Advanced tools for optimization and efficiently monitoring behaviour in service stage of buildings using renewable energy

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Abstract. In the topographical surveying works devices have got among the required accessories also tools called tripod. They have the role of correctly installing and settling the equipment above the station point in order to perform the measurements. Various types of tripods are known: the classic tripod (made from aluminum or wood), the adjustable laser tripod, the elevator tripod, the tripod for supporting and adjusting the picket. The aim of this scientific paper is to present my invention that is concerned on a new type of tripod device with photovoltaic cells called mobile solar tripod which has the purpose of providing the energy needed for the equipment used and thus extending the duration of survey measurements by using renewable energies. The tripod being an almost universal accessory along with other topographic instruments, it can be used for some topo-geodetic activities such as monitoring behavior in service stage of buildings, marking the points on the ground, determining ground elevations and other works that require a long time for the objects studied. This present work will describe the advantages and disadvantages of using the existing tripods compared to the new proposed device.

1. Introduction

The evolution of terrestrial measurements and topography is directly correlated with the development and continuous improvement of topographic instruments. The progress of the equipment area for determining geometric elements, means of calculation and reporting data influences the upgrade of methods and procedures in topographic measurements. This automatically involves making more complex jobs and improving their quality at a faster pace, with cost savings. Monitoring behaviour in service stage of buildings is accomplished with different methods and techniques. The progression of technology is characterized by the ways used for efficiently monitoring the behaviour of buildings in time, used to optimize the costs and duration of their execution. The objective of this scientific paper is to present a modern device that can be universally used for several types of topographical equipment that assures their own autonomy by accumulating and then converting the solar energy into electrical energy called mobile solar tripod. Also, we will present the advantages and disadvantages of existing tripods compared to the device proposed by the authors.
2. Material and method

Together with making of first maps and topographic plans, the requirement to measure the size and shape of land appeared. This led to the materialization of the first tools for drawing graphical representations. Topographic devices have progressed in terms of construction and technologies due to the achievements of electronics [1]. Surveying instruments have among the essential accessories, also the use of tripod. This tool has the role of supporting many types of devices such as: total stations, level, laser scanner, static Global Positioning System (GPS) and others [2]. Such instruments have been used since ancient times, but the components were separate and their assembly was needed. The tripod is made from three legs provided with three spikes for fixing in the ground, three clamps to be able to slide, made of metal (Figure 1b) or wood (Figure 1a). At the top of the instrument, it is found the tripod table on which it is placed the survey device fixed with the screw pump. It can be placed above the point station in a convenient place and can be adjusted to a height that is favourable for the operator [3]. The role of this device is to support and maintain the stability of the instruments against horizontal movements and forces. At first they were made from wood then made from aluminium greatly which reduced their weight. Tripods can sustain the equipment (Figure 2) and its accessories [3].

Furthermore, the evolution is found also in the change of design, material and use of modern tripods. Contemporary tripods are manufactured for supporting the survey equipment, but also for topographic accessories. In the next paragraphs, we will present some of the latest tripods which are used in the survey work. The tripod for supporting and adjusting the staff according to the patent created by Voicu F. and Domilescu V.M in 1989 consists of a tripod case with screws on each leg which modifies vertically and allows adjustments of rod at different heights with the help of a bar and a staff support. Keeping in position the device is done with by the means of fixing screws and a bridle clamp [4]. Another tool is the elevator tripod. This invention is made from a body to which a crank mechanism and a wheel are attached, used to raise the equipment to the desired level by the user. The device is generally applied in civil engineering to elevate the level to the operator’s height in order to save time for setting and adjustments [4]. The tripod for supporting the surveying peg regardless of the kind of land without the help of an operator. The patent developed by Vargas R. in 1983 is a two-legged topographic tripod and a central pole. A telescopic tube is found inside the central pole and is extended to a suitable height with the help of compression clamps at the upper end. The goal of the telescopic tube is to increase the height of the tripod [5]. Starting from the classic tripod that performs only support, settling on the station point and stability over the entire length of measurements, reaching at many types of instruments that have one or more uses (tripod for staff/peg support, tripod with elevator). On the other hand, there are types of tripods used in different areas besides topography. We can enumerate the tripod (Figure 4) used in meteorology, which is a part from the weather station that consists from lighting rod, solar radiation sensor, wind speed direction sensor, RT/cellular antenna, solar panel, relative humidity sensor with radiation shield, enclosure houses datalogger, power supply and modem, raingage and grounding rod [6]. Furthermore, we can add the solar powered led tripod beacon (Figure 5) used in road traffic for allowing easier visibility on the streets or highways, made from a tripod stand and reflector with flashing lights on the left and right side [7]. Also, in the construction area tripods are used for levels, mostly for
measuring interiors and tripods (Figure 5) are found in photography for supporting cameras when taking pictures.

![Figure 3. Weather station](image)

![Figure 4. Solar powered led tripod beacon](image)

![Figure 5. Tripod-photography](image)

This is due to the evolution of technologies that radically changed the range of land measurements, facilitating the way in which works are done and achieving technically and economically feasible results.

3. Results and discussions

The modern system built for contemporary topographic instruments, presented in this scientific paper can be used in supervising the activity of buildings. In fact, through this modern tripod it is created the autonomy needed for the measurement process efficiently utilizing the renewable solar energy. Thus, we can use electronic devices for a long time without being conditioned by traditional batteries that are limited to a certain number of hours while operating. The proposed invention called Mobile Solar Tripod (Figure 6a) keeps the classic principle of a building tripod: three spikes that have the function of fixing the three legs in the ground and three clamps which allow the feet to be adjusted at different heights convenient to the operator. The innovation of this device consists in fixing photovoltaic panels on each leg of the tripod (Figure 6c) to provide continuous energy to the instrument that performs the topographic measurement activity. The layout of photovoltaic cells on each side of the tripod is necessary due to the movement of the Sun, thus offering the possibility of catching the light source from any position. Panels transfer the energy through a cable connected to the solar energy conversion system in electricity. The converter is placed in the tripod table (Figure 6b), located at the top of the legs. The solar energy conversion device is connected to a battery that operates as an external accumulator. The transmission of the electrical energy to the measuring instrument's battery is made by a cable whose length allows the device to rotate in the set of directions.

![a) Solar tripod view](image)

![b) Connection view panel-battery](image)

![c) Tripod leg view](image)

Figure 6. Mobile solar tripod

Photovoltaic systems represent the future of technology [8-10], especially in areas where access to an electrical power is impossible. Its components include: solar cells, accumulator batteries, load regulators, static converters and other components useful for the achievement of a solar energy system (protections against electrical discharges, circuit breakers and fuses). The photoelectric cell is assimilated to a photosensitive diode, its process is relying on the properties of semiconductor materials.
The operating principle is called the photoelectric effect. There are also other researchers who have studied the renewable energy conversion phenomenon of a various forms [11-14]. For the production of solar cells, silicon is often used as a semiconductor material. There are several types of photovoltaic cells: monocrystalline cells, polycrystalline cells, amorphous cells, Cadmium telluride photovoltaics cells (CdTe), Copper Indium Selenium solar cells (CIS), Copper indium gallium selenide solar cells (CIGS). Monocrystalline cells are the first to have been made on the basis of a silicon block crystallized in a single crystal. Their capacity is between 12-16%. They have two disadvantages: the high price and long payback time of the supplied energy [14-18]. Polycrystalline cells are built on the basis of a silicon block crystallized in several crystals having different orientations. Their yield is 11-13%, but they imply lower production costs than monocrystalline ones [14-18]. On the other hand, amorphous cells have lower production, 5-10% than crystalline and costs are low. They consist of a glass support or synthetic material on which a thin layer of silicon is deposited. Their advantage is good behavior in diffuse or fluorescent light, having good performance during high temperatures (Renewable energy course). Cadmium telluride photovoltaics (CdTe), Copper Indium Selenium (CIS), Copper indium gallium selenide (CIGS) technologies are under industrialization, but their development may be stopped due to the high levels of cadmium in their composition being highly toxic. The cell generates a voltage of 0.5, regardless of its type (monocrystalline or polycrystalline). Depending on their size, they produce a current of up to 8 amperes (A). The battery of the total station has 6 V, so for a good charging performance it is necessary:

\[ x = \frac{6 \text{ V}}{0.5 \text{ V}} = 10 \]  

where \( x \) represents the number of photovoltaic cells that are useful for recharging the battery in the device. The most advisable alternative from the point of view of productivity and the cost of manufacturing the device could be polycrystalline cells. Photovoltaic cells have a length of life for 25 years, with very good resistance to temperatures of - 40 ° Celsius [14-18].The glass of the top layer is self-cleaning during rain and also periodic dust removal is recommended. It is advisable to position the feet from the ground at an angle between 30 ° and 45 ° to better capture the sun's energy.

| Types of tripods                        | Advantages                                                                 | Disadvantages                                                                 |
|----------------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Classic tripod                         | - performs the centering and supporting during the measurement;             | - it does not contain other features that facilitate the performance of terrestrial measurements; |
| Tripod for supporting and adjusting the staff | - allows only fixing and centering the staff at different heights for reading the topometric point; | - it cannot support the equipment during the measurements; |
| Elevator tripod                        | - performs only centering, riding and adjusting the machine at the operator's height; | - is only useful for construction works (yard) or for building interiors; |
| Tripod for supporting the surveying peg | - performs only the support of the peg in vertical position, regardless the land’s composition; | - the device only performs the tasks of supporting the peg in the upright position; |
| Mobile solar tripod                    | - performs centering, setting and supporting the device during measurements; | - the high cost of the instrument due to the photovoltaic cell construction; |
|                                        | - it can be used continuously without interrupting the measurement cycle for changing battery; | - the replacement of accumulator batteries or electronic equipment (battery inverter, solar charger) may occur periodically; |
|                                        | - the layout of the panels on each leg of the device is useful for retaining solar energy from any angle; | |
The proposed device by the authors, called „Mobile Solar Tripod” keeps the classic construction of a simple tripod, but instead it uses renewable energy to charge the battery of the topographic instruments during measurements. The advantages of using the mobile solar tripod are: centering, setting and assuring stability during topographical determinations, its use provides a continuous rhythm of the measurement cycle without the need for changing or charging the battery to complete the operations and the arrangement of panels on each leg of the equipment provides the ability to collect solar energy regardless of the position of the Sun (table 1). The price for building this device can be between 2000 – 3000 euros depending on the type of the solar panels used, generator and accumulator. A solution for reducing costs would be adding only one solar panel outside the tripod like in the weather station case, but it depends on the autonomy the tools used during topographic measurements need to fully charge. Although, in this scientific paper we presented a novelty in the topographic area by making this solar tripod, it can be improved by attaching extra solar panels on the tripod’s table or by enclosing a extra device like an external battery if more power is demanded. We can add that especially for more complex operations like monitoring buildings deformations in service stage, the necessity of the continuous process of monitoring instruments and consequently the need for a continuous supply of the battery accumulators can occur and with this modern device this inconvenience completely disappears. The only disadvantages could be the value of the instrument’s construction due to photovoltaic panels and materials used, but also the situation where accumulators, battery inverters or solar chargers can be damaged and they need to be changed.

4. Conclusions

Topography has a well-defined utility and role in land surveys. This field is divided into two extended categories: general topography (elevations in the plan and field profiles) and engineering topography, which includes the monitoring of buildings behavior over time. Both use contemporary tools and methods to achieve goals. Currently, in many fields the tripod is used: meteorology, civil engineering, photography, road traffic for supporting different equipment in vertical position. On the other hand, the decisive elements that have transformed the concept of survey measurements consist of modern digital technologies and tools. In addition to digital equipment, the mobile solar tripod is an optimal solution for long-term topography operations, such as monitoring of building’s behavior in time, providing them with the necessary energy autonomy. It ensures the efficiently monitoring behavior in service stage of buildings using renewable energy with photovoltaic panels. The novelty of this instrument is that it provides continuous power to the device's accumulator during the process of survey measurements without the need to change the battery or interrupt topographic operations. Also, the device is universal, applying to several types of topo-geodetic equipment: total station, static Global Positioning System (GPS), laser scanner, digital level. Our future perspective is to build the device, showing that the instrument works, can provide energy through solar cells and continuous use of measuring tools during the monitoring of buildings in service stage. Also, in order to put in practice the solar tripod, we need an expert in electricity and solar panels to guide us during the fabrication of the patent. In conclusion, we can state that the proposal made is indispensable by the autonomy provided to the building monitoring devices in the service stage because they can ensure an efficient functioning of these instruments which will allow them to obtain data with high accuracy and relatively low cost. Thus, by introducing the use of these innovative tools from technical point of view we obtain an optimization of time, precision and especially the rational use of renewable energy is achieved.

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