer is also studied to compare the lamps on the basis correlated colour temperature (CCT) i.e. colour of the surrounding and colour rendering index (CRI) i.e. colour variation capability under a certain lamp. Their shift of CCT and CRI during voltage variation is also studied. Mainly two popular light sources used in road lighting i.e. HPS (high pressure sodium vapour (lamp) and MH (metal halide) lamps are compared considering one as yellow light source with low colour rendering ability and other as white light source with high colour rendering ability .With that LPS (low pressure sodium vapour lamp) are also compared for its highest purity in colour output and high luminous efficacy to determine whether it can become a potential alternative. Led lamps too are compared with that for high energy efficiency and as it has a high future prospectus.

V. LUMEN OUTPUT VARIATION GRAPHS WITH AND SPECTRAL OUTPUT CURVES OBTAINED OF DIFFERENT LAMPS

A. *High pressure sodium vapour lamp-*

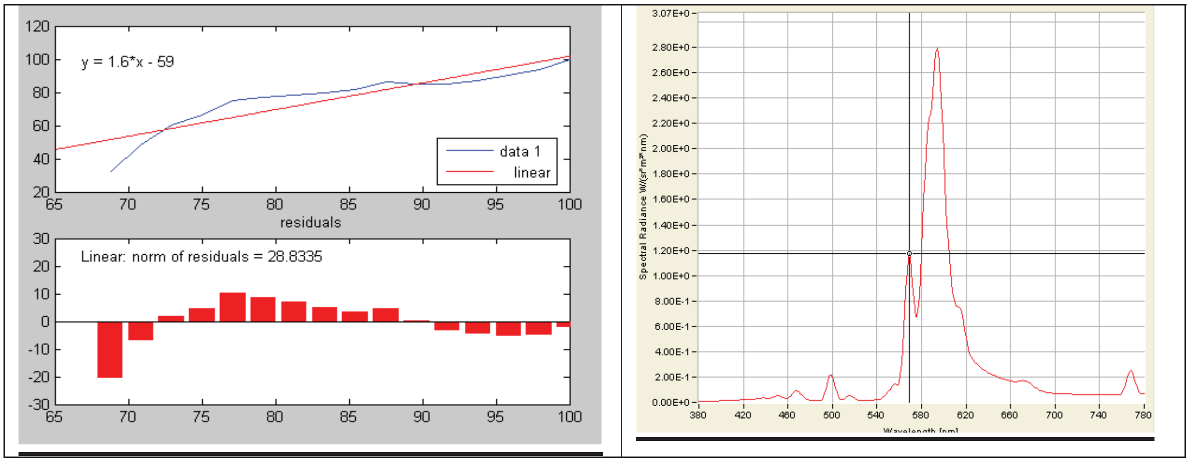

Figure 1.Graph of % lumen output decrement with % variation in voltage & Spectral output of HPS lamp

Table -1 High pressure sodium vapour lamp

Luminanous flux	5200 lm
Correlated colour temperature [K]	1904
Dominated wavelength[nm]	589
PE[%]	87.7
CRI	27

High pressure sodium vapour lamp normally gives yellowish ambience when used in road lighting. Normally it has a lamp life hour of about 56000 hrs. It gives a luminous flux of 5200 lm under full excitation. Its spectral output shows that it is almost monochromatic with dominated wavelength at 589nm i.e. at yellowish orange region. It is almost devoid of other wavelengths so have a purity of 87.7% and have a very low CRI of 27

When the voltage is gradually decreased its lumen output at first level tries to maintain its value but after 75% of voltage decrement its lumen output drastically reduces. A slope of m=1.6 obtained.

Its CCT decreases from 1904 k to 1777 k when the voltage is reduced i.e. more towards greenish yellow region and CRI from 27 to 9 thus producing unnatural yellowish dark environment. So every object under it appears as monochromatic. Blue coloured object is least visible due to devoid of prominent wavelength in blue region. Red and green coloured object though appeared monochromatic but the luminance contrast against road is good for them.

B. Low pressure sodium vapour lamp

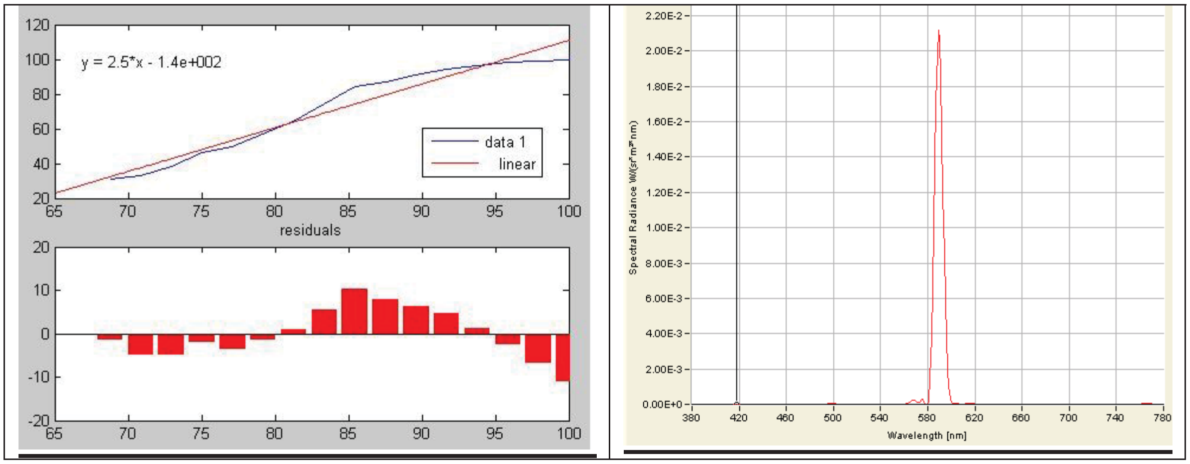

Figure 2. Graph of % lumen output decrement with % variation in voltage & Spectral output of LPS lamp

Table -2 Low pressure sodium vapour lamp

Luminous flux	3200 lm
Correlated colour temperature [K]	1795
Dominated wavelength[nm]	589
PE[%]	99.2
CRI	5

Low pressure sodium vapour lamp normally gives very unnatural yellowish ambience when used in road lighting. Normally it has a lamp life hour of 18000hrs. It gives a luminous flux 3200 lm of under full excitation. Its spectral output shows that it is totally monochromatic with dominated wavelength at 589nm i.e. at yellowish orange region. It is fully devoid of other wavelengths so have a purity of 99.2% and have a very low CRI of 5

When the voltage is gradually decreased its lumen output decreases at very faster rate. A saggy slope of m=2.5 is obtained. The pattern of lumen decrement shows its voltage stability is not satisfactory.

Its CCT decreases from 1795 k to 1504 k when the voltage is reduced i.e. more towards greenish yellow region and CRI from 5 to 1 thus producing very much unnatural yellowish dark environment. So every object under it appears purely monochromatic. Blue coloured object is almost invisible due to devoid of any wavelength in blue region. Red and green coloured object appeared monochromatic and very dark.Overall ambience become very dark.

C. *Metal halide lamp*

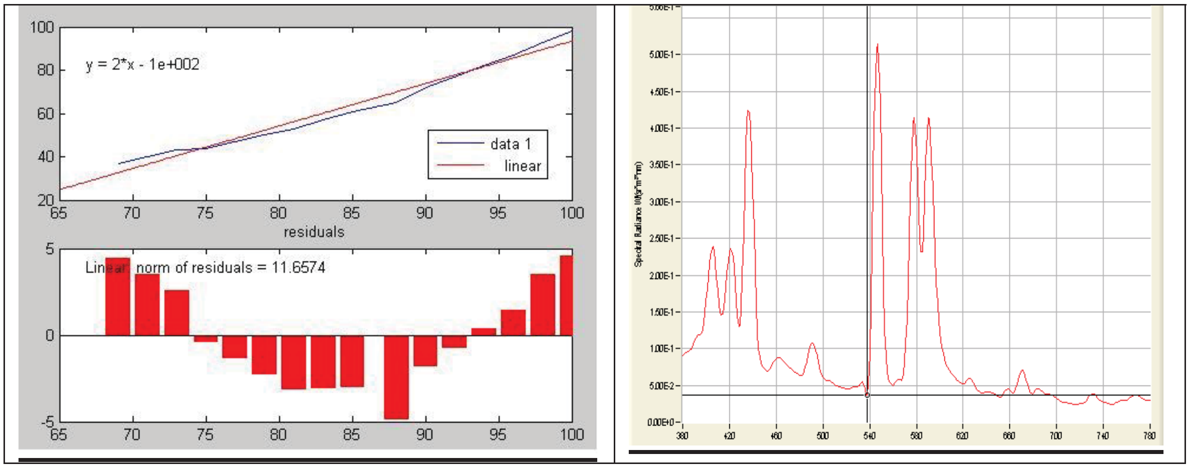

Figure 3. Graph of % lumen output decrement with % variation in voltage & Spectral output of MH lamp

Table -3 Metal halide lamp

Luminous flux	6300 lm
Correlated colour temperature [K]	5026
Dominated wavelength[nm]	494
PE[%]	2.6
CRI	85

Metal halide lamp normally gives natural white ambience when used in road lighting. Normally it has a lamp life hour of 12000hrs. It gives a luminous flux of 6300 lm under full excitation. Its spectral output shows that it is a white light source with dominated wavelength at 494 nm i.e. at bluish region. It has almost other wavelengths so have a purity of 2.6% and have a high CRI of 85

Whether voltage is gradually decreased, its lumen output decrease at a very steep rate. A slope of m=2.0 obtained. The pattern of lumen decrement shows its voltage stability is not satisfactory

Its CCT decreases from 4200 k to 3500 k when the voltage is reduced i.e. more towards greenish region and CRI from 85 to 45 thus producing unnatural greenish environment. So most of object under it appears as monochromatic. Blue coloured object is most visible due to availability of wavelength in blue region but have very low luminance level. Green coloured object appears grayish but is normally visible. Red coloured object appeared monochromatic and darkish due to almost no wavelength in red region.

D. LED lamp

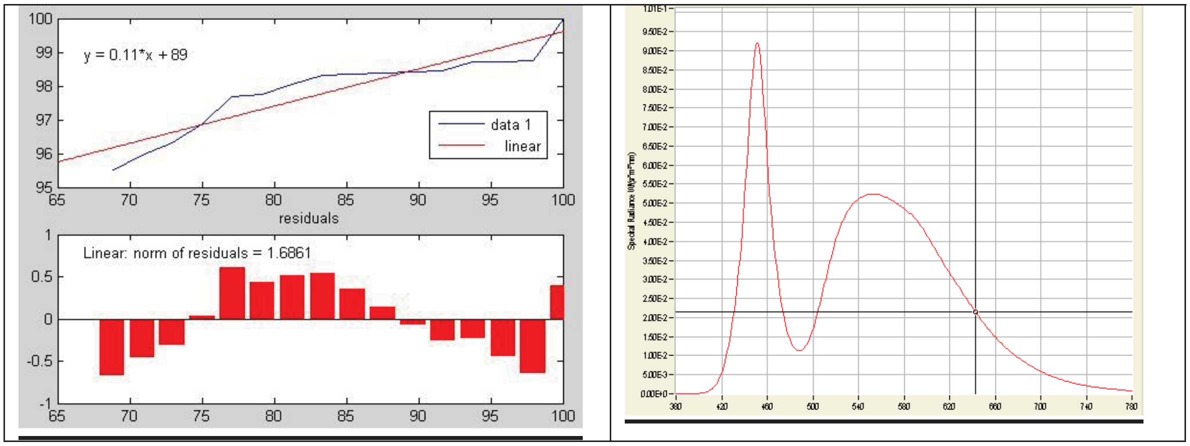

Figure 4. Graph of % lumen output decrement with % variation in voltage & Spectral output of LED lamp

Table -4 LED lamp

Luminous flux	6300 lm
Correlated colour temperature[K]	6041
Dominated wavelength[nm]	491
PE[%]	4.2
CRI	85

LED lamp normally gives natural white ambience when used in road lighting. Normally it has a lamp life hour of 80000.hrs. It gives a luminous flux 6300 lm under full excitation. Its spectral output shows that it is a white light source with dominated wavelength at 491 nm i.e. at bluish region. It has almost all other wavelengths so have a purity of 4.2% and have a high CRI of 85.

When the voltage is gradually decreased its lumen output at first level tries to maintain its value but after 75% of voltage decrement its lumen output drastically reduces. A very low slope of m=1 obtained.

Its CCT decreases from 4000 k to 3000k when the voltage is reduced i.e. more towards greenish region and CRI from 85 to 65 thus producing almost greenish white environment. So some of object under it appears as monochromatic. Blue coloured object is most visible due to availability of wavelength in blue region. Green coloured object appears greenish grey but is normally best visible. Red coloured object appeared grayish due to almost very low amount of wavelength in red region.

VI.CONCLUSION

The results of the voltage variation experiment reveals that the four light sources that are compared have both merits and demerits. So coming to one specific or best solution is not possible. Among the four sources low pressure sodium vapour lamp performs least for the lumen output during voltage variation experiment. Again due to its pure monochromatic characteristics the coloured objects appear darker during low excited condition. But as its purity is very high i.e. it is not a combination light of different wave length like white light sources, so the dispersion under hazardous conditions like fog, smoke etc is very less. So it produce pure image during hazardous condition.

High pressure sodium vapor lamp performs well by producing almost stable lumen output during voltage variation experiment. But it has a problem of colour rendering which became even worse during low voltage situation thus producing yellowish green light. Again it forms an unnatural night environment which is not esthetically viable. Though the objects become monochromatic under this lamp but image perception by luminous contrast is good.

Again as it has almost single prominent wavelength image dispersion is much lesser than combination white light during foggy environment.

Among the two white light sources LED has almost stable lumen output during voltage variation than metal halide. Again due to its smooth curve of spectral output image perception with colour perception is much better than metal halide during low voltage condition. Both the light sources produces natural night environment by producing white light.

When our visual field reduces to one to three percent, i.e when we look at the distant object colour perception reduces and image perception increases. So in highways where the speed of the vehicle is high and distance between them is more high pressure sodium vapour lamp is more viable. Because the image perception is more important to avoid accidents than to get colour perception of the object. But in the populated city environment where the distance of the vehicle and speed are not very much LED shows a good future by producing a good colour perception and natural night environment.

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