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Solar Panel Mechanical Cleaning Systems in Commercial Buildings

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Abstract
Solar energy is the most common supply of energy for all kinds of life on Earth. It is also the fundamental source of all energy sources except nuclear energy. However, solar technology has not progressed to the same level as traditional energy sources. It has several obstacles, including high costs, irregular and unexpected weather, the necessity for storage, and low efficiency. Thus, this paper explores and discusses the components and materials of solar panels, the assembling and assembling, and the market potential for solar panel mechanical cleaning systems in commercial buildings. A simulation method through the application of Google SketchUp Pro 2021, Keyframe Animation, and Windows Movie Maker for the demonstration enhanced the visual of the potential innovation product of solar panel mechanical cleaning system. It offers to create a Solar Panel Mechanical Cleaning System that regularly clears the collected dust on its surface while maintaining the performance of the solar power plant. The structure is a mechanical system that can move autonomously on the surface of solar panels using dry cleaning techniques such as a rotating cylindrical cloth and a squeegee while keeping in mind the limited availability of water in areas where such plants are mostly found. This initiative also intends to eliminate human interference in the solar panel cleaning operation, as it is a dangerous environment for workers under the blazing heat.
Keywords: Commercial Building, Mechanical Cleaning, Solar Panel.

Introduction

Construction Industry Development Board Malaysia (CIDB) has often taken a proactive approach to address the matter of sustainable construction and assisting stakeholders in its implementation. The CIDB created a technical committee back in June 1999 to examine creating excellent environmental standards in the building sector. Environmental specialists from government agencies, professional organisations, academia, and construction-related associations make up the Technical Committee 9 on Good Environmental Practices in the Construction Industry (TC9) (Rostami et al., 2015). However, the Current development framework from Twelfth Malaysia Plan, 2021-2025 is also focused on a low-carbon, clean, inclusive, and resilient development strategy. It aims to cut greenhouse gas emissions intensity to GDP by up to 45 percent by 2030 (depending on emission levels in 2005) as part of an attempt to become a low-carbon country and migrate to a circular economy (Economic Planning Unit, 2021). Green technology is the creation and deployment of goods, tools, and methods used to protect the natural environment and supplies while reducing the negative effect of human activities and meeting the five requirements of Green technology, as such (I) reduces environmental degradation; (ii) emits zero or low levels of greenhouse gases; (iii) is safe to use and supports a healthy environment for all forms of life; (iv) conserves energy and natural resources; and (v) encourages the use of renewable resources (Kamaruzzaman et al., 2012)

Adding to that, Renewable Energy (RE) for power generation is also regarded as one of the most efficient ways to assist the climate change policy and long-term growth (Gielen et al., 2019). Therefore, back in 2009, the government of Malaysia through the Sustainable Energy Development Authority (SEDA) announced The National Renewable Energy Policy and Action Plan (NREPAP) with the vision of 'improving the usage of indigenous renewable energy (RE) resources and contributing to national electricity supply security and sustainable socioeconomic development in order to achieve 20% renewable energy capacity mix by 2025 and also as an alternatives energy sources for the coming years (Sustainable Energy Development Authority, 2008). This strategy also has significant benefits in terms of minimising environmental consequences, especially climate change. Given the severe consequences of climate change, this strategy has advocated for the passage of the Renewable Energy Act 2011 (Act 725), which concentrates on the implementation of renewable energy for power generation in Malaysia. Under initiatives of Sustainable Development Goal (SDG), potential product development through the development of a mechanical cleaning system for solar panels is supporting the idea of SDG number 7 aims in ensuring access to affordable, reliable, sustainable, and modern energy for all users. Fostering sustainable industries, as well as investing in scientific research and innovation, are all important strategies to aid in sustainable development through boosting resource and energy efficiency (United Nations Department, 2020).

Solar Panel Mechanical Cleaning System

High-rise buildings as a structured form are a nineteenth-century technical invention in reaction to economic, industrial, and social developments. The tremendous rise of the major countries' economies contributes to the creation of large cities. Population density is growing as a result of extensive internally and externally migration to major cities. As a response, the number of modern multi-story and high-rise buildings is expanding, and engineering and transportation infrastructure is evolving at a breakneck rate (Giyasov and Giyasova, 2018). High-rise building is now a metropolitan phenomenon that cannot be ignored without having an impact on urban development. It is obvious that a variety of considerations such as population, land value, worldwide image, and sustainability are driving forces for tall buildings (Baiz et al., 2017). The capacity of the glass cover to enable light to pass via the compilation area affects the effectiveness of the solar energy system. Because PV modules are installed in accessible areas, they are vulnerable to circulating air, which contains dust, rain, snow, and another molecule (Ndiaye et al., 2013). As a result, the correct form and characteristics of solar panel cleaning must be included particularly for solar PV panels. The goal of a solar panel cleaning system is to increase the peak power production of solar panels while reducing the strength of human workers.

With rising energy consumption and climate change being driven using fossil fuels, there seems to be a massive rise in renewable energy sources like direct utilisation of solar radiation via photovoltaic cells (solar panels) (Ohunakin et al., 2014). Solar energy is extremely abundant as a major energy source. Solar cells produce a brilliant night light for several functions, such as streetlights. These, on the other hand, are susceptible to deterioration in efficacy due to aspects such as location, environment, and weather conditions. Other factors involve dust accumulation on panels, shadowing from objects like as trees and buildings, seasonal variations, weather influences like snow, rain, and cloud, and animal migratory paths near the production site (birds, for example) (Mekhilef et al., 2012). The impurity of panels produced by these pieces influences the output voltage of the panel and thus the source of electricity (Zorrilla-Casanova et al., 2011).

A build-up of dust particles, bird droppings, or fallen leaves on the area of a photovoltaic PV panel may distort incident light, prohibiting a few of the power from being used. This problem may degrade cells' ability to enable the free entrance of photons and capture solar energy, reducing the lifespan of their storage power after several months of installation and leading to a long-lasting or long-term malfunction, especially in drylands. Due to dust, sand, and algal blooms bits on the surface of solar panels, their productivity has been seen to reduce by up to 85 %, needing frequent cleaning to sustain production levels (Sulaiman et al., 2014). Contamination-induced masking is divided into two types: gentle shading generated by air pollution and severe shading produced by other variables (Maghami et al., 2016). Light transmittance fluctuates with physical attributes and dust kind, like particle sizes, resulting in changes in PV panel efficiency (Abderrezek and Fathi, 2017). Dust is comprised of particles of various sizes and compositions (Altıntaş and Arslan, 2021). Several dust particles cause particle grouping in the dust coating because of ionic charges, which might impact adhesion to hard substrates. Therefore, the amount of effort and power needed to extract dust particles from panels may rise significantly (Yilbas et al., 2019).

Changing the dust coating to lower surface adhesion, which assists in the cleaning process, is one passive strategy for cleaning solar panels (Sayyah et al., 2017). Cleaning operations for PV panels have used a range of technologies, and different ways are being invented when standard cleaning methods are inadequate or harmful. Natural forces such as wind and rain will clear the dust. Mechanical tools, self-cleaning nano-films, and electrostatic devices are employed. As a response, adequate solar panel cleaning methods and functionalities, notably for solar PV panels, should be supplied. The goal of a solar panel cleaning system is to enhance the peak energy production of solar panels while reducing the power of human labor (He et al., 2011). Therefore, this paper explores and discusses the current situation of solar panel dust accumulation, current techniques of dust removal in solar panel modules, and the market potential for solar panel mechanical cleaning systems in commercial buildings.

Research Methodology

The simulation of the innovation idea is made by using a sketching application which is Google SketchUp Pro 2021. Google SketchUp Pro 2021 is a 3-dimensional (3D) design software that is commonly used to create desirable design ideas to visualize 3D imagery of an object. For the solar panel mechanical cleaning systems, each component was drawn and sketched in the Google SketchUp Pro 2021 to construct the solar cleaning panel in 3D to create the imagery of the innovation idea before realizing the innovation idea into a prototype. Google SketchUp contains extensions that create animations of the 3D design.

One of the extensions that were used to create animations for the innovation idea is Keyframe Animation version 2.0.12 which allows the object to be movable and create motion from one place to another. Another application was used to create the combination of the operational demonstration. The video application Windows Movie Maker may allow several videos of movement to be combined into one. The application of Google SketchUp Pro 2021, Keyframe Animation, and Windows Movie Maker for the demonstration enhanced the visual of the innovation idea to suit the features and characteristics provided in the innovation idea as a solution to the problems identified. The operation of the innovation idea is demonstrated by using Windows Movie Maker which was animated by using Keyframe Animation provided in Google SketchUp. The movement of the solar cleaning panel is presented in the demonstration.

Results and Findings

Components and Materials of Solar Panel Mechanical Cleaning System

The solar cleaning panel comprises eight components and materials as shown in Table 1. The first component is a frame with dimensions of width is 0.4 metres, and a length is 2 metres, which is the breadth of the spool and the distance reserved for the power system. Second, stainless steel rotisserie rod and microfiber-based cloth wiper on the solar panel using a central bevel/mitre gear mechanism. A pulley rotates a long, central pinion gear, which drives the microfiber-based cloth wiper to clean the solar panel when the mitre gear mechanism is engaged. This design aims to increase the productivity and efficiency of the solar cleaning panel. Third, a stroke linear actuator is used to convert the rotatory motion of the stepper motor into linear motion. Fourth, the proximity sensors were used to detect if the frame has reached the end of the array on the X-axis. Fifth, an L-shaped metal angle bracket attached the V-wheel assembly to the aluminium alloy frame using screws. Sixth, the squeegee is used to remove or control the flow of fluids on a solar panel. Seventh, C-clamp is used to clamp the aluminium alloy panel frame and stainless-steel rotisserie rod. Last components, as a result, the V wheel assembly is rotated perpendicular to the x-axis to clean another solar panel.

Table 1
Components and Materials of a Solar Panel Mechanical Cleaning System

Components and Materials	**Descriptions**
1. Aluminium alloy panel frame	The proportions of the frame were chosen to cover a fourth of the plant's surface area. The plant's width is 0.4 meters, and the length is 2 meters, which is the breadth of the spool and the distance reserved for the power system.
2. Stainless steel rotisserie rod and microfiber-based cloth wiper	The rotisserie rod design rotates a microfiber-based cloth wiper on the solar panel using a central bevel/mitre gear mechanism.
3. Stroke Linear Actuator	A linear actuator converts the rotatory motion of the stepper motor into the linear motion
4. Proximity sensors	To detect if the frame has reached the end of the array in the X-axis.
5. Bracket L	Polymer constructed to link two pieces at a 90-degree angle
6. Squeegee	to remove or control the flow of fluids on a solar panel

7. C-Clamp	A fastening device is used to hold or secure objects tightly together to prevent movement or separation through the application of inward pressure.
8. V Wheel Assembly	Allow large objects to be moved easily, allowing movement or transit while bearing a weight

Simulation and Assembling Method of Solar Panel Mechanical Cleaning System

Figure 1 shows the simulation and assembling method of solar panel mechanical cleaning systems in commercial buildings. The frame of dimensions of 2m by 0.4m covers the entire module at a time with two motors, one to move the frame horizontally along the array and the other to move the robot body vertically, and two proximity sensors to stop the frame when it reaches the array's edges, and an encoder to start the cleaning cycle after a certain distance. The frame attaches the horizontal steel aluminium to the panel frame using brackets and screws it using bolts and nuts. In conjunction with axles, V wheels allow large objects to be moved easily, allowing movement or transit while bearing weight. A C-Clamp is used to clamp the aluminium alloy panel frame and stainless-steel rotisserie rod. The v-wheels are attached for movement upward and downward. Lastly, the battery is attached to the DC motor on the top of the panel frame. Due to the motors chosen to be DC motors, the high-speed motor requires 24 volts to run at its rated speed while the other requires 12 volts, two 12-volt batteries are required.

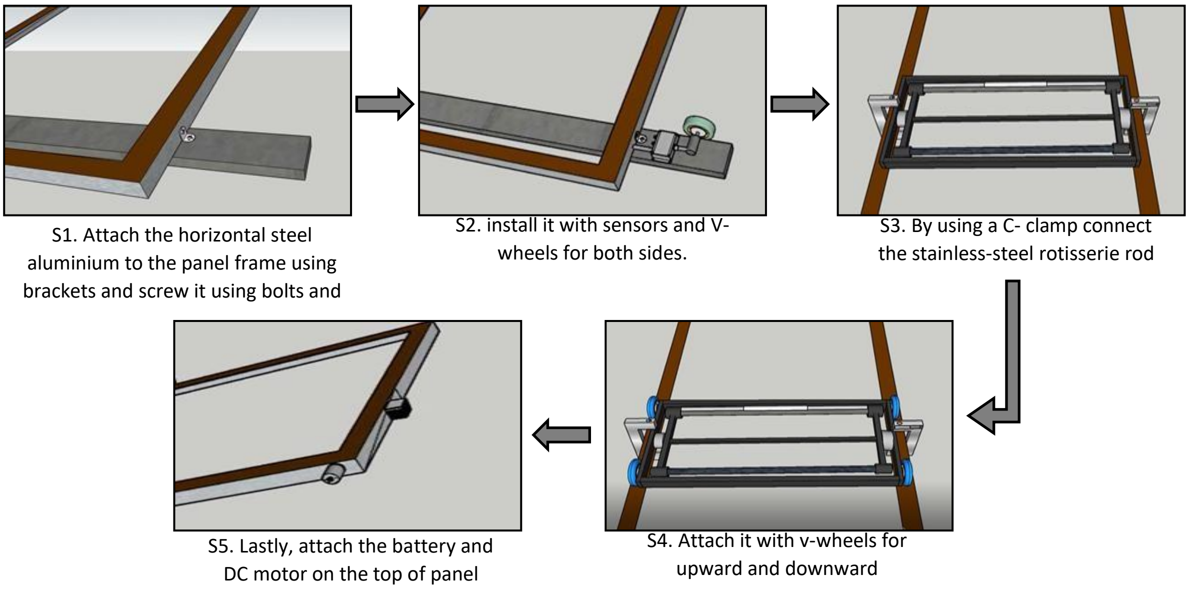

Figure 1: Simulation and Assembling Method of a Solar Panel Mechanical Cleaning System

Operation Process of Solar Panel Mechanical Cleaning System

Figure 2 shows the simulation operation process of a solar panel mechanical cleaning system in a commercial building. The mechanical cleaning system, which is designed to clean dust and undesirable particles from the surface of the solar panel, cleans the panel surface using a microfiber cloth and a squeegee. The mechanical system is made up of sensors, which will inform when the output of the solar panels falls below a certain threshold. An illuminance sensor is used in the mechanical cleaning system to assess light intensity. Furthermore, impacting aspects such as temperature and humidity are detected by temperature and humidity sensors, respectively, while a dust sensor records dust density. These sensors are integrated into a single sensor component at the same time. When the solar panel's performance falls below the stated limit, the mechanical system is supposed to emit a 'time to clean' signal.

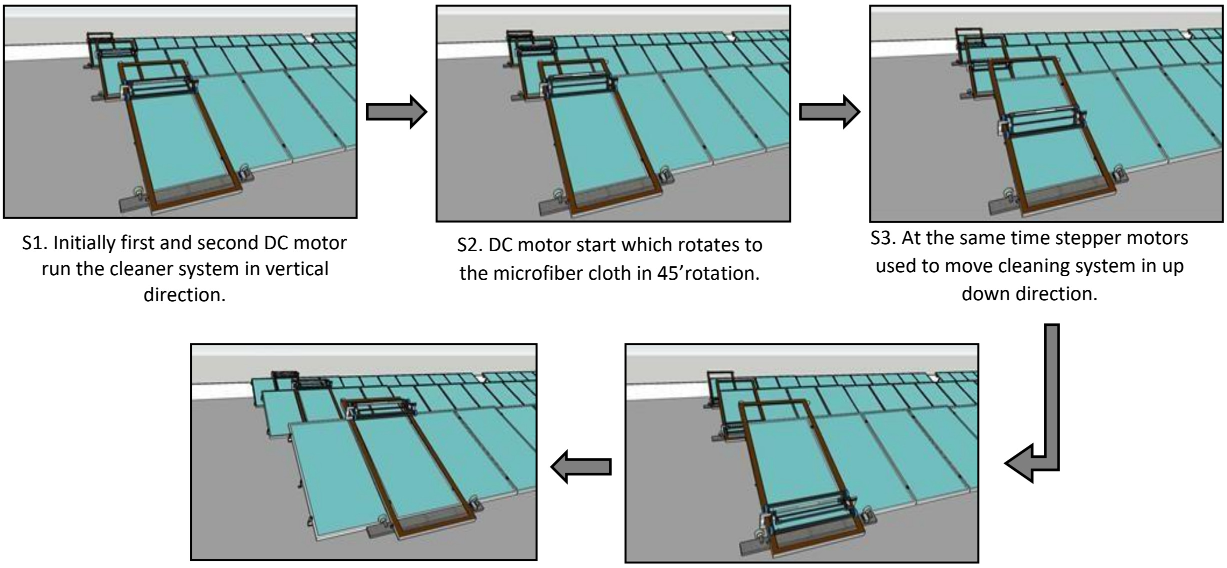

Figure 2: Simulation Operation Process of a Solar Panel Mechanical Cleaning System

The mechanical cleaning system cleaned the whole array by traveling along the length of an array of panels. The mechanical cleaning method cleans along a row of panels using a rotating array of microfiber cloth. The mechanical cleaning system goes back and forth on the centre spline. The cylindrical microfiber cloth is attached to a revolving stainless steel rotisseries rod, spun by the primary drive dc motor. It pushes the dust to move in the direction of the cleaning system's action throughout the whole journey, eventually blowing it away at the panel's edge.

The system will be propelled by a V wheel assembly powered by a dc electric motor. The wheels then advance in a path parallel to the edge of the solar panel until they reach the unclean area of the panel. Following this, the mechanical cleaning system is started again, and the procedure is repeated until the whole array is cleaned. Once one array of solar panels has been cleaned, it is transferred to another array. Using a single motor saves money and simplifies things. However, the driving dc motor must generate a high torque to work correctly. A series of lighter cleaning cycles will be employed rather than a single more thorough cleaning to decrease stress on the system and the panel surface. This machine will move across a row of panels before returning to its initial location. A battery will run the machine. The battery will have a shorter operating life than the bulk of the other devices. Battery replacement every few years will be required as part of the product's maintenance needs. The system has been provided with an outer protective case to extend the life of the device and its subsystem. The clear acrylic enclosure protects the system from rain and debris while allowing sunlight to pass through, reducing any influence on solar energy output. An inbuilt dc mot and sensor control the whole system. This control system can fully automate the system's cleaning operation and schedule cleanings at any time.

Discussion on Marketability of Solar Panel Mechanical Cleaning System

Solar panel cleaning is the act of eliminating collected elements from the panel surface, such as dust, bird droppings, and ashes from wildfires. This procedure is used to restore PV power conversion capabilities when collected particles act as a barrier between the panels and the sunlight. Furthermore, several approaches are used within the process across applications due to their effectiveness in recovering module efficiency and providing higher power output (Saravanan and Darvekar, 2018; Tripathi et al., 2017). The wet segment of the solar panel cleaning market is anticipated to grow rapidly due to its high efficiency in cleaning panel surfaces and extensive application and practicability across a wide variety of soiling scenarios. Furthermore, the availability of organic compounds as a replacement for water-based cleaning processes will aid product acceptance. Furthermore, low unit cost, excellent reliability, and ease of access are key attributes that will drive product demand (Al-Housani et al., 2019). The dry solar panel cleaning sector will benefit from strict government laws to protect dwindling water sources and prevent a severe drop in subsurface water levels. Furthermore, rising customer preference for environmentally friendly cleaning methods and the deployment of sophisticated technologies to effectively remove accumulated particles without harming the modules will help propel the market forward (Tripathi et al., 2017).

The mechanical solar panel cleaning market will be fuelled by a growing reliance on automated technologies such as machine learning and artificial intelligence, and rising uncrewed operations demand due to fewer human errors. In addition, broad applicability across large-scale solar power generation facilities and good performance and dependability in harsh temperatures will encourage technology adoption. In addition, the industry picture will be bolstered by increased demand for quick and effective panel cleaning procedures, which is in line with the deployment of technologies across big industrial panel sites (Al-Housani et al., 2019). The semi-automated section of the market will benefit from limiting high soiling rates, faster cleaning services, and minimal maintenance costs. Integrating cloud computing and artificial intelligence to improve operation in extreme weather will round out the product's implementation. Furthermore, variable cleaning needs, upfront cost sensitivity, and highly compatible proximity sensors are vital factors that will drive product demand (Hou et al., 2022).

The commercial solar panel cleaning market will be fuelled by rapid commercialization in emerging nations and rising demand for sophisticated solar technology. Furthermore, reforms and mandates requiring zero-emission buildings and effective energy management systems will increase the demand for technology. The service industry will be upscaled due to the strong consumer outlook aided by tax benefits linked with the deployment of solar components. Furthermore, the industry's growth prospects are bolstered by rising electricity costs combined with ample roof space availability across all companies (Baiz et al., 2017). In order to promote energy optimization and intensify efforts to lessen reliance on non-renewable power sources, government targets will accelerate the implementation of large-scale solar projects. Furthermore, an increasing focus on financial savings, carbon reduction, and maintaining a consistent power output will open opportunities for corporate growth. The industrial & utility section of the solar panel cleaning market will grow due to an increase in large-scale solar installations throughout agricultural farms and coastal areas, as well as excessive soiling accumulation (Al-Housani et al., 2019). With this mechanical solar cleaning system innovation, the marketability of solar cleaning will grow all around the country. Besides, the cleaning of solar panels is necessary for commercial, industrial, and residential sectors.

Conclusion

The presence of dust events in which light-weighted dust particles are performed by dry winds, dust storms, vehicular movements, pedestrian walking, and a variety of other actions (Maghami et al., 2016). The level of dust emergence is unquestionably dependent on the intensity of the activity and local weather conditions. The accumulated dust will form a thin film on the surface of the solar module, which may be put in a variety of configurations (Paudyal and Shakya, 2016). Because of the impact mentioned above, periodic maintenance and cleaning of solar panels are required to keep them operating correctly. Cleaning a solar panel with traditional techniques such as vacuum cleaning or hand wiping/cleaning is complex and, in some situations, impossible due to standard installation and mechanics. The most familiar practices are vacuum suction cleaning and manual wipe or cleaning, both challenging to implement and sometimes ineffective (Mizuno, 2000). The concept emphasizes the advancement of solar cleaning systems in the building sector.

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