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Using solar energy by a smart window for the needs of urban residents

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ABSTRACT

The study is devoted to the development of the device working on solar cells with the function of dust collection and possibility of controlling the light and heat, as well as a sound flow into the room. The aim of this development is to increase the profitability of the device and consumer attractiveness of the device, using solar energy in urban environments. Solar panel and the protective plate location height with respect to the window are controlled by the prescribed scenarios on the Arduino controller. In the work, technical solutions for the device mounting and movement of mobile modules were selected; together with option of using an additional green block from a roll lawn was developed. Simulation of the technical part of the device was performed in the AutoCAD Mechanical. It was also designed a valid device model of 1:5 scale for testing implemented functions. This device can be used to improve the ecology of cities located between 35° and 55° latitudes.

Selection and peer-review under responsibility of the scientific committee of the 7th International Conference on Nanomaterials and Advanced Energy Storage Systems.

1. Introduction

According to the global sustainable development goals [1], it has been taken a policy to increase the share of green energy in Kazakhstan in the context of improving the environmental situation described by Baizakova in the paper [2]. In cities where environmental degradation is particularly pronounced, the use of renewable energy sources in residential and office buildings can lead to a reduction in greenhouse gas emissions which is described by Panopoulos in the work [3] and improvement of the environment. Traditionally, solar panels are installed on the roofs of buildings. However, in large cities where mainly high-rise buildings are located, it is more efficient to use the facade of buildings rather than roofs.

In order to assess the consumer demand for the use of facade modernization technology, there were conducted surveys on the feasibility of ecological construction which were presented by Venkataraman [4] and Berawi [5] and an approximate cost of maintaining green buildings was calculated by Lung [6] and Yin [7].

Different countries are currently developing various types of prototypes for the use of facade areas for different latitudes like it was made in the work [8] by Mikhailov. For example, a prototype of a multifunctional smart window using a combination of photovoltaic blinds with a building ventilation system was developed by Jung in the paper [9], and Riaz in the work [10] the thermal energy emitted by solar panels was used for heating and cooling of the rooms. At the same time, the inclusion of solar photovoltaic systems into the facades of a residential villa was carried out by Farrag in the paper [11]. Papers [12] and [13] by Dussault and Papathanasopoulos, correspondingly, show control systems where the transmission of radiation by electrochromic windows was designed and simulated.

Simultaneously with the use of solar energy, there are prototypes of the location of vertical gardens on the facades of buildings described by Davis in the paper [14] as an alternative cooling device for a hot climate. Of course, modernization of the facades of residential buildings, and their maintenance will fall on the shoulders of consumers, but according to Ofek in the work [15] in Israel consumers prefer the "green" building rather than a traditional building, and they were ready to pay 30% more for it than for a traditional one.

However, despite the various options of technical solutions for the modernization of facades, in the work [16] by Aigbavbo, residents and workers of buildings with "green facades" were dissatisfied with the quality of the environment inside the room. In particular, people noted the ineffectiveness of blocking natural light, which affected performance and productivity.

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In this paper it is proposed to use solar panels mounted to the facade of the building to regulate the illumination and sound flow into the room. The relevance of the design is related to the global sustainable development goals [1], namely: Goal 11 - aimed at improving the ecology of cities, Goal 7 - promoting the use of clean energy and Goal 13 - measures to combat climate change.

2. Results & discussion

The developing device has a modular principle to simplify operation and consists of a main frame module, 2 solar cells with an 0.85 m^2 area and 125 W of power rating, a transparent dielectric protective plate on which a charging potential is induced, a mobile unit with vegetation (roll lawn), a cleaning unit and an automation unit that is connected to general electrical circuit of the device.

One of the features of the developing device, 3D layout of which is shown in Fig. 1, is an ease of operation. There is no need to order special equipment to mount all the modules.

As can be seen from Fig. 1, the device is mounted through a window on the facade of a residential or office building. The panels can move up and down along the guide pin located at an angle 5-10° (depending on the opening depth of the window) with respect to the facade of the building. The movement of the cells and the protective plate is limited at the bottom by the solar cells, and above - by the window size. Presence of a mobile protective plate made of Plexiglas (3 mm), which protects the front surface of the solar cell from contamination in a passive mode, and allows blocking sound flow and excessive natural lighting into the room from the street when picked up by a metric screw gear made on a fastening stud. An additional function of the protective plate is to trap dust particles from the external environment like it was proposed in the paper [17] by Mikhailov, which are held on the surface of the panel by induced potentials from the external electrode and periodically cleaned by the wiper. In addition to the direct cleaning of the front surface from dust, the wiper removes the electrostatic potential from the panel surface allowing carrying out a cycle of induced charge on the dust particles and their subsequent collection again.

The device control system, in other words a smart window, runs on the basis of an Arduino controller using arbitrary logic (scripts) for various events in and out of the room. These events include: a) day and night cycles, b) presence and absence of permissible noise levels according to the State Standard of Kazakhstan Republic [18] c) presence and absence of excessive natural light according to the Building Regulation of Kazakhstan Republic [19] d) presence and absence of precipitation in the summer/winter period, e) the presence and absence of wind. Depending on the chosen scenario, the work varies: the height of the raising of the solar cells and the protective plate; the magnitude of the applied charging potential on the plate; frequency of cleaning the front surface of the plate by wiper; blocking of functions in case of emergency.

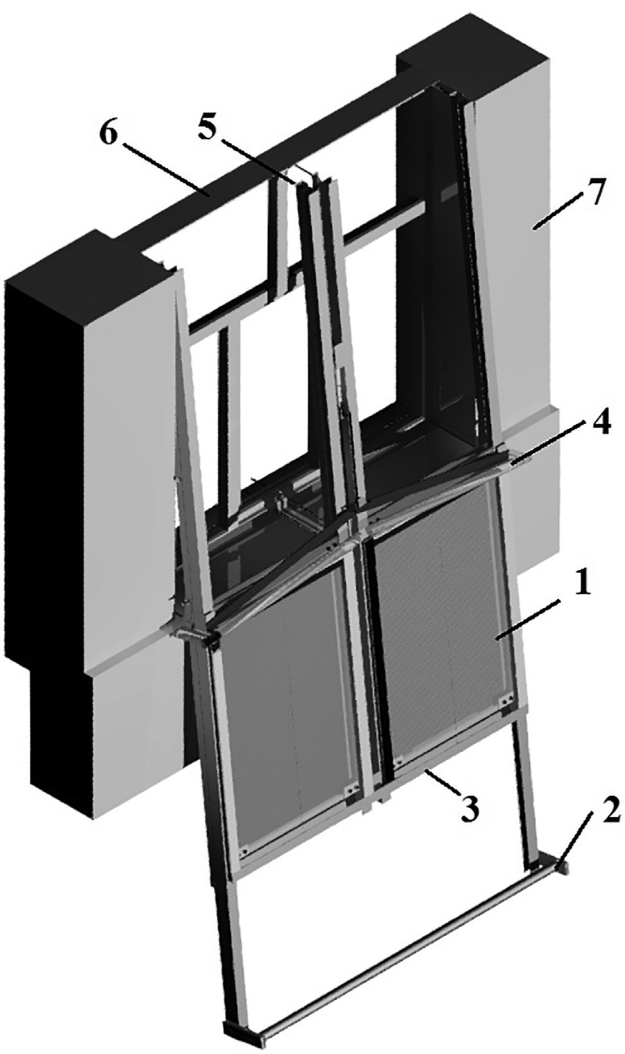

Fig. 1. 3D layout of the developing device, made in AutoCAD Mechanical. 1 – solar cell; 2 – high-voltage charging electrode; 3 – mounting of dielectric plate; 4 – washing unit with a wiper; 5 – corners on which solar cells can move; 6 – window frame; 7 – outer facade of the building

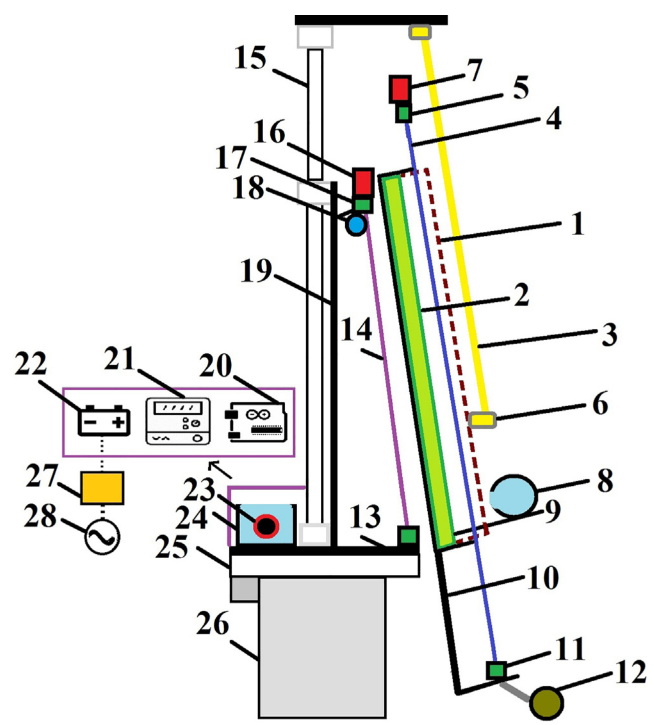

Fig. 2. Diagram of a variant of the device with a green unit. 1 – solar cell; 2 – "green" unit; 3 – protective plate; 4 – pin on which the protective panel moves; 5, 11, 17 – bearings, 6 – rubber for cleaning the front surface of the solar panel; 7, 16 – gear motor, 8 – flush wiper; 9 – mounts of flushing wiper; 10 – mounts of the solar cell and the "green" unit (corners); 12 – charging electrode; 13 – mount of the device through the window sill; 14 – pin for the movement of solar cells and the green block; 15 – window; 18 – key block; 19 – vertical mounting device; 20 – Arduino controller; 21 – the controller; 22 – battery; 23 – pump; 24 – a tan with water; 25 – window sill; 26 – wall (facade); 27 – power supply; 28 – power network. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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In addition to the listed functions and units, an option for vertical gardening is being developed to add as a unit (Fig. 2).

According to Fig. 2, for the selected window it is proposed to use 2 solar cells, one of two panels can be replaced with unit of plants (in the model it is planned to use a rolled lawn), which will perform decorative functions, increase the humidity of the air, collect dust and carbon dioxide.

Currently, a working model of the developed device has been manufactured, reduced to a 1:5 scale, as well as a full-size device layout.

Since the device will experience sufficiently rigid mechanical loads from gravity and wind, the frame is made of a durable, corrosion resistant material - duralumin of the brand AD 31. As shown in Fig. 2, F10 studs are stretched through the window frame, pressed by clamps to the walls of the building, the ceiling and window sill. In the maximum configuration, which content 4 solar panels and 2 green panels, the maximum weight of the structure is 80 kg, 20 kg of which is the weight of the frame. The whole structure is designed for 200 kg (kilogram force), as a precaution, because the structure may be affected by dynamic (shock) loads, wind loads or snow sticking. In addition, it can be calculated so that the structure can additionally support the weight of one person in case of emergency (fire).

Four bearing corners are attached to the studs, along which the solar cells and vegetation unit move. For 5–10 min (depending on the dimensions of the device) the panel moves from one extreme position to another, absorbing no more than 2 W•hour of electricity from the battery to overcome friction forces in a pin with metric thread, friction in the gearbox and gravity of the panels.

The use of the system is intended for cities located in mid-latitudes (between 35° and 55° latitudes, i.e. where it is necessary to store heat), such as Almaty, Beijing, Seoul, etc., where environmental problems are particularly vital.

3. Conclusion

In the work the possibility of control of excessive light and sound fluxes which coming into and out of the room with the possibility of self-cleaning and dust collection through a smart-window device in a household window system using solar energy were justified.

In the work, technical solutions for mounting the device and mobility of the units were selected, and the option of using an additional green unit from the lawn was developed. The simulation of the technical part of the device was performed in AutoCAD Mechanical. Also, a device layout was designed, executed on a 1:5 scale for testing the implementation of developing consumer functions. This device can be used to improve the ecology of cities in the middle latitudes.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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