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The Smart and Autonomous Stand-Alone Speed Limit Road Sign According to the Weather Changes

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ABSTRACT
The degradation of the weather conditions is dangerous for driving and should incite drivers to reduce the car speed. The present work solves this problem of the speed limit in city road and highway by changing automatically the authorized speed with the weather conditions.
The new developed stand-alone speed limit road sign is intelligent and is capable to analyze the weather context using sensors, and to display the most adapted speed limit according to the surrounding environment. Several scenarios have been proposed to develop a pre industrialized prototype and to analyze them according to different criteria (cost, consumption, endurance and reliability). In addition, the system is an autonomous stand alone and uses the solar energy as source of supply. The pre-industrial prototype of the system was successfully achieved. However to develop a ”low cost” system a new concept of meteorological sensors was done, for the low consumption of the display we use the LED (light emitting diode) components.

KEYWORDS
Road safety — Autonomous panel — Speed limit — Degraded weather conditions — Meteorological sensors.

1. Introduction

Conscious of the consequences engendered by the degradation of the weather conditions, the authorities in charge of roads introduce some danger signs (handle area, fog, be careful slip ...) into the most dangerous areas, to incite the drivers to reduce their speed. These conventional panels cannot change the limit of speed posted, and are generally constituted by an aluminum box with a retro reflective film for better visibility at night, and of course, with a galvanized steel mast in case of installation on highways and of aluminum in case of urban area to give an esthetic aspect to the panel.
Other systems in highways can display the speed limit depending on weather conditions and offer the ability to display various messages with the aim of making indirectly the link between the regulations and the local risk identified on the road (Ex : Accidents, traffic jams ...)[1]. But this solution does not answer suitably the

composed problem. Indeed, on one hand, the size of panels is very large and requires important works of civil engineering and metallic structures. On the other hand, these panels marketed require significant electrical power which requires the use of expensive power source in case of isolated site (e.g. generator), which decreases the economic and ecological interest.

Moreover, communication problems arise; this type of panels of variable message communicate with a central meteorological station periodically to acquire the data and act on this data, this complicates the installation of one hand and on the other hand it may be that these data do not reflect the local reality in the display area [2].

Currently, the determination of the speed limits on roads does not consider the changes of the surrounding environment, in particular the changes of the weather conditions, which can return these inappropriate limits; rain making the surface slippery, strong winds, low visibility, etc. These conditions significantly increase the risk of accidents. For these reasons, the drivers are obliged to slow down to minimize this risk.

The developed system aims to build a road sign for the speed limit by using LED display varying the limit of speed posted according to the current meteorological conditions. It concerns firstly the domain of dynamic traffic signs, secondly the meteorological domain of the sensors to measure the wind speed and the rain precipitation. To change the display we have developed two new electronics card, the first one is a control card, and the second one is a power interface card [3].

2. Description of the solution

The studied system allows to a large extent to answer the problematic of the speed limit in case of degradation of weather conditions; it also allows to ally technical innovation and ecological concerns, while proposing an efficiency solution and easy to implement. Besides, the system works with solar energy (photovoltaic module (1-Figure 1), regulator (2) and solar battery (3)). Thus, the system ensures low consumption compared with solutions aforesaid, which represents an important asset especially in case of isolated site.

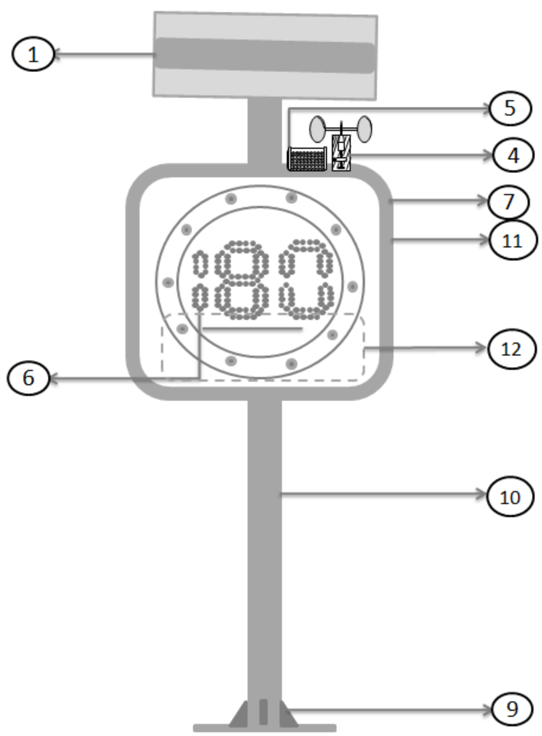

Figure 1. *Global overview of the panel*

Besides, the system works with these own meteorological sensors (sensors of wind (4) and of precipitation (5) deposited in patents 37055 and 37058 respectively) what will allow a local measure reflecting the state of the weather report covering the zone of the panel. The display belongs to LEDs (6); this LEDs are implanted into the trap in an esthetic way (with vacation and rounding's between digits). For optimization of the consumption,

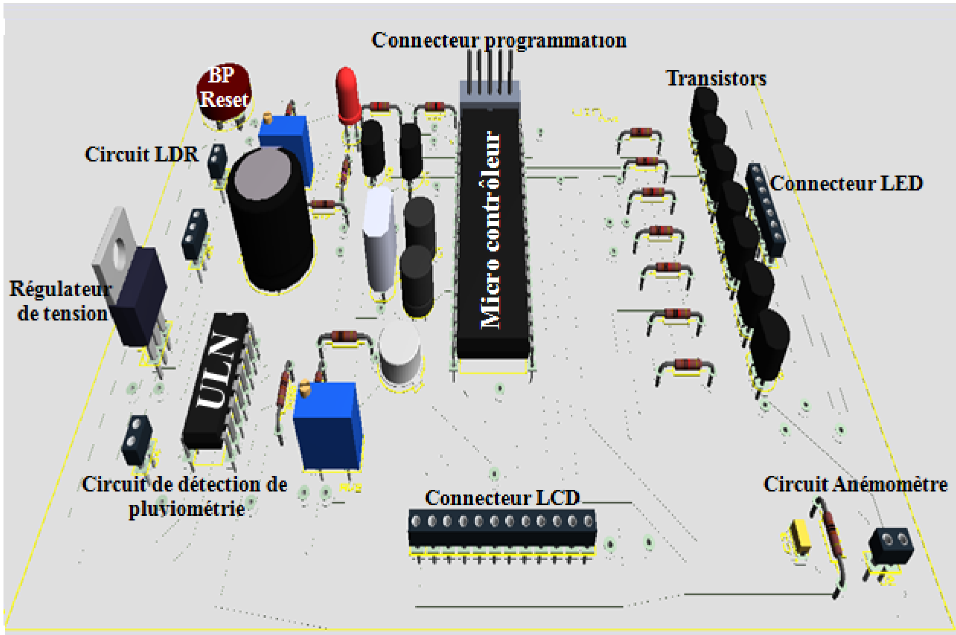

Figure 2. *Printed Circuit Board*

the system is endowed with a crepuscular sensor (7) allowing changing the LEDs luminosity according to the ambient luminosity. This allows an energy earnings estimated at 25% of the average consumption. The system is controlled by a card of command (13 (Figure 3) and Figure 2) established mainly by a flash type 16 bits microcontroller (8) and of a set of electronic components and integrated circuits assuring the acquisition of the data stemming from meteorological sensors. This electronic card, with the crepuscular sensor ensure the management of the LEDs power consumption, the data processing, the LCD displayer, and the display of the speed limit, the most suited according to the current state of the weather report. Finally, the system results in simple components, less dear, accessible on the market and simple to maintain and allows a less expensive access to the solar energy. The card of command (Figure 2) intended in the piloting of the panel is capable of assuring the following features:

- Acquisition of data from meteorological sensors,
- Data processing: calculation of the speed of wind and comparison with the predefined thresholds and the detection of the precipitation,
- Display of the limit of speed the most suited according to the meteorological context,
- Management of the luminosity: the panel is capable to varying the luminous intensity of the LEDs according to the ambient luminosity,
- Management of the consumption of the LEDs: use of a PWM (Pulse of Width of Modulation),
- Display of the interactive messages with the user via a billposter LCD.

The control board is made up of:

- A circuit of the pluviometric detector which makes it possible to convert an analog signal into a digital signal (0,1) via an ULN circuit;
- A circuit of acquisition of the anemometer which makes it possible to detect the pulse resulting from the magnetic switch of the sensor, in order to transfer them towards the control board;
- A LDR circuit which makes it possible to measure the luminous intensity by the LDR (Light Depend Resistor);

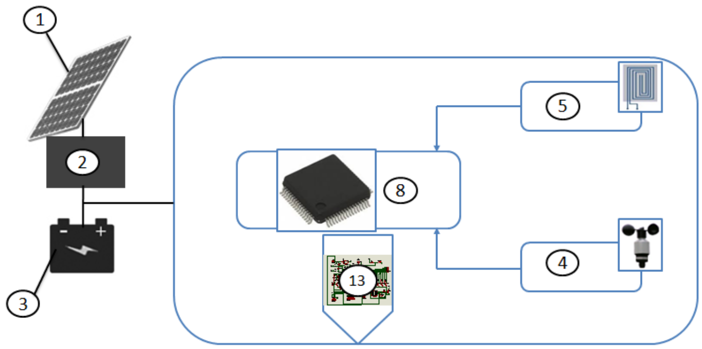

Figure 3. *High Tech solution*

- A PWM circuit (Pulse Width Modulation); is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off.

3. Battery based stand-alone PV systems

Stand-alone PV systems need battery to save enough energy for periods without enough adequate solar radiation. Unfortunately battery in stand-alone systems is the weakest part of the system. Therefore, 30% or even more of lifetime expenses of solar off-grid systems goes to storage. Frequently, the storage battery of a stand-alone PV system is sized to guarantee, if the solar irradiation is inadequate, the imagined loads could be powered for at least 3-4 days. The product of such typical sizing is that the daily depth of a PV battery discharge is in the range of 25-30% of its rated capacity (10 *h*). Besides, the dimensioning of the PV generator might generally be expected to cover the entire energy request of the fore-seen loads under normal sun conditions. These two fundamental assumptions allow the following points with respect to the typical operating conditions of a battery in a stand-alone PV system to be presumed (see also Figure 4).

Consequently, the operating conditions and lifetime of a PV battery are basically estimated by the number of days when the battery realizes full charge condition (which is the ideal) and the number of days when it achieves the minimum discharge voltage threshold (worst operating condition). Assuming the PV generator has been sized to be extremely small for the predicted loads, the battery will reach deep discharge conditions more often throughout the year and its lifetime will be short. Provided that, instead, the PV generator is over-dimensioned, the battery will achieve full charge conditions about every day of the year, and it will have longer life time [4]. As battery lifetime is one of the most important considerations, determining lifetime expenses of the entire stand-alone photovoltaic system, LiFePO4 battery is considered for this investigation. Due to the noticeable decreasing of solar panels expenses in the last few years, batteries are playing, cost wise, a more principal role.

Their limited lifespan in comparison with solar modules (20+years) raises the total cost of the entire system accordingly. Since lead acid batteries have several disadvantages like possible acid leakage, poisonous vapor given during charging and their extra weight, they are not attractive for stand-alone systems any-more. Also disposal of lead acid batteries can cause environmental problems which lead to long term health risk for people. In addition to all the mentioned issues, these batteries have ageing problem when they have been kept in low state of charge. The combination of all these factors leads more cost over time. However, LiFePO4batteries are widely utilized within electrical mobility applications, because of their preferences over different sorts of battery types; one of its significant characteristics is the superior thermal and chemical stability, which delivers preferable safety properties over lithium-ion batteries with other cathode materials. Because of stronger bonds between the oxygen atoms in the phosphate (contrasted with cobalt, for instance), oxygen is not easily discharged and as a result, lithium iron phosphate cells are nearly incombustible in the occasion of misuse, and can survive high temperatures up to 85°C without decomposing.

The LiFePO4battery is friendly to the environment, i.e. there is no dangerous or harmful substance inside the battery, which is also a superb characteristic for a stand-alone solar system application, on the ground that the greater part of the end users is located in remote zones, where safety awareness is extremely low. The

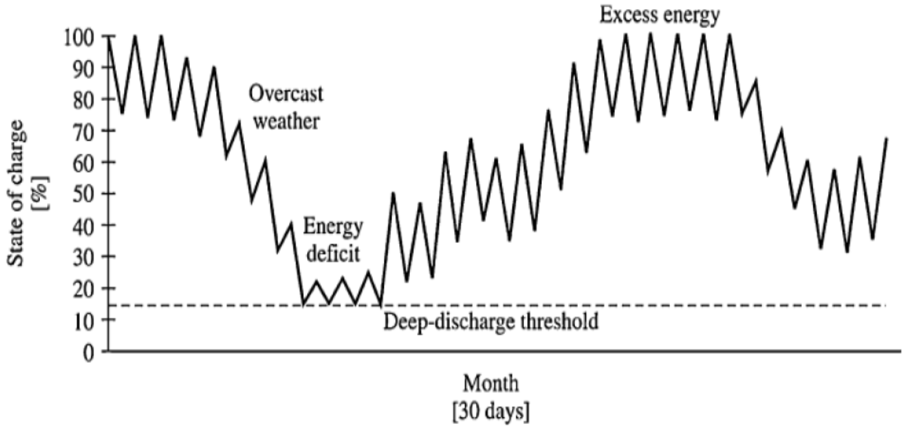

Figure 4. *Operating conditions of batteries in PV systems*

Table 1. *Panel properties*

Maximum power (Wp)	20 W
Maximum power voltage (V)	17.3
Maximum power current (A)	1.17
Open circuit voltage (V)	21.6
Short circuit current (A)	1.26
Size of module (mm)	514x348x20
Maximum system voltage (V)	30
Temperature coefficients of Isc (%)	+0.035 %/°C
Temperature coefficients of Voc (%)	-0.051 %/°C
Temperature coefficients of Pm (%)	-0.47 %/°C
Weight (kg)	2.5
Standard test conditions	Irradiance of 1000 W/m^2, AM1.5 Spectrum and Cell Temperature of 25°C

specific volume and the weight of a LiFePO4battery is 65% and 33% of lead-acid batteries respectively that also makes the battery more portable. The total lifespan (cycles) is around 2000 cycles with the limit as of now arriving at 80%, which is 6-7 times higher than lead acid batteries over the whole lifetime. Additionally, it is maintenance-free and does not get influenced by more extended lengths of time in low states of charge, which allows a higher use of its ability [5].

4. Design of stand-alone photovoltaic system

4.1 Silicon solar cell materials

In our case, in order to design a battery based stand-alone system, amorphous silicon (a-Si) panel are used as the electricity generator. Silicon is being used in semiconductor industry for several years. Also solar cell industry has started to use this material, since the first days. There are several reasons for this but the first is that simply it is easy to make silicon devices. This means that although silicon is not the best material for solar cells, because of this reason, availability and low cost of this material it could book a major part of solar cell market. What makes silicon devices easy to make is a unique oxide layer that forms on its surface when heated to high temperatures which remove defects on the silicon surface and allows back to back easy processing [6]. Panel's properties are shown in Table 1.

4.2 Battery identification

To be able to size the photovoltaic field of the system, it is advisable to consider the lowest daily solar energy of the year [7]. For the region of Rabat/Salé, the lowest average irradiation of the year is in the order of 4.72 kWh /

m^2[8]. We will identify the principal criteria which define the most adapted battery to the studied system, by consideration of technical aspect and economic and security using [9].
The Technical aspect of solar batteries undergoes a large number of charges/discharge cycles and their state of load is depending of the solar irradiation conditions during seasons. The battery to be chosen must answer the following specifications:

- It must support a large number of cycles of charge/discharge and must support the deep discharge;
- It must be optimal and should store electrical energy with less possible loss (good output of load);
- Once discharged, it must accept all energy coming from the solar panels to avoid wasting produced energy. The acceptance of the load must be good, so that batteries are reloaded quickly;
- Once stored in chemical form, this electrical energy should not be lost: the auto-discharge of the battery must be weakest possible;
- The battery must be not very sensitive to bad parameters of load (solar controller not suitable, not adjusted, ...) in order to increase its lifetime.

Criteria related to the security are very important because it takes into account the risk of acid and hydrogen evolution projections. We opt for the choice of the battery with gel which is distinguished from other technologies of the solar batteries and represents several advantages:

- Good to very good cycling life: the best gel batteries reach 2500 cycles at 50% discharge only(lifetime: 3 -15 years).
- A gel battery can withstand the discharge 100%.
- Low self-discharge rate (1-3% per month).
- Very weak hydrogen release.
- No maintenance, no addition of distilled water. Security reinforced compared to the batteries open lead.

4.3 Low-consumption wind sensor

The idea is to design and implement a simple wind sensor that meets the following criteria:

- Adapting to our needs with the limit values of the wind speed
- Low consumption
- Low cost

While being compact, the anemometer containing the magnetic switch is capable of measuring the speed of the wind with a variable measuring range while delivering a digital signal (0 or 1) comparable to that offered by a cup anemometer or encoder rotary, but with very low consumption.
The consumption of this device is estimated to 112 mW, contrary to an incremental optical anemometer) which is of the order of 125 mW or an anemometer dynamo (analog) requiring heating circuit consuming on average 480 mW .

4.4 Low-consumption pluviometry detector

The main advantage of this sensor is with very low power consumption (125 mW) and don’t require maintenance, contrary to that of a rocker or optical bucket.

5. Results and discussion

After calculating (Take into account the solar radiation in the region, the performance of PV modules, power losses, orientation and inclination of PV modules, technologies of the PV module/ Battery and regulation) we get the following results:

- Daily energy required: 40 Wh/days.
- Power peak to be installed: 12 Wp.

So it will thus be necessary to install a photovoltaic power of at least 12 Wp. This sizing is valid just in the region of Rabat/Salé. We shall also need a capacity of the battery of the order of 14 Ah to assure autonomy of 3 days. The best orientation of the PV module is thus southward (azimuth of 0°). The most suitable angle of inclination would be between 30° and 32°. We opt for a inclination of 32° of the photovoltaic module. The Functional tests are successfully done in order to validate the technical specifications according to the technical standard for the industrialization phase. The figure 5 shows the panel in the test phase.

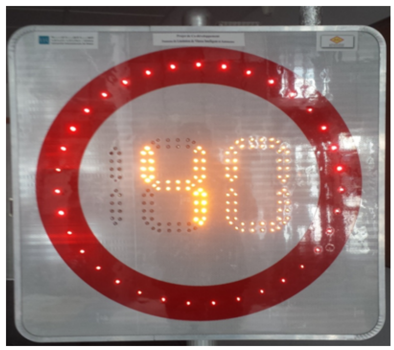

Figure 5. *Phase of the functional tests*

6. Conclusion

The Smart and Autonomous stand-alone speed limit road sign according to the weather changes present a new concept for more secure roads for drivers. The saving of energy is considerable by using PV panel and batteries for storage. The system is low cost in comparison with the existing technologies, which is linked with the fabrication of two sensors and two high-tech electronic cards.

The pilot system is fabricated and the functional test is done. However, our project remains open to several extensions that can be added; the system will be able to communicate the new limit of speed posted according to the meteorological conditions to a road RADAR via a GSM or GPRS modem.

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