AN APPROACH TO CONTROL AND DISPATCH STREET LIGHTING SYSTEMS WITH NEW DIMMING METHOD FOR LED-EYE SETS

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ABSTRACT

This paper presents a new approach to street lighting systems using LED lamp sets, called LED-eye sets. A new dimming method is proposed to regulate lamp sets having some LED eyes that helps to lengthen their life time and lighting stability. This paper also proposes some more solutions to design and operate LED-eye sets basing on dimming method such as using hybrid power supplies, artificial intelligence and smart lighting zone to create intelligent lighting areas. They will help to reduce power consumption from electric grid, ensure a comfort illumination and decrease the effect of artificial lighting to the environment. The proposed dimming solution is verified by an experimental model which uses lamp sets having three LED eyes for each set. Moreover, the haar cascade classifier is used to identify vehicle density in this study that helps to decide on/off control signal for each LED eye. These proposed solutions can be applied to regulate all LED-eye sets and make lighting systems become more intelligent and greener.

MỘT CÁCH TIẾP CẬN ĐỂ ĐIỀU KHIỂN VÀ VẬN HÀNH HỆ THỐNG CHIẾU SÁNG ĐƯỜNG VỚI PHƯƠNG PHÁP LÀM MỜ MỚI CHO CÁC BỘ ĐÈN CÓ NHIỀU MẮT LED

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THÔNG TIN BÀI BÁO

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TỪ KHÓA

Trí tuệ nhân tạo
Bộ làm mờ
Làm mờ
Năng lượng tái tạo
Hệ thống chiếu sáng đường
Khu vực chiếu sáng thông minh

TÓM TẮT

Bài báo này trình bày một cách tiếp cận mới với hệ thống chiếu sáng đường sử dụng bộ đèn LED. Một giải pháp làm mờ mới được đề xuất với bộ đèn có vài mắt LED giúp nâng cao tuổi thọ và độ ổn định cho bộ đèn. Dựa trên đề xuất mới, bài báo thiết lập một số giải pháp thiết kế và vận hành bộ đèn LED như kết hợp nguồn lai, trí tuệ nhân tạo, smart zone để tăng tính thông minh cho hệ thống chiếu sáng trong một khu vực. Những giải pháp này giúp hạn chế lượng điện năng tiêu thụ từ lưới điện, đảm bảo tiện nghi chiếu sáng và giảm ảnh hưởng của ánh sáng nhân tạo tới môi trường. Giải pháp làm mờ mới đã được kiểm chứng thông qua một mô hình thực nghiệm có các bộ đèn có 3 mắt LED, mỗi mắt có công suất 50W. Đồng thời, phương pháp haar cascade được mô phỏng để nhận diện phương tiện giao thông, từ đó gửi tín hiệu điều khiển đóng/cắt từng mắt LED. Tập hợp các giải pháp đề xuất có thể được áp dụng cho tất cả các bộ đèn, giúp hệ thống chiếu sáng trở nên thông minh, xanh và tiết kiệm năng lượng.

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1. Introduction

Lighting systems provide artificial illumination for human activities. It has been developed and applied many techniques to meet many requirements. Their purpose is to limit the effect of human to the environment on earth while still ensuring comfort lighting. They can be dimming, renewable energy, internet of things (IoT), etc. to reduce power consumption from the electric grid and make more intelligent for whole systems [1]-[3].

Dimming is a good solution to decrease power consumption and reduce light output of lamp sets. Dimmers has been developed for traditional lamps (such as metal halide) and LED lamps [4], [5]. For LED lamps, dimmers often use pulse width modulation controller to regulate the current through LEDs but they affect to color light due to changing wave length of light, decrease the efficacy of lamp sets and require high technique [6]. Recently, a new prototype of LED lamp sets has been designed basing on using some LED eyes on each set, called LED-eye set. It is the main object to study in this paper and must be had a new dimming method without intervening in rated parameters (current/voltage).

Intelligent lighting has been become the goal of many researches in the world recently. It means that LED-eye sets must be adapt to the change of vehicle density or environment to improve comfort illumination and reduce power consumption [7]. The intelligence can be created by combining many different technologies such as sensors, internet, artificial intelligence (AI) and communication [1]-[3], [8]. It can help LED-eye sets talk to others and have flexible response to different requirements if it has a suitable a dimming technology.

To meet above problems, this paper will propose a new dimming solution applied to LED-eye sets. It will be represented in the next section when combined with other solutions such as hybrid power supplies, AI and smart lighting zone. The last section will show some conclusions about achieved issues.

2. New dimming solution for LED-eye sets

LED-eye sets often have (2÷5) LED eyes, where each LED eye has (50÷70)W-rated power and power is supplied by an individual driver. However, three LED eyes (rated power for each LED eye is 50W) are the most suitable number for LED-eye sets because their light output is similar to 250W-metal halide lamp sets, very popular sets in traditional lighting systems [8].

A new dimming solution is proposed for LED-eye sets based on switching on/off each LED eye as requirements to reduce power consumption and light output. The advantages of this solution are: not intervening to rated parameters (voltage and current) of each LED eye, ensuring rated life time and color light output of whole LED-eye set as designed by manufacturers. Fig. 1 describes an example using a LED-eye set with three drivers (D1, D2, D3) for three LED eyes.

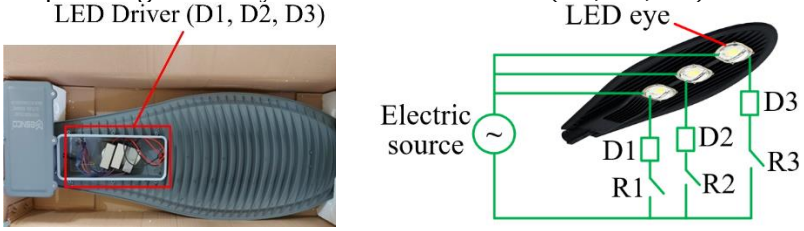


Fig. 1. *Proposed dimming solution for LED-eye sets*

This solution establishes three dimming levels that are 33.3%, 66.7% and 100% (corresponding to 33.3%, 66.7% and 100% power consumption levels). With three levels, light output is fully proportional to power consumption and the efficacy is always constant that makes a difference between proposed dimming and traditional solutions [4]. The light output and energy consumption will be compared between a 150W-LED lamp set and a 250W-metal halide lamp set

in cases of dimming and not dimming. Compared results are represented in Fig. 2 for a normal operating day corresponding to high, medium and low levels of vehicle density: 100% power consumption from 6 pm to 10 pm; 66.7% power consumption from 10 pm to 12 pm; 33.3% power consumption from 0 am to 5 am.

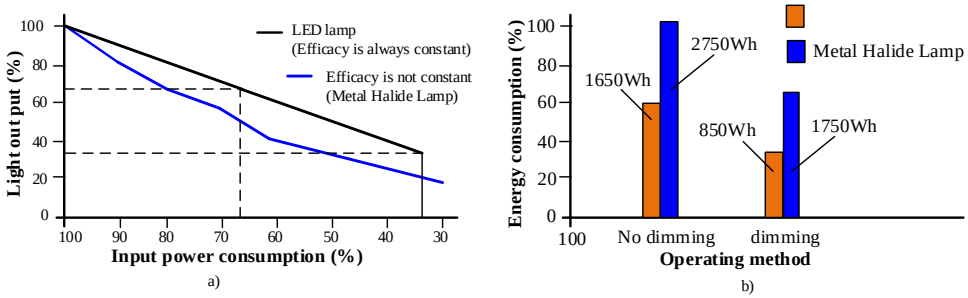


Fig. 2. *Compared results between LED-eye and metal halide lamp sets*

Results in Fig. 2 shows light output from a metal halide lamp set is smaller than a LED-eye set at 66.7% and 33.3% input power consumption (the smaller power consumption is, the larger difference of light output is). Compared to metal halide lamp sets, energy consumption of a LED-eye sets in considered range time only equals 60% in case of not dimming and 48.6% in case of dimming. It means that the proposed solution helps LED-eye sets overcome the light degradation and consume electric power much smaller than traditional lamp sets.

An experimental model using three LED-eye sets was designed in Thai Nguyen University of Technology (TNUT), Vietnam to verify the proposed dimming solution. Experimental results are depicted in Fig. 3.

Fig. 3. *Experimental dimming results*

Results in Fig. 3 show the capability to individually switch LED eyes on/off and color light out does not change all dimming time as required. Because it reduces the working time of LED eyes, the proposed dimming solution also help to increase life time for LED-eye sets in whole operating cycle. It makes high energy and light efficiency as desired.

3. Street lighting approach with new dimming solution

3.1. Hybrid power sources

Power of each LED-eye posts can be supplied from hybrid power sources that are electric grid and renewable generations (wind and photovoltaic) in the half-isolated structure [8]. Only in case of being lack of power from renewable sources (and energy storage), the grid source is automatically mobilized to supply power to lighting posts. A photovoltaic panel and a wind turbine (with power converters) are implemented on each lighting post. Almost amount power from solar irradiance and wind is absorbed to charge to energy storage at daytime. Almost required power of a LED-eye set is supplied by energy storage and apart by wind turbine in night-time [8]. The combination of the proposed dimming and renewable generations is

represented in Fig. 4. It brings high stability for LED-eye sets and helps to reduce large amount power mobilized from the grid.

a. Not working *b. 1 LED eye is on* *c. 2 LED eyes are on* *d. 3 LED eye is on*

Fig. 4. *Working modes for the combination of proposed dimming and renewable solutions*

At a lighting post using a LED-eye set, the most suitable values for rated power are (200÷300) W for the photovoltaic panel and 200 W for the wind turbine. Because power converters become cheaper and more reliable, the hybrid structure can be easy to implement and design its control management system.

To have half-isolated structure for power circuit in a LED-eye post, it must be desiged a automatic switcher and its control signal is calculated by using collected information about instantaneous capacity, available capacity in next time range to have stability, minimum capacity to maintain the ability to work in long time of energy storage. The operation of power circuit is depicted by the algorithm in Fig. 5.

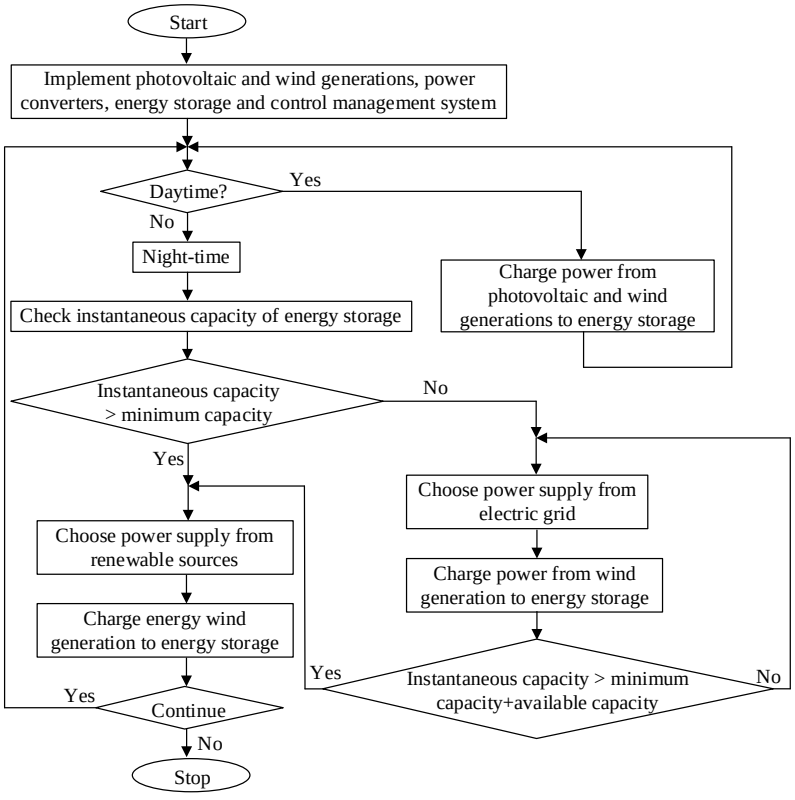
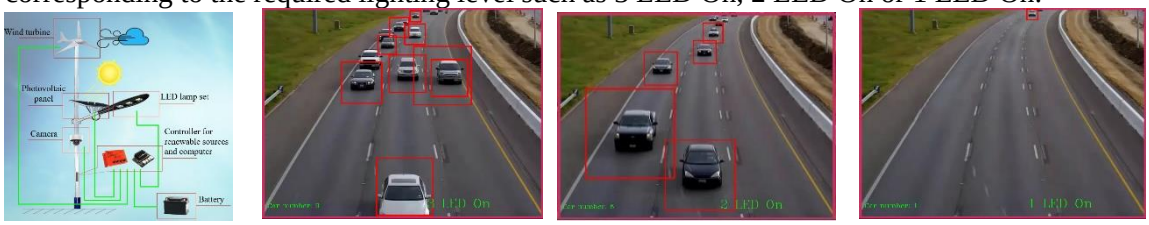


Fig. 5. *Operation of power circuit at a LED-eye post*

3.2. Integration of AI

Switching LED eyes on/off at fixed time ranges can not be suitable for real requirements, locations and different time. Due to the development of AI as haar cascade classifier [9], levels of vehicle density in streets can be identified automatically by using a camera and a small computer at each a lighting post or a group of lighting posts as described in Fig. 6a (with the structure of hybrid sources). Using haar cascade classifier, simulation results are represented in Fig. 6b, Fig. 6c, and Fig. 6d. The number of vehicles is analyzed to three level (high, medium, and low) and switched LED eyes on/off. The number of switched LED eyes is always displayed on the screen corresponding to the required lighting level such as 3 LED On, 2 LED On or 1 LED On.



a. Hardware *b. 3 LED on* *c. 2 LED on* *d. 1 LED on*

Fig. 6. *Simulation results with haar cascade classifier at LED-eyes posts with the participation of hybrid sources*

The cabinet at each LED-eye post can be used some popular controllers such as Programmable Logic Controller, Arduino Controller, Jetson family computer, Raspberry Pi computer,... The haar cascade classifier is the best AI technique to identify the number of vehicle in this system because it can be run by above controllers with low cost and easy to execute. High or low levels of GPIOs (general purpose input output) or digital gates on above controllers will be decided by vehicle density and the balance of working time for all LED eyes. The intervention of AI to the work of LED eyes is represented by the algorithm in Fig.7. It brings an adaptive operating solution to switch LED eyes on/off automatically corresponding to the current traffic state.

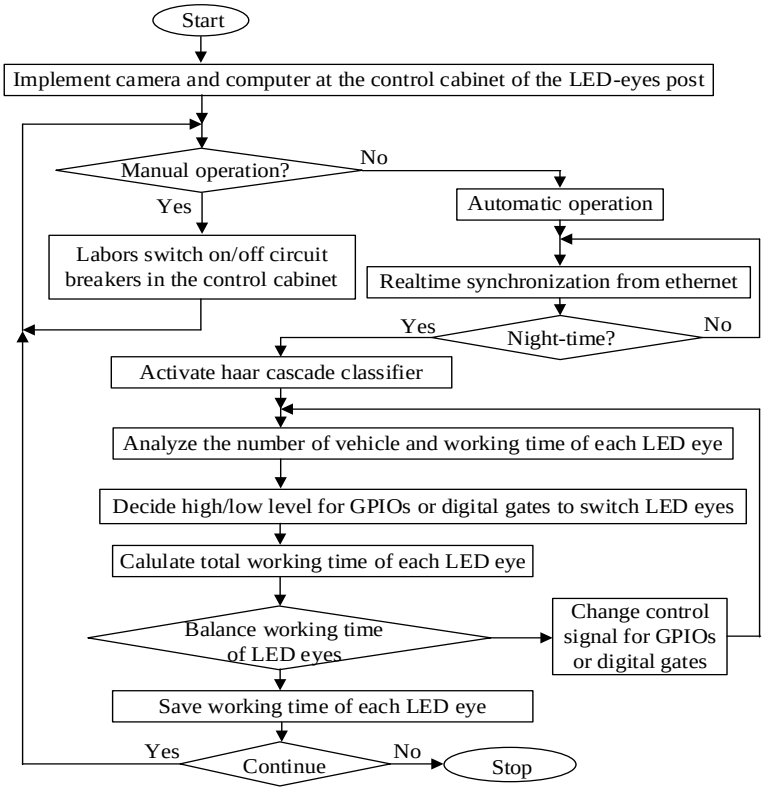


Fig. 7. *Integration of AI to the work of LED eyes*

3.3. Smart lighting zone

Smart lighting zone is a part or whole area managed by a lighting supply company. It makes intelligent capability and reduces cost for labors to operate systems. Lighting in smart lighting zone is executed automatically based on data analysis about natural light, vehicle density and the variation of weather conditions. Due to being operating in a distributed structure, it makes the difference between a smart lighting zone and a traditional lighting zone. Dispatchers will intervene to the smart lighting zone only when receiving special commands from the national power system due to not ensuring power supply or unnormal operating conditions [8]. The structure of a smart lighting zone is shown in Fig. 8.

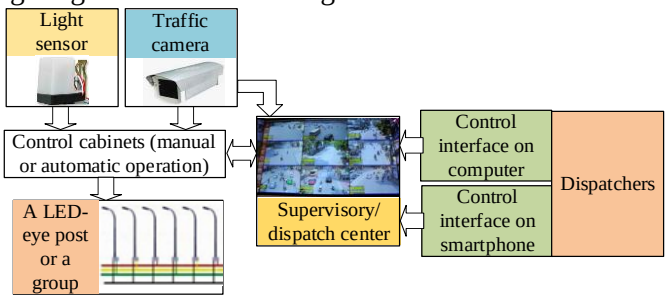


Fig. 8. *Structure of a smart lighting zone*

In Fig. 8, light sensor closes signal circuit when the power of natural light is smaller than allowable value in night-time. It must be noted that night-time changes corresponding to each zone because it depends on weather condition very much. An example for night-time of lighting zone in Vietnam is from 5 pm on this day to 6 am on the next day.

The intervention of AI can change the way to operate groups of LED-eye posts. The information about vehicle density received from the camera and the computer at this LED-eye post can be used to regulate next others. It means that AI in a smart lighting zone can help to create inheritable phenomenon for a series of LED-eye posts as represented in Fig. 9.

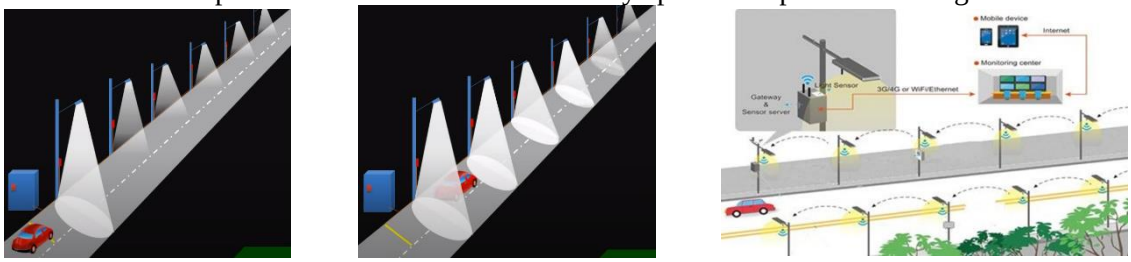


Fig. 9. *Inheritable phenomenon for a series of lamp posts in smart zone*

Lighting demands at different areas are also different due to the variation of weather conditions. Sensors can be combined with AI at some LED-eye posts to have information about the decrease of natural light and help them talk to others [8]. All LED eyes in a smart lighting zone can be controlled to balance total working time that ensure the equalization of life time for each LED eye. It must be connected to ethernet to synchronize data in whole system. Keeping pace with intelligent trends for all fields, smart lighting zone will bring many benefits for managers and the environment to lengthen lives on the earth.

4. Conclusion

This paper proposed a new dimming solution for lamp sets having some LED eyes based on switching on/off each LED eye. The purpose of this solution is to reduce power consumption and light output of each LED-eye set at times that does not need artificial lighting much, lengthen life

time. It aslo makes high stability for whole LED-eye sets that don't affect much to comfort illumination. Experimental results executed in TNUT showed the accuracy of above feasibilities and the high ability to implement in real lighting systems. The proposed solution can be used to design modern and simple dimmers for lamp sets having some LED eyes to replace traditional dimmers.

Basing on the new dimming solution, this paper also proposes to apply other hardware and software solutions to limit power consumption from electric grid and enhance the intelligence for whole lighting system. They are hybrid power sources (combining with renewable energy and energy storage), camera and small computer with the intervention of AI at LED-eye posts to identify vehicle density and the topology of smart lighting zone. These solutions can help electric grid at each LED-eye post work as an half-isolated power supply structure and switch on/off each LED eyes automatically. Simulation results in this paper shows that the participation of AI (haar cascade classifier) can help to analyze vehicle density and decide the working modes of all LED eyes in each lamp set or group of each lamp sets without requiring high speed computer. Combining with technologies of IoT, all LED-eye posts can talk to others to create a smart lighting zone that switch on/off LED eyes automatically corresponding to the speed of vehicle to increase comfort illumination.

This paper created a new approach with some solutions to design dimmers for LED lamps and dispatch real lighting systems. These solutions help to solve the problem of power shortage, reduce pressure of using fossil fuels or destroying environment to build new power plants and reduce the effect of artificial light to creature. They must be continued to study more deeply and applied other technologies in the 4.0 revolution to improve the intelligence and meet requirements of energy efficiency and comfort illumination for human's activities.

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