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Daylight perceptive lighting and data fusion with artificial neutral network

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ABSTRACT

The basic concept of daylight perceptive is that the artificial light automatically dims to the appropriate level to keep constant indoor illumination when sufficient daylight is not available. Energy efficient character of daylight perceptive lighting was analyzed and a method to evaluate energy saving was present; according to the presentation, the more energy is saved if the longer T_{last}—duration of indoor illumination being is less than threshold. A daylight perceptive controller was developed and the output power of LED light source under different PWM was measured, according to the measurement, work current and output power of LED is proportional to duty cycle. With two sensors, a data fusion method was put forward to exclude interference and improve lighting comfort. With more than two sensors, data fusion based on neutral network was discussed.

1. Introduction

The problem such as energy crisis, global warming, and aggravation of environment are all linked to the excessive energy consumption and unreasonable energy structure, which makes the energy-saving issue attracted great attention around the world. At present lighting constitute19% of the total global energy consumed. Considering the current lighting equipment and technology which are used widespread, energy-saving lighting has a broad improvement space. The following measures can be taken: the development of efficient illumination sources and lamps, optimal lighting design, making daylight into the workplace where sunlight is not easy to enter such as underground, supermarket, and parking etc., by optical fiber or light pipe [1–3]. The effects of sunlight should be considered adequately in lighting design, because of its advantages such as inexhaustible and clean. Research and apply of lighting technology corresponding to daylight lighting help energy saving and environment improvement. Therefore, daylight lighting technology is drawing great attention and the scope of application is expanding increasingly.

2. Daylight perceptive lighting and its energy efficient characters

Considering gradient character of sunlight with time, daylight perceptive lighting system adjust luminous intensity of artificial light source through automatic control technology, referring to illuminance threshold, to keep indoor illuminance constant both energy-efficient and comfortable lighting effects are realized. Illuminance is a key parameter to evaluate effect of lighting, higher the light source luminous intensity is, bigger the illuminance on work surface becomes. When illuminance bellows to a value, called threshold illuminance in this paper, the normal activity of human beings are affected so that the attention cannot focus the study and the work efficiency decreases. Compared with traditional lighting technology, the energy efficient character of daylight perceptive lighting can be illustrated through Fig. 1. Indoor illuminance decreases to threshold at time t_5 on evening, daylight perceptive lighting system begins to adjust output power of light source being bigger, it is completely dark until time t_6 and output power of light source becomes maximum, duration of t_6-t_5 is presented by T_{last}. To traditional lighting system, its output power of artificial light source is unchangeable; the power consumption of the system is constant p_{const}. From time t_5 to t_6, $p_{lamp}(t)$ stand for instantaneous power consumption of daylight lighting system, $f_{sun}(t)$ stand for indoor instantaneous illuminance only came into being by sunlight. Similar method can be used to analyze the situation down, from time t_1 to t_2, although change of indoor illuminance and artificial light output power are all contrary to situation at evenings.

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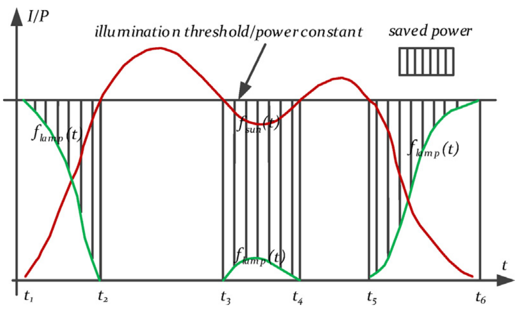

Fig. 1. Sketch curve between indoor illuminance and output power of light source at evening.

Between t_3 and t_4, dark clouds might shelter the sun and result in illuminance dropping below threshold.

As for daylight perceptive lighting, from t_5 to t_6, energy consumption of artificial light source can be written as

$$p_{\text{used}} = \int_{t_5}^{t_6} p_{\text{lamp}}(t)\,\mathrm{d}t \tag{1}$$

As for traditional lighting, energy consumption of artificial light source can be written as

$$p_{\text{tra}} = p_{\text{const}} \times (t_6 - t_5) \tag{2}$$

The saved energy caused by daylight perceptive lighting can be written as

$$\begin{aligned} p_{\text{saved}} &= p_{\text{tra}} - p_{\text{used}} \\ &= p_{\text{const}} \times (t_6 - t_5) - p_{\text{used}} \\ &= p_{\text{const}} \times (t_6 - t_5) - \int_{t_5}^{t_6} p_{\text{lamp}}(t)\,dt \end{aligned} \tag{3}$$

According to the integral mid-value law, $\exists \varepsilon \in [t_6, t_5]$, following equation can be derived:

$$\begin{aligned} p_{\text{saved}} &= p_{\text{const}} \times (t_6 - t_5) - p_{\text{lamp}}(\varepsilon) \times (t_6 - t_5) \\ &= [p_{\text{const}} - p_{\text{lamp}}(\varepsilon)] \times (t_6 - t_5) \end{aligned} \tag{4}$$

As the sun sinking, shown in Fig. 1, indoor illuminance is monotonic decreasing and $p_{\text{lamp}}(t)$ is monotone increasing, then $p_{\text{const}} - p_{\text{lamp}}(\varepsilon) > 0$. It was concluded that the longer $t_6 - t_5$ is, the more energy is being saved. Relative to the traditional constant power lighting, daylight perceptive lighting saves more energy in cloudy days because of its longer $t_6 - t_5$. Considerable energy can be saved, if indoor daylight is insufficient for a long time and need artificial light to compensate indoor illuminance.

3. Daylight perceptive lighting system

Daylight perceptive lighting system compromises the automatic control technology, consisting of sensing unit, processing unit, execution unit, and light source, which form a closed-loop lighting control system. Sensing unit measure the illuminance of the work surface, processing unit transfer the illumination into a control signal through control algorithm, and the execution unit adjust the brightness of the light source according to the control signal. Based on the PWM dimming technology, a daylight perceptive lighting controller was developed, shown in Fig. 2. The controller makes the illumination as the control parameter and the light source as the control object, and dynamically adjusts the luminous intensity of the light source when sunlight increases or decreases gradually in the morning or evening in order to maintain the indoor illuminance stable. Considering the contribution of gradient sunlight intensity to indoor lighting and adjusting output power of artificial light, daylight perceptive lighting saves energy compared to traditional lighting. Artificial light source dimming performance and synchronism of luminous intensity change with working current is important to keep constant indoor illuminance control effect. If variation of artificial light intensity lag behind its working current, as sodium lamp behave, intensity of light lag behind control command, giving rise to fluctuation of indoor illumination and making equiluminous control effect difficult. As next generation artificial lighting source, light-emitting diode (LED) has excellent dimming synchronization character and wide dimming range, besides high luminous efficiency and long life, these make LED compatible with daylight perceptive lighting.

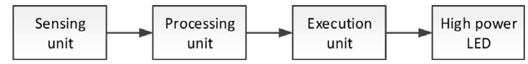

Fig. 2. Block diagram of daylight perceptive controller for LED.

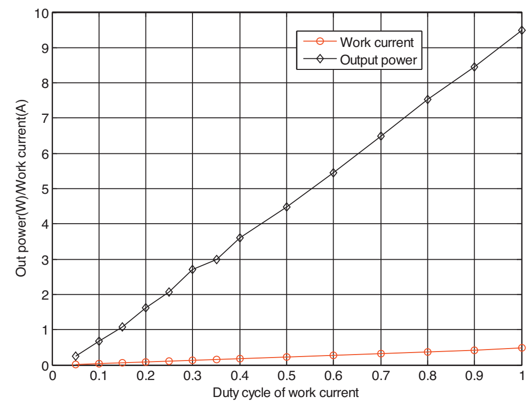

Fig. 3. Relationship between power and duty cycle of LED daylight lamp.

Through the controller, shown in Fig. 2, working current of a LED daylight lamp with different duty cycle was measured and the result was presented in Fig. 3. Output power of light source was calculated by $W = UI$, U being constant at 20 V and supplied by DC power supply Agilent 5750. U was input through direct-current input pin, and then was transferred into PWM current by the execution unit to drive LED light source from PWM current output pin allocated on the controller. As shown in Fig. 3, both work current and output power of LED daylight lamp are proportional to duty cycle. So taking full advantage of sunlight and applying appropriate duty cycle, dimming artificial light and keeping indoor illuminance constant, reduce output power of light source and saves energy. Fig. 4.

4. Illuminance control issue

As mentioned above, daylight perceptive lighting system consists of processing unit, execution unit to drive high power LED, sensing unit, and artificial source-high power LED. Sensing

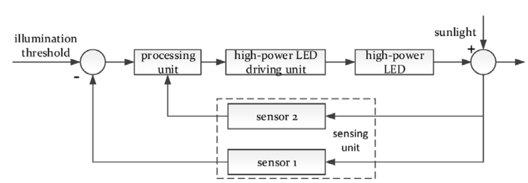

Fig. 4. Block diagram of illuminance control system.