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Flexible lighting distribution on "party ships"

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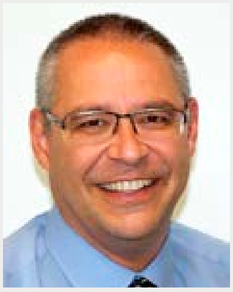

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Key words: TRIZ, TIPS, trimming, function analysis, FOS, trends, IFR, resources

Abstract

TRIZ trends predict an increased electrification of engineering systems. One of the visible effects of this is lighting, in this case party lights on boats. The need to furnish a boat with colorful illumination requires a flexible, redispatchable system. Cable-bound illumination does not meet this requirement. A solution is presented in this paper using TRIZ as a problem-solving methodology. TRIZ comprises a set of heuristic tools for problem analysis, reformulation, root cause analysis, and problem-solving algorithms. TRIZ, however, concentrates on generating solutions to problems irrespective of given limitations concerning, for example, safety, producibility, or cost. TRIZ provides a direction of thinking that has been proven successful in the past for similar problems. Other tools must, nevertheless, be used to carry out a technical evaluation of the feasibility of the solution, scalability, practicability, or cost target. TRIZ tools are widely used by engineers in multinational corporations such as Intel, GE, Philips, Siemens, Bosch, Boeing, Samsung, LG, and Cochlear. In this paper, selected tools from the overall TRIZ toolbox will be used and explained, with a focus on functional analysis, trimming, and resources. However, other aspects (Trends, Function Oriented Search (FOS), and Ideal Final Result (IFR)) will also be presented.

Introduction

A FOS (Terninko, Zusman, & Zlotin, 1998; Rantanen & Domb, 2002) raised the question of who else needed redispatchable, distributed lights at the lowest cost. Today, solar garden lamps are commonly used to decorate gardens at night, being fixed in the soil with a lamp mounted on top. This is part of a trend to apply lighting design to domestic settings. Several lights are needed to generate a particular effect, meaning that these lamps have to be cheap.

Trend, Function Oriented Search, & Ideal Final Result

Most innovations begin with a fuzzily stated problem or customer need. In Bavaria, Germany, in recent years, it has become popular to hold evening and night-time parties on a ship cruising on a river (e.g., the Danube). This idea has been taken up by several shipping companies, with dance floor lighting installed in ships and the vessel's silhouette being highlighted by LED lines placed all around it. This requires the pulling and fixing of a large number of cables. As all the shipping companies are carrying out these installations, the question has arisen as to how differentiation from the competition might be achieved.

The strategic approach for the stated problem is the application of TRIZ trends (Altshuller, 1984, 1996, 1997). The outcome of the analysis is a dynamized solution. This means that instead of mounting the lamps in one place only and having a large amount of wiring, a solution should be sought whereby the lamps can be moved easily, without wiring. This implies that the lamps should have their own power source. A FOS (Terninko, Zusman, & Zlotin, 1998; Rantanen & Domb, 2002) is another TRIZ tool that translates a specific function into a generalized one. (In this case, the function would be that a lamp without wiring needs a unit which emits light and is self-powered). With this generalized functionality one can look at all the existing industries in the world and ask which of them has provided this functionality as a core competence. We found the answer in this case to be solar light companies. The next step, therefore, is to analyze their technology and evaluate how it might be transferable to our specific needs.

This TRIZ example is of special interest because those most frequently cited refer to mechanical or electromechanical cases, and seldom to pure electronics. This paper demonstrates how TRIZ can be applied to solar powered lamps. Such lamps have mechanical and electric parts and optimization can be carried out on each part separately. TRIZ was not used in the original development of solar lamps; however, interestingly, it appears from talks with developers that they followed the methodology. It took four years to arrive at the development described. In this paper a stringent application is demonstrated which leads more quickly to a solution.

The first lamps were grid-connected, incandescent, lightbulb lamps. They were expensive and energy-consuming, for which reasons engineers soon began looking for alternatives. They started with pain points from customers, and stated:

- The lamp's location cannot be arbitrary: there must be electric current there.
- One lamp is pleasant but several are needed to illuminate a party area.
- If a set of lamps is needed to illuminate a party area, then they need to be very cheap.

Translating these points into a problem statement and an ideal desired result can be formulated in a condensed form as an IFR (Zlotin & Zusman, 2001):

- Solar lamps need to power themselves.
- They need to be independent units with respect to handling.
- They should be independent of environmental resources.
- They need to be very simple in order to be produced at low cost.
- The raw material needs to be available at low cost.

Functional analysis

A functional analysis (Kosse, 1999; Salamatov, 1999) of the system detects two levels: a mechanical level, which deals with all the mechanical parts, and an electronic level which deals with the powering and controls for the light (Figure 1).

Figure 1. Solar lamp

Figure 2. Electronics for lamp (top) with light sensor (bottom)

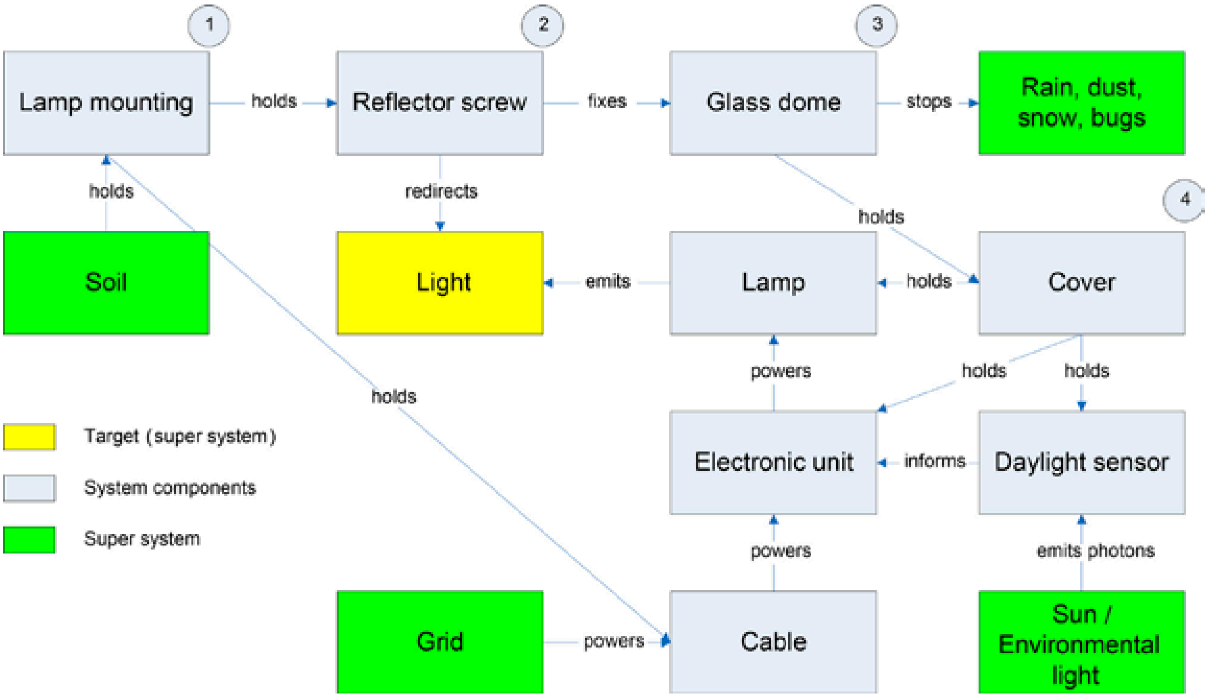

Figure 3. Functional diagram of the mechanical part of the solar lamp

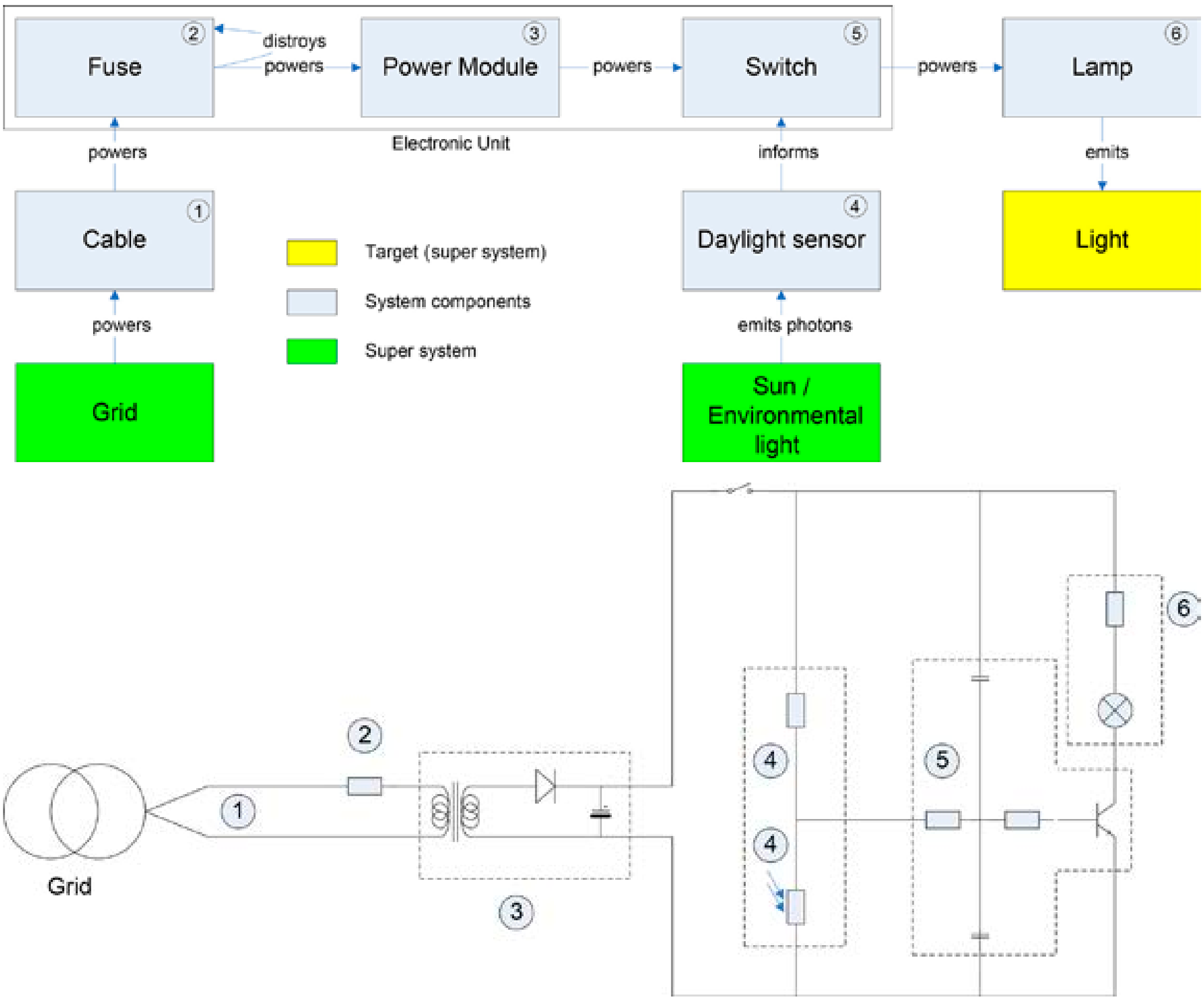

Figure 4. Functional and electrical diagram of the solar lamp (the circled numbers in the function graph refer to the dashed units in the electric circuit diagram)

The reflector, including a screw, fixes the glass dome to the lamp monopole. The cover holding the electronics (Figure 2), the light sensor (that is, a solar cell, the cheapest sensor), and the lamp (a 3 V, 50 mA incandescent lamp), is turn-clicked onto the glass dome.

On a mechanical level, the electronic part is just a black box that needs to be handled as one unit. The corresponding mechanical model of the system is shown in Figure 3. A second model has been created for the electronic unit, which is shown in Figure 4. This replaces the electronic unit box in the mechanical model. Due to the different detailing levels, the models are treated separately.

Innovations can be broken down into different categories:

- Differentiation: A product has to be changed so it has a unique differentiation from other products (increased functionality).
- Neutralization: A product has to be changed in order to compensate for advantages possessed by other products (functionality catch-up).
- Optimization: A product or production line has to be optimized so that its cost is reduced and its functionality is maintained.

Trimming and Resources

In this example, optimization innovation was targeted as the functionality was accepted by customers. Trimming and Resources (Ball, 2002; Clausing & Fey, 2004) are the TRIZ tools of choice for the optimization approach.

As a first step, we embarked on an extended trimming of the mechanical parts, as shown in Figure 5.

1. If the lamp mounting were trimmed, what other component could take the functionality of supporting the reflector screw? The situation is similar to point 1, and this idea was discarded for the same reason. This also reflects the fact that there is no soil on a ship in which a lamp can be fixed; the soil is therefore replaced by the "ship's deck installation". As the focus of the current paper is the electric aspect, the mounting topic was no longer pursued.
2. If the reflector screw were trimmed, what other component could take the functionality of supporting the glass cover, fixing it to the lamp monopole, and reflecting and spreading the light beam? One could integrate the screw into the glass dome, that is, two parts could be integrated into one. The next question is whether the glass dome needs to be screwed onto the pile or whether it can also be stuck. This idea, of the "integration of components (trend of composition from the super-system)" will be checked in greater detail.
3. If the glass dome were trimmed, what other component could take the functionality of holding the cover and guiding the light beam to the reflector? Here, the idea was to think of a different material

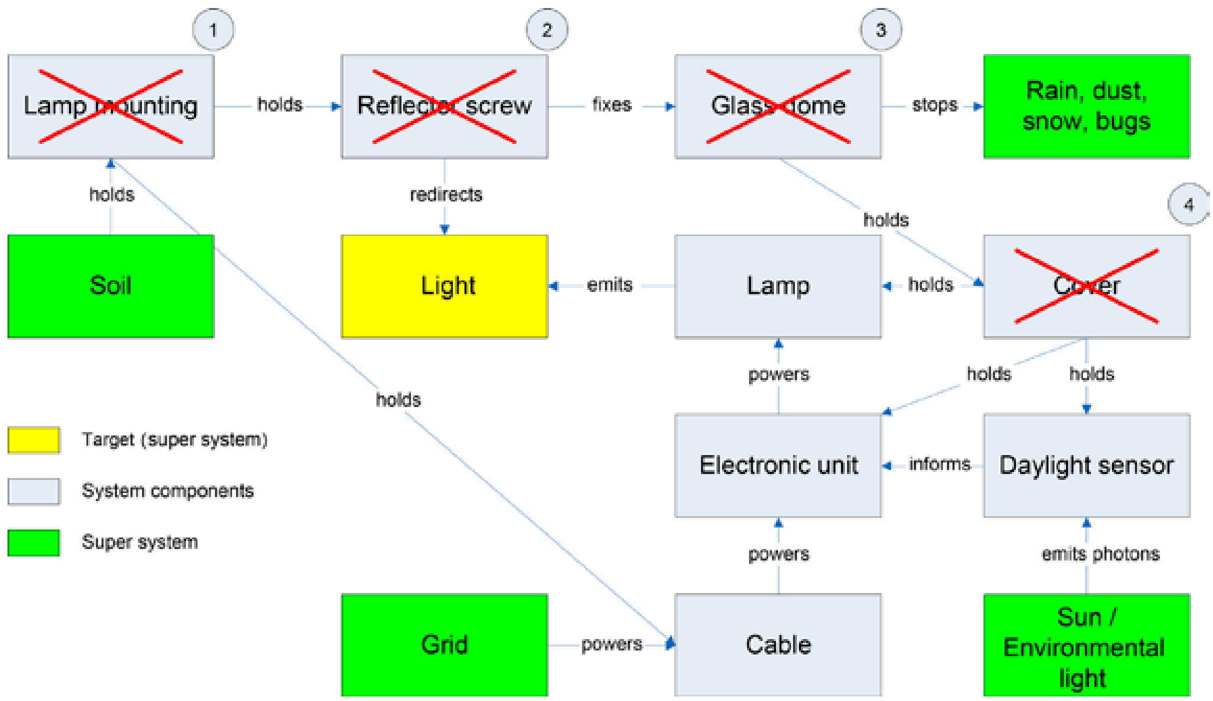

Figure 5. Extended trimming of the mechanical parts

which might ensure easier production and lower weight.

4. If the cover were trimmed, what other component could take the functionality of sealing the glass dome, holding the light source and electronic unit and protecting them from the environment, and supporting the light sensor looking towards the sky? This part operates like a packaging device. This point is crucial for production and it was therefore decided to rate this component as a lower priority for trimming.

The next step consisted of extended trimming of the electronic parts, as shown in Figure 6. Before deciding what should or can be trimmed, it is necessary to evaluate the functionalities; for example, the capacitors with the resistors are for EMC (electro-magnetic compatibility) and therefore cannot be trimmed.

1. If the grid cable were trimmed, what other component could take the functionality of transporting electric energy to the fuse and power module? This is the same question as for the mechanical part (point 7). In fact, we need a power source that delivers enough energy to provide lighting with at least 100 lux for six hours (requirement definition). This depends, of course, on the total power consumption of the system and, in this case, principally the lamp. The technologies identified are/were: temperature gradient soil/air, solar radiation, saltwater battery, rain, air itself, biomass around, etc.
2. If the fuse were trimmed, what other component could take the functionality of transporting electric energy to the power unit? The fuse protects the system in the event of failure because the grid is capable of providing very high power and energy (>3 kW). If we use an alternative power source that operates at a lower voltage (< 42 V) and lower power (< 5 W), a different protection system may be used.
3. If the power module were trimmed, what other component could take the functionality of

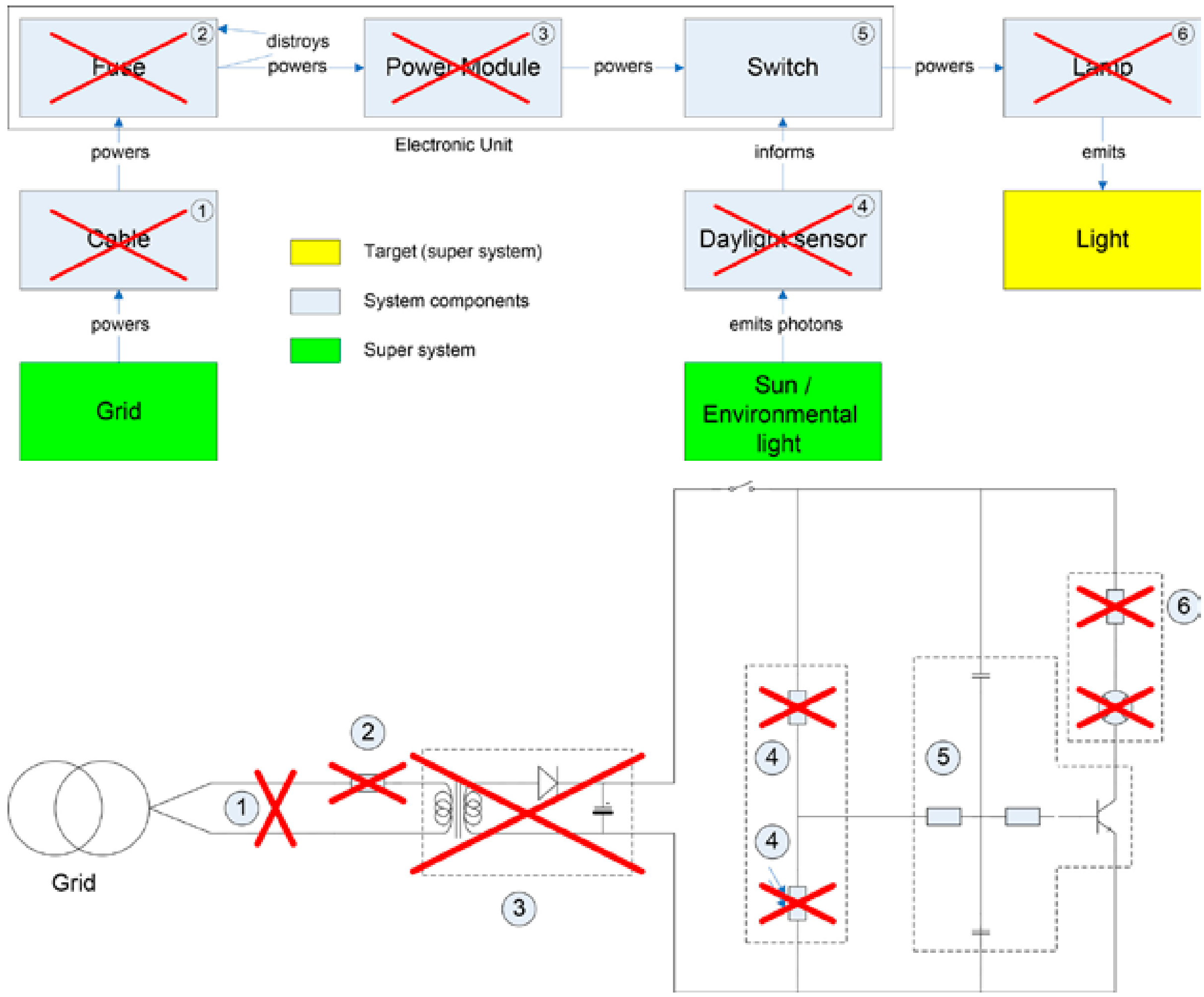

Figure 6. Extended trimming of the electrical parts (the circled numbers in the function graph refer to the dashed units in the electric circuit diagram)

converting the power to the level required by a solar lamp? If we find an alternative power source, as suggested in point 1, there is no longer any need for a power module.
4. If the voltage divider, consisting of a fixed resistor and a Light Dependent Resistor (LDR) were trimmed, what other component could take the functionality of delivering a voltage proportional to the signal of the environmental light? It may be of interest to note that a proportional signal is not needed but only discrete information, that is, turn lamp on or off.
5. If the resistor and lamp were trimmed, what other component could take the functionality of emitting light? Different technologies generate photons, such as tungsten lamps, fluorescence, Light Emitting Diodes (LEDs), fireflies, chemical light, etc.

The focus question was how to eliminate the power supply from the grid. From the identified technologies, namely temperature gradient soil/air, solar radiation, saltwater battery, rain, air itself, and biomass around, solar radiation was detected as that which had the highest power density, and was the most easily available and most cost-effective product. The biggest challenge is that is has to be mounted in such a way that direct solar irradiance hits the device, and the mounting place is dependent on the user rather than being determined by the manufacturer.

Applying solar power generation, which means reduced power density, entails an immediate focus on a reduction of energy consumption/increase in efficiency. Replacing the lamp with a LED was a simple solution whereby it is possible to maintain 75 Lux.

Exchanging the grid power for a solar power device entails trimming the grid, fuse, and power module (Figure 7). These parts are replaced by eight solar cells in series (0.5 V per device due to physics), leading to a total voltage of 4 V. This is operated via a diode (0.5 V voltage drop) and a current limiting resistor that is simultaneously working as a low pass filter with the capacitor, to three NiMH batteries in series (1.2 V each).

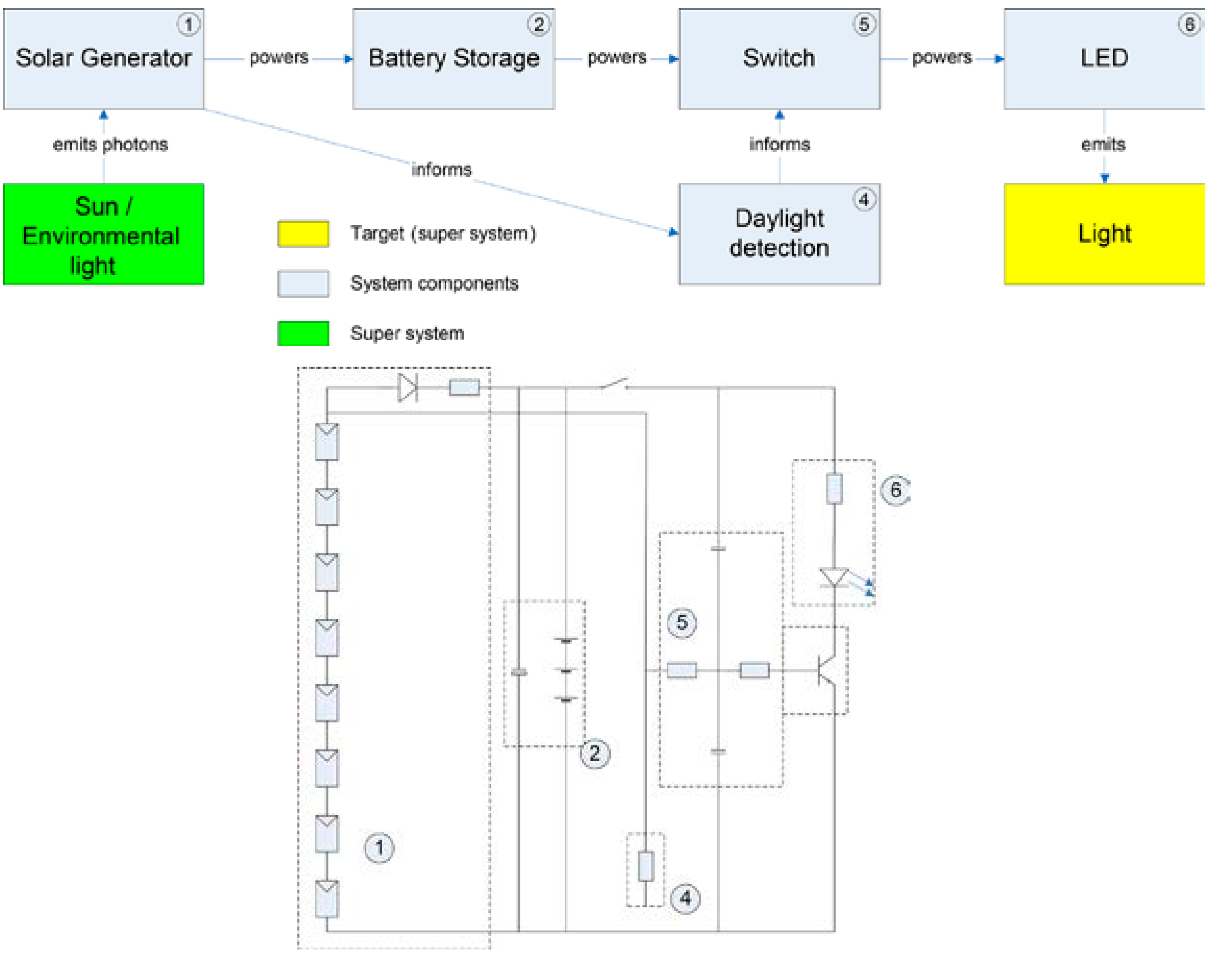

Figure 7. Grid power replaced by solar power supply (the circled numbers in the function graph refer to the dashed units in the electric circuit diagram)

If solar cells are used, they can also be used to detect day/night changes. Therefore, the LDR and resistor can be trimmed.

The rest of the system stays the same. This solution was operational, and worked well. However, when an analysis of parts to be sourced and purchased was carried out, it appeared that the sourcing of all parts was more expensive than with the grid solution, and that the most expensive parts were the batteries. For this reason, another trimming (a second round) was applied (Figure 8).

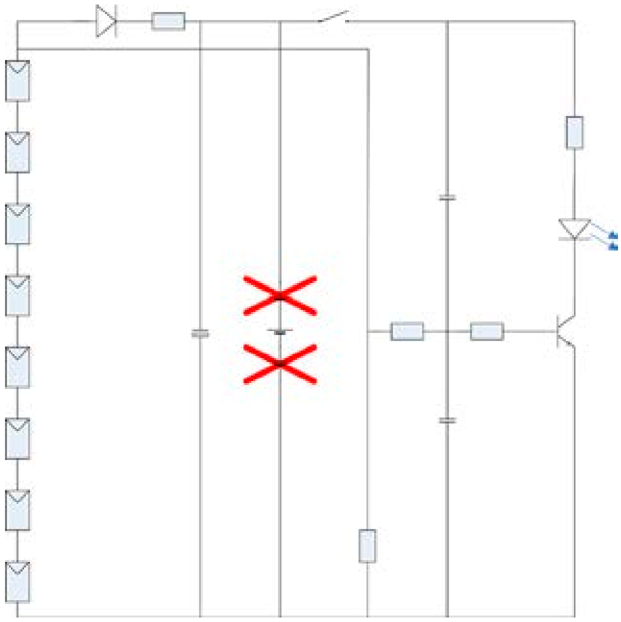

Figure 8. Second round trimming for solar power generation

If the batteries were trimmed, what other component could take the functionality of storing energy? As no answers to this question were forthcoming, the trimming was reduced to the question of how, if two batteries were trimmed, their functionality can be maintained. The challenge was that the LED requires 2 V but one battery only provides 1.2 V.

Considering electronic solutions such as a MATChEMIB (MATChEMIB = Mechanical, Acoustic, Thermal, Chemical, Electrical, Magnetic, Intermolecular, Biological, and is a standard set of technical field resources to be considered (Timokhov, 2002; Mann, 2003)) for electronics, one can find step-up converters that will transform lower voltages into higher ones with the help of LC-circuits (Coil–Capacitor). The corresponding circuit is shown in Figure 9.

Circuit Explanation: A current is flowing from the +pol of the battery through coil L2 and L1 and loads the capacitor C3. If C3 is loaded enough that

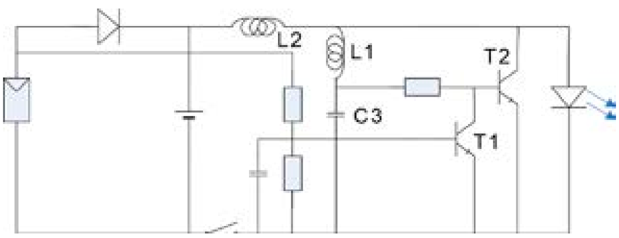

Figure 9. Second round trimming for solar power generation

sufficient current can flow over R1, transistor T1 will conduct. By this, voltage will be dropped at L2. This leads to a rise in current at L1 and a voltage spike which will put T2 to full conduction for a short time. This happens until the energy of L1 is deloaded and C3 is discharged. When T1 is closing, the voltage of L2 is adding to the battery voltage, which becomes higher than necessary for the LED, for which reason it starts to light up until L1 is discharged. Then the cycle starts again.

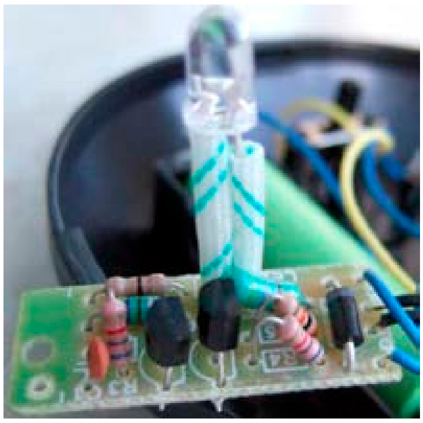

Figure 10. Realization of simplified electronics

This solution is more cost-effective than with three batteries. Figure 10 shows the realized electronic module in a modern solar lamp. The next step would be a change of storage technology. Batteries could, for example, be replaced by ultra--capacitors.

Result

The developed technology can be transferred into small, cheap light units that can be located at any place on a ship in different colors (Figure 11). Relocation would need no wiring and is therefore easy. During the day, sunlight will charge the lamps. The developed solution satisfies the customer's main requirements: an individual can repeatedly decorate the party area without having to consider changing the wiring.

Figure 11. Toronto party boat (Wikimedia, 2017)

Conclusions

This paper demonstrated how a solution for a problem statement was developed with TRIZ tools. Selected tools from the TRIZ toolbox have been demonstrated. The value of TRIZ versus, for example, brainstorming is that it decisively accelerates the innovation process. TRIZ directs thinking in directions that have proved to work in the past. These development directions have their origin in the analysis of hundreds of thousands of successful patents.

The mentioned literature represents an overview of the full TRIZ toolbox by various authors with different viewpoints. TRIZ can be considered as a systematic methodology for solving engineering problems or as a modelling tool for engineering systems. The presented literature gives an insight into the powerful TRIZ method.

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