imc data acquisition onboard solar vehicle “Twente One”

Fig. 1: Presentation of the Solar powered vehicle “Twente One” ©Solar Team Twente

A team of students from the Saxion Poly Technical College and from the University of Twente (Enschede, The Netherlands) took part in the World Solar Challenge. This race for solar-powered vehicles covers 3010km across Australia. It started in the city of Darwin, traversed across the Australian desert and finished in Adelaide.

With an imc C-SERIES 7008 data acquisition device on board and imc Online FAMOS the team used a versatile and robust data acquisition and online analysis system, keeping control over the data during the race, while their solar powered vehicle “Twente One” was reaching top speeds of 120km/h.

System overview

imc Measurement Device	
imc C-SERIES CS-7008	1
imc Module	
imc CANSAS	2
imc Software	
imc Online FAMOS	
imc STUDIO	
imc FAMOS	

The car “Twente One”

The solar car “Twente One” had a completely new and innovative design. Not only mechanically, but also electrically and electronically, the Solar Team Twente used the newest technology.

Catching the Sun

Because race regulations limited the active area of solar cells to 6 m^2, and photovoltaic cells come in different qualities, but the budget of the team was limited, they decided to use a mix of both silicon cells and Gallium Arsenide (GaAs) cells. The latter, which are the most efficient cells, have an efficiency of around 30%. To use these cells to their full extent, they added an innovative idea: concentrators.

Concentrators

Linear Fresnel lenses were used on two sides of the “solar wing”. The idea was to position the focal line exactly onto the high efficient cells underneath. One of the difficulties was to shift the focal line when the angle of the incident radiation changed. To overcome this, the array of (GaAs) solar cells was mounted on a translating surface. The whole surface could move slightly sideways by means of some small electric motors.

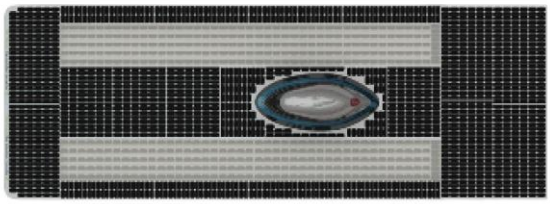

Fig. 2: Top-view of the solar panel with concentrators on each side ©Solar Team Twente

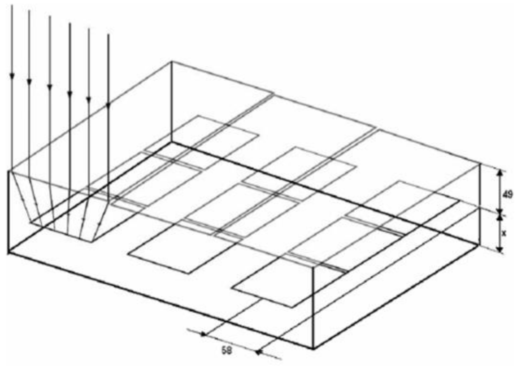

Fig. 3: Fresnel lenses concentrating sunlight onto the cells ©Solar Team Twente

Tilting panel

When driving from north to south, the angle at which the solar rays reach the solar panel changes during the day. This results in a substantial lower efficiency in the morning and in the evening. With the tilting solar panel, the team overcame this problem. The angle of the solar cells stayed perpendicular to the rays. Although the tilting panel solved the problem of the changing angle of incident radiation, it also introduced many other mechanical and aerodynamic problems.

Fig. 4: Solar car with tilting “solar wing” and support vehicle in the background. ©Solar Team Twente

Controlling a solar car

The “Twente One” was a high-tech vehicle, not only mechanically, but also electronically.

The basic idea was to parallel the solar panel output with the batteries and the motor controller. (Fig. 5)

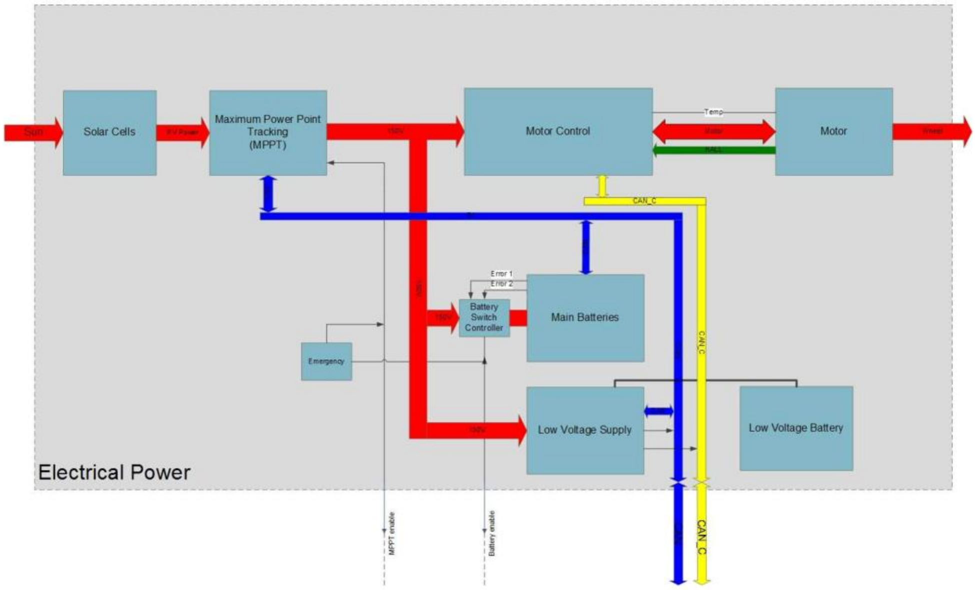

Fig. 5: Electrical schematic of the solar car ©Solar Team Twente

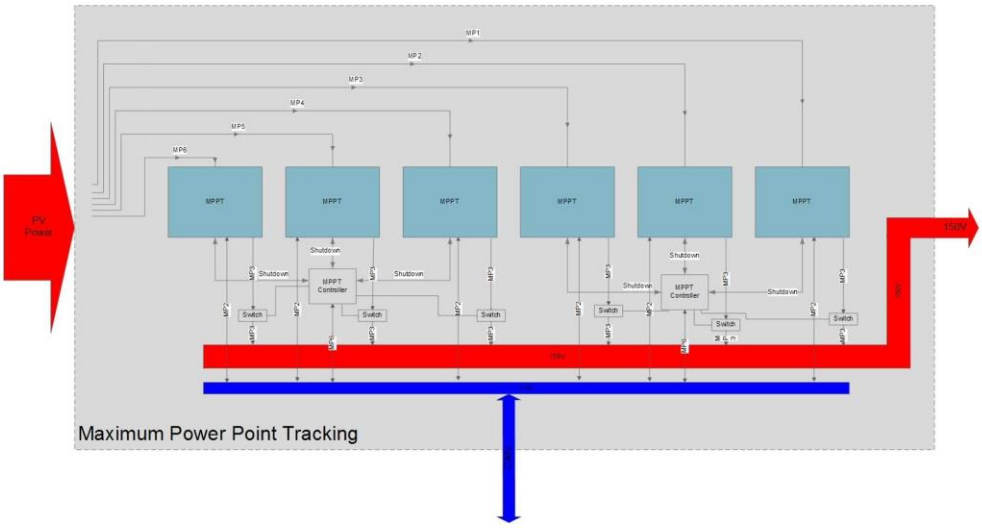

Fig. 6: Maximum Power Point Trackers (MPPT) control the solar panel’s output ©Solar Team Twente

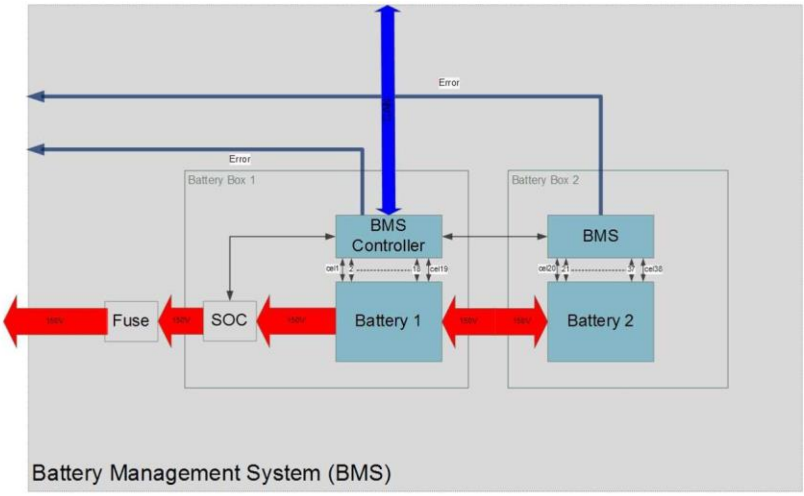

Fig. 7: Battery management schematic ©Solar Team Twente

Right from the early design-stage of the car, the electrical students thought of CAN bus as the main bus type for linking the various electrical components. In the "Twente One" it was decided to use two separate CAN buses: one for the critical processes (CAN_C), and the other (CAN) for more common tasks. Even the pedal box speaks "CAN".

Optimizing solar cells

The maximum energy you can get from photovoltaic cells depends both on the generated voltage and the current drawn. Too high of current will make the voltage drop, thus, the delivered power. A high voltage with little current is also not very efficient. As a consequence, the solar cells were connected to six Maximum Power Point Trackers (MPPT).
These controllers adjusted voltage and current a few times per second to make the solar cells operate at their maximum. The output voltage of the MPPTs is at 150
VDC. With the help of these MPPTs, solar cells could also be switched off in case of an unsafe situation. All six MPPTs had a CAN bus interface that communicated with the vehicle. The power from the solar panel on the "Twente One" depended on the amount of sunlight, but an output power of 1800 Watts was most often achieved. (Fig. 6)
The output of the solar cells is affected by their temperature: the higher the temperature, the smaller the delivered energy. In the testing phase, the cell temperature was closely monitored with 32 thermocouples in the "solar wing". These thermocouples were measured with two imc CANSAS modules that converted the thermocouple voltages into temperature values on the CAN bus. The decreasing performance of the cells at higher temperatures was compared with possible aerodynamic measures taken. Making a hole to cool the cells had effects on the aerodynamic behavior.

Battery

Since the incident radiation and the energy consumption of the vehicle were not constant, the car was equipped with batteries. Especially when using the brakes, the energy was stored in the batteries. The total capacity of the lithium-polymer batteries is 5 kWh. The batteries were positioned in stiff boxes made of sandwich material with a controlled airflow. Because it was important that these batteries did not overheat, a sophisticated electronic

Battery Management System (BMS) monitored the charging conditions of the cells and took action in case of error. Via a shunt, the BMS kept track of the amount of energy going in and out of the batteries. It was possible to predict the amount of energy left in the battery (state of charge). (Fig. 7)

Motor

The “Twente One” was equipped with a 6 kW CSIRO electric motor with permanent magnets. The motor gave an almost constant torque over the complete rpm range. To make this three-phase motor run, it was connected to a motor controller that converted the 150 VDC from the cells or battery to an electrical wave shape. Like all the other electronic units in the vehicle, the motor controller was connected to a CAN bus.

Monitoring and control via Wi-Fi

The heart of the electronic system (see Fig. 9) was the imc C-SERIES 7008 intelligent data acquisition system.
This unit served several purposes:

- communication with the trailing car via Wi-Fi
- link to the GPS antenna, gathering GPS data
- controller for two CAN buses
- acquisition unit with internal storage
- connection to various analog sensors
- controller for dashboard display

Fig. 8: Data acquisition system imc C-SERIES CS-7008

With all these functions, it was possible to monitor all measurement data pre-processed, and in real time, in the car following the solar vehicle. When cruising along, around 200 data channels were continuously transmitted from the “Twente One”. The data were used for monitoring and for determining the strategy (together with the weather forecast and route). Based on the strategy, the set point for the cruise control could be set from the car behind the solar car. Likewise, the tilting of the “solar wing” and the translation of the cell arrays underneath the concentrators were controlled remotely.

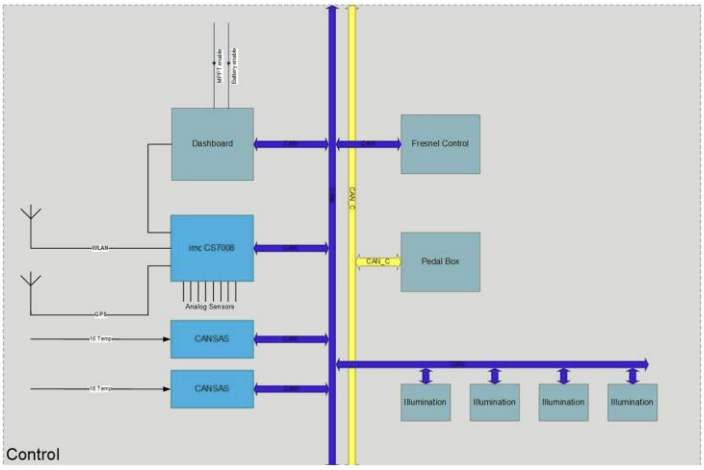

Fig. 9: Data acquisition system imc C-SERIES 7008 with imc CANSAS modules ©Solar Team Twente

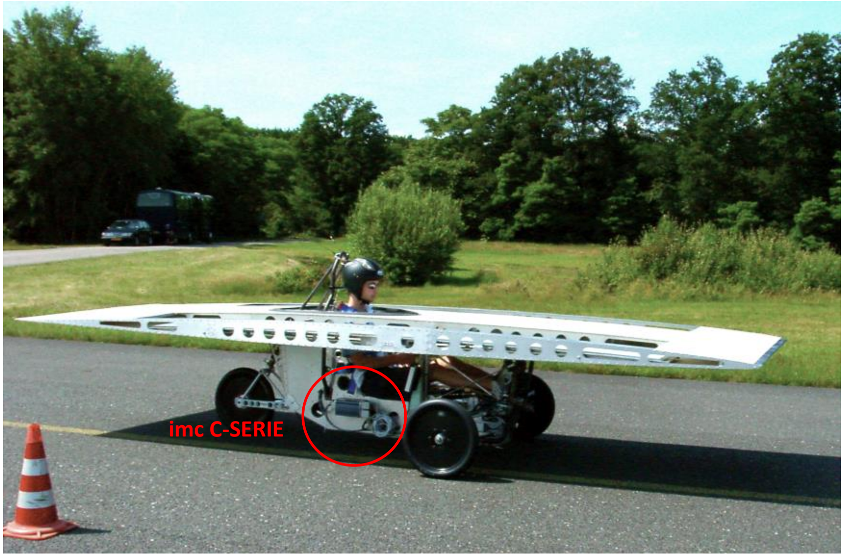

Fig. 10: First test with the imc data acquisition system ©Solar Team Twente

Analog signals

Besides all the digital information gathered by the imc system, analog signals were also measured. This played an important role in the design phase of the vehicle as well, when strain gauges were used to measure the mechanical load on the wheel suspension. During the race the following sensors were connected:

- 3x potentiometric displacement sensors – wheel suspension movement
- 3x infrared thermocouple sensors – tire temperature measurement
- Strain gauge bridge on rear wing mounting joint

With the infrared thermocouples directed towards the surface of the tires, it was easy to detect any problems. Even a little puncture would show a temperature increase on the tires.

Software

In the early stages of development, the team used the standard imc Devices software. However, they quickly discovered the ease of use and flexibility of the online signal processing of imc Online FAMOS. All measurement data was evaluated using imc's analysis software imc FAMOS. During the race, a dedicated program was developed based on the imc COM interface. This program facilitated an easy link to a database. It was important to have this data available to plan the racing strategy.

Race results

Coping with high tech design challenges is one thing, finishing in the World Solar Challenge is something completely different. During their journey, the Solar Team Twente faced many problems – most of them mechanical. The rough road conditions caused a broken front wheel suspension and other problems, but did not stop the team from finishing. After many hours of hard work, they proudly finished in sixth place.

Fig. 11: Finish in Adelaide ©Solar Team Twente

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