HyEnRo: A Novel Platform for the Study of Energy Hybridization for Autonomous Robots in Precision Agriculture

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***Abstract*- HyEnRo is a flexible and configurable robotic platform developed to allow the combination of different types of power sources. The platform was designed to be flexible and reconfigurable, easing the test of different control strategies for power maximization and cost optimization. Three power sources were integrated in the prototype: LiPo battery, super capacitors and solar cells. A robotic test bench was also developed to allow the evaluation of the platform directly on the field performing precision agriculture missions. The prototype includes an autopilot for simple autonomous and manual mode operation using GPS and waypoints for mission definition, a companion computer with robot operating system (ROS) for sensor integration and to control all the components of the system.**

***Keywords*- Hybrid, Robot, Agro-bot, Agriculture 4.0**

I. INTRODUCTION

Agricultural robots or agro-bots are experimenting a high impulse in research during the last years thanks to their multiple applications and the availability of improved sensors and embedded computers. Moreover, the development precision agriculture techniques and specialized sensors (machine vision based, GNSS, LiDAR, soil resistivity, etc.), actuators for different agricultural tasks (harvesting, pruning, seeding, weed control) allowed for the first commercial robots to be available on the market [1]. These autonomous systems provide different advantages: reducing the workforce needed, optimize the use of resources (water, fertilizers etc.) and to optimize yield and quality. Different tasks can be performed by robotic systems in agriculture: autonomous driving of agricultural machinery, seed planting, interrow weed control, harvesting, variable application rates of fertilizers or sprays, etc. The use of agricultural robots not only optimize production costs, but also reduce the environmental impact by optimizing chemical dosage and thus waste and pollution.

Even when there are many advantages associated to the use of agro-bots, they are not widely used in industrial environments, being one of the reasons the lack of enough operational range, with agro-bots not being able to operate without recharging or refuelling for an entire workday. Batteries from different technologies are the most used power sources for robots nowadays, but there exist robotic platforms powered by internal combustion engines (ICE), solar cells or fuel cells. Every power source has its pros and cons, for example, high power density and lower recharging times when using combustion engines but they require

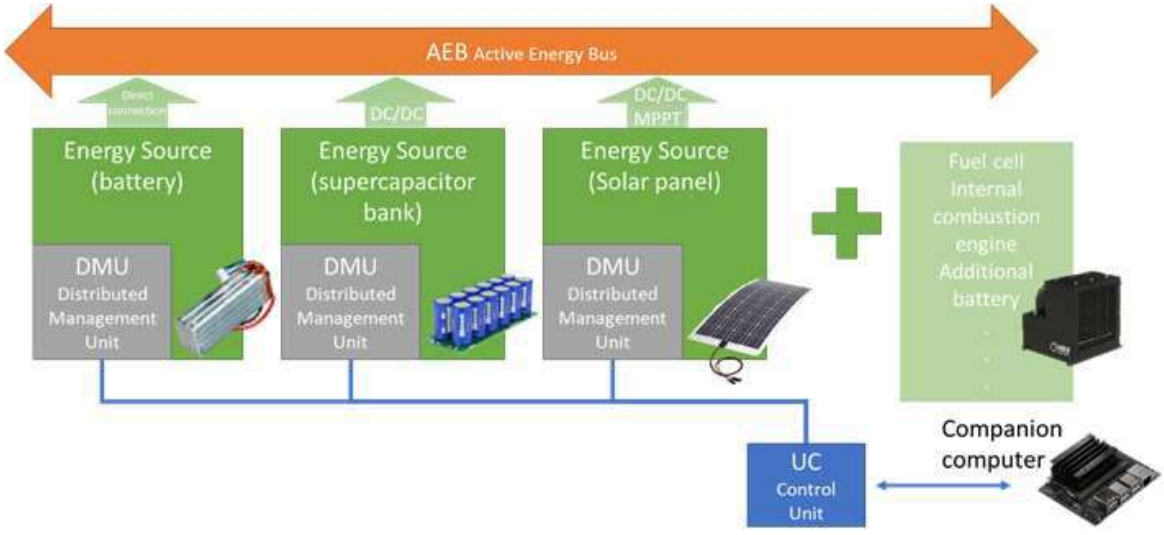

Fig. 1. Components of the Energy Management System. The three on the left are currently installed in HyEnRo prototype

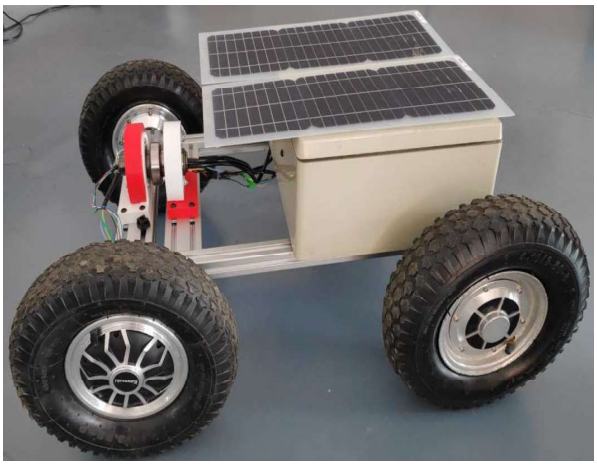

Fig. 2. HyEnRo robotic platform

maintenance, are noisy, dirty and cannot be easily used in small scale robots [2,3]. Combining different energy sources allows for obtaining the best from every option and to complement different source's characteristics but at the cost of more complex installation [4]. Moreover, a finely tuned combination of power sources will excel in an application at the cost of underperformance in other scenarios. To be able to easily reconfigure the power sources in a robotic platform will allow to obtain optimal performance in heterogeneous tasks that are common in precision agriculture tasks.

HyEnRo aims at developing an architecture able to combine different power sources and control the energy flow for precision agriculture robotics application. This combination will enhance every energy source advantage reducing the associated drawbacks.

II. HyEnRo components

Fig 2. Shows a general view of the robotic platform. The energy management system (EMS), the main component of HyEnRo is depicted in Fig. 1. It is composed by three different power sources connected to an Active Energy Bus (AEB) through DC/DC converters to regulate the energy flow. Every source has an embedded distributed management unit to (DMU) control and monitor the status of the module.

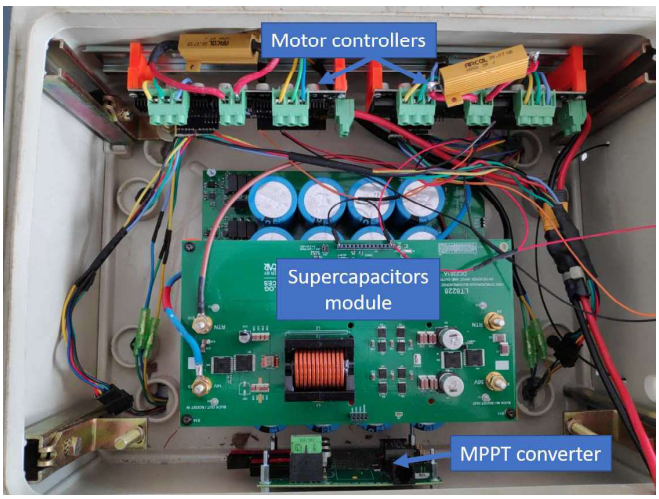

Fig. 3. Electronic components of HyEnRo installed in an electrical connection box

The DMU's are connected to a control unit that acts as a hub and interface with the companion computer, where the energy use and flow is controlled based on the control strategies. The system is designed to be flexible and expandable, allowing different configurations of energy sources depending on the mission of the robot.

The battery of the system is a 10sp2 LiPo that is directly connected to the AEB and fixes the voltage of the system. A board was developed for the supercapacitor module (Fig. 3). It is composed by 20 supercapacitors (KEMET 200F 2.7 V) connected in a 5sp4 arrangement. It includes voltage and current monitor and protection with configurable limits. A reversible DC/DC converter was installed to allow the flow of the current in both directions. A DC/DC Maximum Power Point Tracking (MPPT) converter is connected to two monocrystalline solar cells installed in top of the electrical box (Fig. 2).

Apart from the EMS, HyEnRo also encompasses a flexible test bench, to evaluate system capabilities in real scenarios for precision agriculture. The chassis was built using aluminium profiles. The front axle is mounted using a hinge that allows it to freely rotate and it is meant to allow the wheels to maximize ground contact when used in rough terrains. Four 350 W outrunner motors controlled by two Odrive Robotics controllers are fitted to provide 4WD capabilities. The Odrive boards are connected to a Holibro PixHawk 4 autopilot that allows for manual and automatic operation. In manual mode, HyEnRo is controlled using an RC radio transmitter, in auto mode, a mission can be defined using MissionPlanner software. Finally, a single board computer (Jetson Nano) controls HyEnRo operation and the connection with different sensors. The main controller runs ROS (Robot Operating System) and is connected to sensors to allow autonomous navigation and agronomic data collection from sensors. A schema of HyEnRo main components is showed in Fig. 4.

III. Conclusions

HyEnRo is a very flexible and configurable platform that allows to test different energy flow strategies for precision agriculture. It is conceived as an upgradeable platform and using open software and easily adaptable hardware.

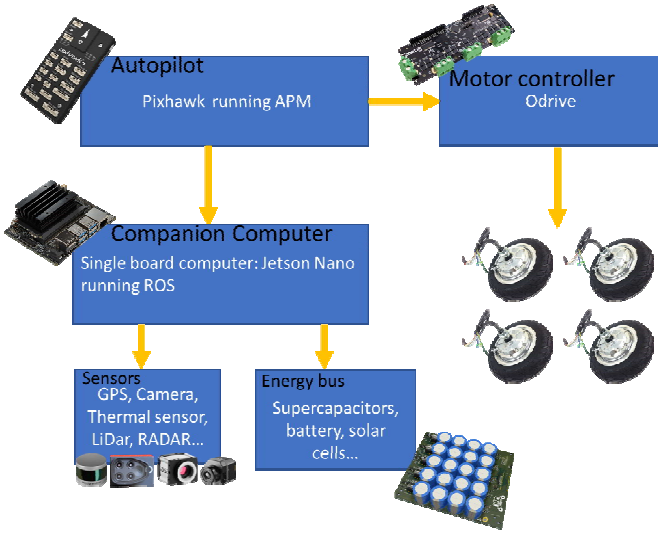

Fig. 4. HyEnRo components architecture

The use of a 4WD platform and easily adjustable chassis allows for the installation of heavy accessories like fuel cells, internal combustion engines or agronomical sensors and actuators.

Future developments include installing a charging port, that will allow to transfer energy from and to the other robotic platforms in the framework of collaborative robots. Increasing the autonomous capabilities of the platform by installation of perception sensors to operate in complex environments in collaboration with humans or other robots.

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