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SOLAR POWERING OF A MOBILE TELEMETRY STATION FOR AIR QUALITY MONITORING

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Abstract – A mobile station has been designed to monitor the air quality. Several of those stations are to be installed on the rooftop of taxis and buses in order to build a real time map of the air quality of a city. The modules are equipped with gas concentration measurement modules for 5 different gases (CO, NO_2, O_3, SO_2, and CO_2), GPS receivers for localization, GSM/GPRS modules for communication and solar panels/batteries for completely autonomous operation. Here we describe in detail the choices made and the problems encountered in the design of the solar powering system for this mobile station.

Keywords: Air Quality; Solar Panel; Measurement System.

1. INTRODUCTION

Big cities all over the world suffer from air pollution due mainly to the massive use of combustion engine vehicles.

Air pollution has dramatic consequences for health, leading to respiratory problems and even death [1]-[3] and for the planet like the greenhouse effect, acid rains and ozone layer reduction [4]. The European Community as come to dedicate special attention to the problem of the most representative pollutant's concentration, such as the case of Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Ozone (O_3) and particles of 10 µm or less (PM_{10}). Although the Carbonic Dioxide (CO_2) isn't considered a pollutant, its concentration was also measured, due to importance of this gas to the Planet's ecosystems.

The system presented here is capable of measuring the following gases in the atmosphere: CO_2, CO, SO_2, NO_2 and O_3.It can be easily upgraded to include the measurement of more gases and small airborne particles.

Many cities, nowadays, have air quality measurement stations that monitor the air quality in different points around the city along the day and make the information accessible to the general public in the internet [5]-[9]. This information is, however, limited to the location where the monitoring stations are installed. To give a more complete knowledge of the air quality over an entire city, a system consisting of mobile air quality measuring stations was developed. By installing those stations on the rooftop of taxis and buses (Fig. 1), which roam the city day and night, it is possible to build a complete map of the air pollution of the city. The mobile station is placed ahead and as far as possible of the exhaust to limit the effect that the gases released by the vehicle carrying the station would have on the measurements made by it. Also, the station is programmed to acquire data only when it is moving.

Fig. 1. Photograph of the mobile station prototype mounted on the rooftop of a car.

One prototype was build to validate the mobile station design. In Fig. 2 and outside view of the module can be seen. On top of the module there are two solar panels that supply the energy required to keep the station operating continuously. Batteries are used to store energy which is used to maintain operation at night and during the day in overcast weather.

Fig. 2. Outside view of a prototype of the mobile station. On top of the station it is possible to see two solar panels and the GPS receiver antenna.

In order to have a mobile, autonomous and automatic device, capable of measuring the concentrations of the different gases that contribute to pollution, several modules had to be designed and integrated into a single system. Those modules are:

- Control module;
- GPS module for station location;
- GSM/GPRS module for data transmission;
- Battery and photovoltaic cells for autonomous operation;
- Sensors for each gas to be monitored;
- Sensors for temperature and movement;
- Temporary data storage.

Fig. 3 shows the inside of the prototype mobile station.

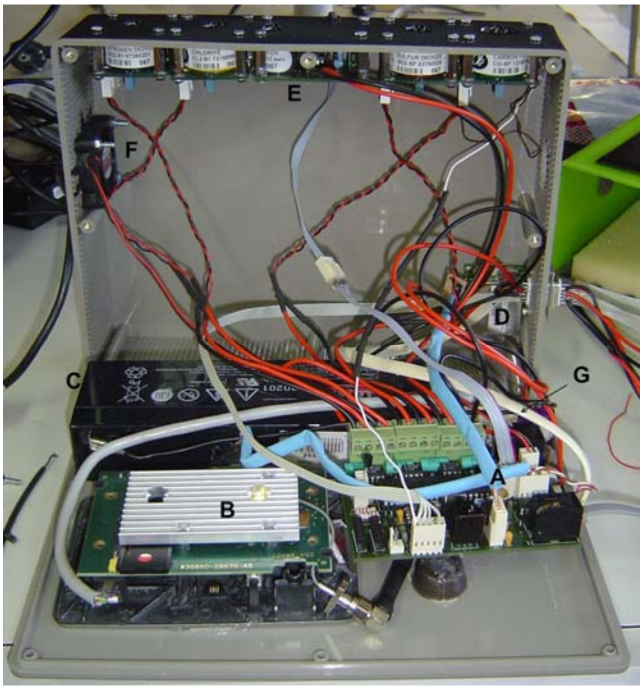

Fig. 3. Interior of the station. Main Board (A). GSM/GPRS modem (B). Battery (C). GPS Module (D). Gas sensors (E). Cooling fan (F). Solar panel controller (not totally observable because it is covered by the main board) (G).

The information obtained from the sensors is sent to a server with internet connection and stored in a database. The mobile station connects to this server through a GSM/GPRS module and uploads the data. The database can be accessed on an internet page which presents some generic information about the station status, displays the concentration ranges of the gases and even allows the system administrator to perform some database maintenance services. Anyone can access the database and see graphically all the information of the measured values and their tracking for a given day. This information is colour coded based on the gases concentration allowing an easy evaluation of the air quality. For each location, the specific concentration of each gas, time and date at which the data was acquired and the local temperature registered at that moment are displayed (Fig. 4).

Fig. 4. Extract from the Web page, with the various samples and their location.

In this paper we describe the design choices and problems encountered when developing the mobile station power supply module made of two solar panels, one battery and one charge controller.

2. POWER CONSUMPTION

The first step in the design of the power supply module of the station was to build a power consumption budget (Table 1).

Table 1. Power Consumption Budget.

Module	Nominal Voltage [V]	Typical Current [mA]	Maximum Current [mA]	Typical Power [mW]	Maximum Power [mW]
Micro-controller	5	22	31	110	155
GPS Receiver	12	33	40	396	480
Relays	5	11	11	55	55
Amplifiers	5	2,1	3,25	10,5	16
DC-DC Converter	5	3,2	5	16	25
Level Converter	5	8	10	40	50
Memory	5	7	10	35	50
Sensors	9	20	24	180	216
Charge Controller	12	4	4	48	48
Terminal GSM/GPRS	12	0,5	330	6	2076

The memory module is only turned on when the microcontroller has data to write to it. It takes a few micro-seconds for the write cycle. The GSM/GPRS module is programmed to turn on only 8 times during each day to transmit the data to the central server. Each time it is turned on it remains active during approximately 1 minute.

It is estimated that the station works only about 15 hours a day. The rest of the time it is in standby mode. The power consumed in the normal mode is 1044.75 mW and the power consumed in standby is 174 mW. The GSM/GPRS module consumes 2076 mW and works for about 8 minutes in each hour. Using these values the average power consumed by the station is 729 mW.

3. SOLAR PANELS

The station has to be completely autonomous and guarantee its own energy supply. It is equipped with a photovoltaic system constituted by two panels, a solar charge controller and a battery.

The solar panels convert energy from the sun into electric energy. These devices are composed by photovoltaic cells. Each photovoltaic cell produces a small amount of power, a solar panel has to aggregate several cells in order to produce more power (in series to increase current or in parallel to increase voltage).

There are different types of solar panels each with different efficiencies as seen in Table 2 [12].

Table 2. Efficiency of different types of solar cells.

Solar Cell Type	Typical	Maximum recorded in the field	Maximum recorded in laboratory
Monocrystalline	12-15%	22.7%	24.0%
Polycrystalline	11-14%	15.3%	18.6%
Amorphous silicon	6 - 7%	10.2%	12.7%

Two monocrystalline solar panels, each with 16 cells and occupying a 180×226 mm area (0.0396 m^2) were used. Their characteristics are listed in Table 3.

Table 3. Parameters of the solar panels used.

Parameter	Value
Peak Power	2.43 W
Maximum Current	310 mA
Maximum Voltage	7.84 V
Short-Circuit Current	310 to 340 mA
Open-Circuit Voltage	9 to 10 V
Number of Cells	16
Length	180 mm
Width	113 mm

Considering their 15.5% efficiency and the worst case average monthly solar radiation in Lisbon, Portugal, which is 63.6 W/m^2 in December [10], the average generated power is 390 mW (0.155×0.0396×63.6). If we consider the annual solar radiation average of 185 W/m^2 [10], we have an annual average 1.14 W (0.155×0.0396×185) power supply.

Using just two solar panels is not enough for the station to have enough power in the months of November, December and January in Lisbon, Portugal. It will be necessary to fit the station with two additional solar panels.

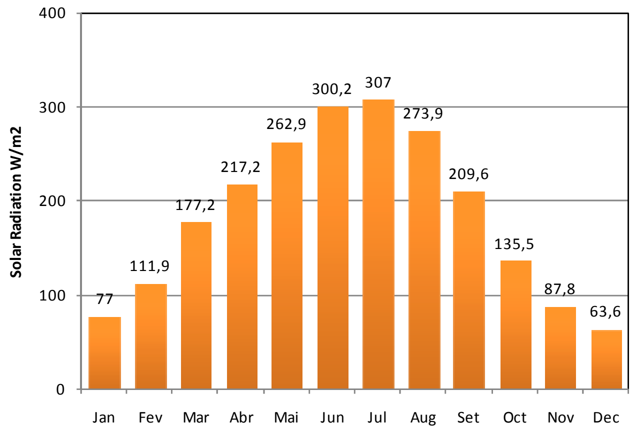

Fig. 5. Average monthly solar radiance in Lisbon, Portugal [10].

4. BATERIES

The mobile station has a battery that converts chemical energy into electric energy, thus giving it the needed power any time of the day. A choice had to be made regarding the type of battery to be used. The things to consider are battery capacity and the number of charges it can take. High capacity NiMH batteries (above 2500 mAh) can be charge for about 500 cycles while NiCd batteries can take up to 1000 charge cycles. NiCd batteries, however, suffer from the problem that they should be fully discharged before being recharged.

The battery used was a 12 V sealed lead-acid with 2 Ah capacity. This type of battery was chosen because it is the most appropriate for applications where there is a constant charging and discharging of the battery. This battery is able to store 24 Wh. Considering an average power consumption of 729 mW, a full battery charge will last 32 hours if not recharged meanwhile. This is enough for night operation.

5. CHARGE CONTROLLER

There are different types of charge regulators available, from the simple shunt or series regulator to the more complex Maximum Power Point Tracking regulators.

The solar charge controller used was from STECA, model Solsum 5.0. It is a shunt regulator which has overload protection, discharge protection, temperature compensation, automatic voltage adaption, cycle charging, boost charging, Schottky diode and a MOSFET switch (Fig. 6).

6. CONCLUSIONS

Here we have presented the solar powering system used in a mobile station for air quality monitoring. The use of solar panels has allowed the autonomous operation of the mobile station. Computations were carried out regarding the power consumption of the system and the power that is available from solar energy. We conclude that just the two small solar panels used were not enough for operation during the winter months in Lisbon, Portugal.

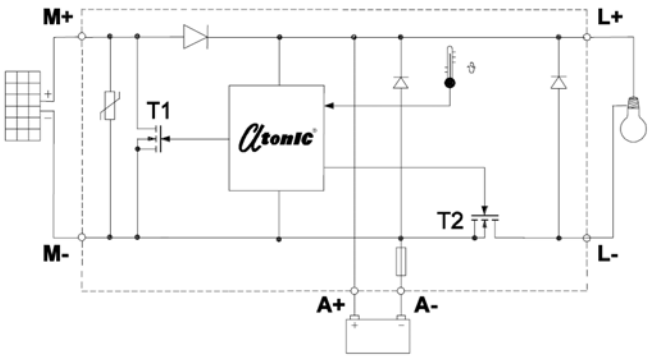

Fig. 6. Schematic of the Solum 5.0 charge regulator.

By looking at the power budget in Table 1 it is possible to see that the modules that consume more power are the GSM/GPRS, the GPS receiver, the gas concentration modules and the microcontroller. To minimize power consumption the data acquired is stored in an EPROM and only transmitted to the server a few times per day. That way, the GSM/GPRS module is only on during a few minutes every day. It would make no sense in transmitting the data immediately after being acquired since it would also lead to increased operational cost due to the data transmission tariffs of the GSM mobile network.

Also the system has a vibration sensor to detect when the mobile station is moving. This allows the microcontroller to switch off, using relays, all the station modules when the station is stationary.

Another alternative that could be implemented in order to reduce power consumption would be to create an ad-hoc network made of the several mobile stations such that the information would be passed from station to station when the vehicles cross each other on the road or when they are close to one of several base stations that would be placed around the city. This would require only a low power RF link like the ones based in IEEE 802.15.4 (Zigbee, for instance) which consume much less power than a GSM link.

The gas sensors could be replaced by others with lower power. The ones used in the prototype are from Alphasense. AppliedSensor, for instance, has CO and NO_2 sensors which consume only 35 mW, significantly less than the 180 mW consumed by the ones used now. Every day new sensors are being developed which consume even less which, if used, would greatly increase the autonomy of the mobile station.

ACKNOWLEDGMENTS

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