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Original Research Paper

Design and development of an improved traffic light control system using hybrid lighting system

Michael Osigbemeh [a,*], *Michael Onuu* [b], *Olumuyiwa Asaolu* [c]

[a] *Department of Electronics and Computer Engineering, Nnamdi Azikiwe University, Awka, Nigeria*
[b] *Department of Physics, Federal University Ndufu-Alike Ikwo, Ebonyi, Nigeria*
[c] *Department of Systems Engineering, University of Lagos, Lagos, Nigeria*

HIGHLIGHTS

- A hybrid traffic lighting system to reduce road accidents by drivers is proposed.
- The design relies on high energy incandescent lamps as complementary to LEDs.
- To improve energy savings a third of high energy lighting is used for each session.
- The control circuitry is designed with discrete components to allow for resilience.
- Allows enhanced sign's image detection and processing for smart based technologies.

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ABSTRACT

The deployment of light emitting diodes (LEDs) based traffic system control created the problem of dim displays when ambient light is similar to traffic lights. It causes some drivers' disability of seeing and obeying traffic signs. This makes drivers violate traffic rules. In this paper, an attempt to use hybrid lighting technology to mitigate this problem was developed. Incandescent lightings with deployed halogen bulbs provided an instantaneous source of highly efficacious illumination which is brighter than the drivers' ambient lights (both daylight, electrical lights and their reflections), which can help drivers get access to enough warning and help them initiate traffic safety warning as necessary. The halogen lightings also offered the required high current draw needed in electrical circuitry to help brighten the LED displays. The problem of heat generated was eliminated by aerating the T-junction traffic light control unit designed for this technology. The result of hybrid lighting system design was found to be high luminosity and capability of gaining driver attention in real-time. It also allowed enhanced sign's image detection and processing for smart based technologies by providing the "light punch" needed for a wide range of visual concerns.

* *Corresponding author*. Tel.: +234 806 511 5922.
E-mail addresses: mykaelosi@yahoo.com (M. Osigbemeh), michaelonuu@yahoo.com (M. Onuu), asaolu@yahoo.com (O. Asaolu).

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1. Introduction

The use of traffic lights to eliminate confusion, chaos, time-wasting and accidents in road junctions and curvets have witnessed a lot of changes over years although the basic color signs retained. Most of these changes have been focused on the type of power utility. Others have been focused on the red, yellow and green sessions timing, and in the compatibility or shape of deployment. Most L-junctions, T-junctions and 4-way junction have different traffic lights in most urban cities in the world nowadays. These traffic control lights which previously used incandescent lights with watts ranging from 20 to 100 W have gradually been replaced with light emitting diodes (LEDs). These LEDs which reduced the power consumption of the traffic lights to a very few watts also created another problem, which is drivers' disability of seeing or interpreting these lights as they approach to the traffic lights on nominal speed. This could be caused as a result of several factors including but not limited to solar glare, different reflections and refractions occurring in real-time in front of the driver. These factors tend to contribute to the drivers' decisions, actions and inactions. Virtual black out of driver's vision when faced to the floodlights of approaching vehicles (light glare) is another reason of drivers not being able to interpret traffic signs. This is because it takes some time for a driver who experiences light glare to adjust to normal lighting since the human eye possesses varied response to light in the visible range of the electromagnetic spectrum. Though in most cases, drivers' error in traffic light interpretations may lead to accidents, much can be done to reduce these accidents because of the low lumen radiated by LEDs comparing with the ambient lighting. The LEDs intensities compared to ambient lighting's intensity created by the sun and the numerous reflections and refractions occurring in front of the driver are very low and not strong enough to give the driver the required command or direction, as the retina of the eye in motion will only respond to brighter light. Also, the pupils of the eyes tend to dilate in order to interpret dimmer lights and this dilation will require the driver to slow down or even completely stop to fully interpret the sign and then take appropriate actions. This is practically difficult as most drivers are in haste or at high speed especially in some countries where speed limits are not regulated or enforced. The hybrid lighting technology (HLT) proposed in this work hopes to eliminate these issues and also provide an option for drivers contending with various solar glares during the daytime and reflections from floodlights in the night.

The increasing design and development of intelligent systems capability of adapting to several parameters in real-time has continued to emerge. Traffic lights in these intelligent systems are designed to literally be adjusted by the traffic itself at any time (i.e., both peak and off peak periods). Several developed countries in the world also rely on centralized and integrated control that allows dynamic control of all traffic from a point using central administration models. Presently, rigorous researches are geared towards the disappearance of traffic lights in the "smart cities" with dependence on autonomous vehicles for identifying and interpreting the traffic signs. Diaz et al. (2015) proposed the use of a priori maps to identify and pre-locate traffic lights stating that the "detection and interpretation of traffic lights meaning remains an active problem for industries and research groups". Desai and Somani (2014), Hegyi et al. (2009) and Kuhne (1991) enumerated different vehicle detection techniques based on sensor readings in real-time to aid computer vision in solving traffic congestion; Chiang et al. (2011) also advocated the use of genetic algorithms for in-car systems in detecting and recognizing traffic lights including the identification of problems such as partial occlusions and LEDs malfunction inherent in such autonomous systems at ranges of 10–115 m to these signs. Li (2013) considered recognition of traffic lights in the night and Diaz-Cabrera et al. (2015) designed algorithms for daytime and night traffic lights interpretation with dependence on fuzzy filtering using one camera. The authors, though applied various morphological operations for image feature extraction, enumerated several limitations in their experiments which including confusion in processing and estimation due to solar glare, changing lights and opaquing lamps in extreme conditions. However, the HLT when deployed along with these futuristic technologies promises to reduce a lot of computational power, enhance better interpretation of detected signal and help correct significant errors which are likely to be generated due to image deterioration, weather conditions and other uncertainties in image acquisition and processing.

1.1. Analysis of a typical traffic intersection

In a report which analyzed the existing backup systems for traffic lights available in New York discovered that traffic light units uses approximately 400 W continuously with short power transients as high as 1800 W (Rensselaer Polytechnic Institute-Advanced Energy Conversion, 2009). The units consisted of sensors, controllers, lamps, etc., which operates at voltages derived from the 120 V utility power supplies. These equipments according to the research failed to minimize energy requirements because some of these units combined energy saving LED lamps and high energy consumption incandescent lamps without proper load sharing scheme. The incandescent lamps were primarily added to the traffic light circuit to provide the necessary large current draw to help brighten the LEDs during operation (Hart, 2011). A typical area view of the vicinity of a 4-way junction traffic control system showing the traffic at daytime according to Rensselaer Polytechnic Institute-Advanced Energy Conversion is shown in Fig. 1.

The total power consumption of a traffic light control system (TLCS) was identified by Coetzee et al. (2008), based on the number of traffic lights operating at any given time and the type of lamp used in the design of the TLCS. The authors used a relatively typical intersection which is shown in Fig. 2 to illustrate power distributions and the type of lightings deployed in such a layout in an urban area in South Africa (SA).

In Fig. 2, S1 shows signal face type and arrows indicate traffic flow.

They pointed out that "most traffic signals in SA still have halogen lamps, with a power consumption of 55 W". South