Analysis of the Characteristics of the Power Types of Collaborative Service Robots

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***Abstract*— The article examines the power supply of a service collaborative robot, powered by a hydrogen fuel cell, intended for transporting seriously injured people and serving them in medical facilities. The qualities of this power supply are analyzed, highlighting its advantages in terms of environmental characteristics and its long "life" during the activities of serving patients in serious health conditions and transporting them to a hospital. Some main characteristics of this type of robot, powered by a hydrogen fuel cell, are analyzed, compared with robots powered by other types of power supplies, and its advantages when working in a hospital are shown.**

Keywords—Service Robot, Cobot, Hydrogen-powered Robot

I. INTRODUCTION

Power supply is a key element in the architecture of any mobile or stationary collaborative service robot (cobot) (CSR). The duration of autonomous operation, functional capabilities and operational safety when interacting with people depend on its reliability, energy efficiency and safety. An analysis of the state of the healthcare system justifies the increasing trend of creating robotic systems to assist medical personnel, especially after the development of the Covid 19 pandemic in recent years. When designing such a "cobot", a number of questions arise and it is important to answer them adequately. Creating such highly intelligent and "smart" robots is a difficult and extremely responsible task. In addition to the use of various sensors to provide information from the environment, on the basis of which a safe trajectory of movement of the robot itself and its manipulator is generated, management in the service process is carried out by recognizing voice commands, which is very important from the point of view of user convenience. The power supply system is of utmost importance for the long-lasting and trouble-free operation of the collaborative robot. The special requirements of these robots, designed to assist people with injuries or those in disadvantaged situations, in terms of the power supply system imply stable, uninterrupted and sufficiently long-term operation to fulfil the set goals. That is why it is necessary to develop and create power supply systems that, on the one hand, should be sufficiently compact and relatively light in weight, while at the same time having the ability and being able to release enough energy necessary to perform the complex tasks set by the supervisor.

In this sense of reasoning, it is particularly important to make a comparison of the characteristics of the existing power supply systems for the collaborative robot and especially to highlight the advantages of the hydrogen fuel cell power supply, which is gaining increasing popularity.

The energy that hydrogen provides is sufficient and is an alternative to fossil fuels with the potential to achieve the goals for the development of society. Hydrogen is found in many chemical compounds, such as water and organic biomass, and when burned, it releases heat energy – without pollutants or carbon dioxide. Increased energy consumption is a universal driver for improving the quality of life in all societies, from developing to developed countries. By supplying and using energy that improves the quality of life without endangering the environment, climate or geopolitical relations, the development effect is achieved. Hydrogen fuel cell technology is the subject of continuous research and development. Hydrogen fuel cells are used as a clean [1] and efficient alternative to traditional internal combustion engines, especially in the transport sector this sense of reasoning, it is particularly important to make a comparison of the characteristics of the existing power supply systems for the collaborative robot and especially to highlight the advantages of hydrogen fuel cell power supply, which is gaining increasing popularity [2].

II. BALANCE IN THE CHOICE OF POWER SUPPLY FOR THE COLLABORATIVE ROBOT

In collaborative robotics, a balance is sought in the power supply between high energy density, low weight, safety and the possibility of quick recharging or replacement. The following table (Table 1) provides the characteristics of the types of power supply for the collaborative robot, so that a comparison can be made between each of them.

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TABLE.1.

Power supply type	Characteristics	Advantages	Disadvantages	Typical applications
1. Battery (electrochemical) Power supply.	Lithium-ion, lithium-polymer, lithium-iron phosphate, nickel-metal hydride cells.	High energy density, compactness, suitable for mobility.	Limited life (cycles), risk of overheating, need for BMS.	Most mobile CSR - hospital assistants, logistics and disinfection robots.
2. Hybrid power supply. (battery + supercapacitors).	Combination of fast-discharge and long-life sources.	Extended battery life, ability to absorb peak loads. .	More complex control electronics.	Robots with high starting currents (manipulators, AGV).
3. Fuel cell power supply (hydrogen or methanol).	Electrochemical conversion of fuel into electricity using PEMFC or DMFC cells.	High energy density, low noise, zero emissions (for H_2).	System complexity, need for BOP (Balance of Plant), safety of H_2 storage.	Robots for long-term missions — medical, rescue, military CSR.
4. Mains (stationary) power supply.	Constant power supply from the mains via adapter or transformer.	Unlimited operating time, stable voltage.	Limited mobility, need for cable management.	Stationary collaborative manipulators in laboratory and industrial environments.
5. Inductive (contactless) charging.	Energy transfer via electromagnetic induction.	Convenient, automated, no wear of connectors.	Energy losses, limited range.	Robots with periodic charging — hospital and service systems.
6. Solar power or energy recycling.	Photovoltaic panels or energy from vibrations, heat and motion.	Environmentally friendly, additional source for long missions.	Low power, strong dependence on conditions.	Robots for outdoor areas, monitoring or agriculture.

3. Criteria for selecting the type of power supply

Of course, there is a system of criteria for selecting the power supply for a collaborative robot intended for work in a medical facility. These requirements are determined by the specifics of the robot's activity and are relatively strict enough to obtain the expected effect of its activity. For example, several such criteria can be listed as follows:

- Duration of autonomous operation - requires high energy density (Li-ion, H_2 cell).
- Safety when interacting with people - low voltage ($\leq$ 48 V DC), overheating protection, EMC compatibility [3].
- Maintenance and replacement - modularity of the battery pack, standardized connectors.
- Energy efficiency - minimal losses in converters (DC/DC, DC/AC).
- Mass and distribution of the center of gravity - important for mobile platforms.
- Environmental friendliness and sustainability - recyclable materials, low emissions.

The use of this system of criteria is quite relative and has its importance in determining the power supply system of the collaborative service robot, taking into account the restrictions imposed by the intended use, certain design limitations, and last but not least, its cost and of course the cost of the robot itself.

4. Example power supply configuration

Naturally, the selection of the type of power supply for a collaborative robot intended for use in healthcare depends on its purpose. If the robot is intended for intra-hospital transport, one type of power supply is assumed. But if this robot is intended to transport victims of car accidents or to transport them from the battlefield and the robot is capable of high cross-country ability, then obviously its power supply has certain specific requirements. In this case, a power supply is assumed that has a high energy density at a minimum volume and weight, which is sufficiently compact from a structural point of view.

As examples of power supply configurations for collaborative robots used in healthcare, the following can be cited, shown in Table 2 [4]. It is interesting to analyze the data from Table 2, where the capabilities of a fuel cell combined with a Li-ion buffer so that it represents a hybrid system are immediately noticeable. The possible capacity of activity, which represents more than 12 hours of continuous operation, is remarkable. Of course, this system also has some disadvantages, such as the need to use a hydrogen tank, which is involved in the process of generating electricity. Usually, this is a metal bottle that contains hydrogen and is convenient for quick replacement with a new bottle after the first one is empty.

Unfortunately, however, these bottles are significant in size and weight, which makes it difficult to constructively integrate them into the robot. With its huge capacity and ability to work continuously, this power supply system is a suitable solution for integration into a collaborative robot with high cross-country ability, which can operate in rough terrain and carry out transport operations of injured people in the open.

The remaining systems have their application in collaborative service robots in various cases of use where a high energy flow density is not required and it is relatively easy to recharge them for a new cycle of work.

TABLE.2.

Configuration	**Voltage**	**Capacity**	**Application**
Li-ion 24 V / 20 Ah + BMS	480 Wh	4–6 h autonomy	Small Mobile CSR
$LiFePO_4$ 48 V / 40 Ah	1920 Wh	8–10 h operation	Medium Mobile Platforms
H_2 Fuel Cell 500 W + Li-ion buffer	500 Wh + H_2 tank	> 12 h continuous operation	Hybrid System
AC/DC 230 V → 24 V PSU 500 W	Continuous	Laboratory Environment	Stationary Collaborative Robot

5. Modern Trends

At the modern stage, characterized by the rapid development of Robotics, certain development trends are noticeable. This also applies to robot power supply systems and, in particular, to those systems built into collaborative service robots. With the introduction and development of control systems with elements of artificial intelligence, the management of these systems is becoming increasingly flexible and intelligent. In general, the following development trends in power supply systems can be noted:

- Intelligent energy management systems (Energy Management Systems - EMS) - dynamic distribution of energy between drive, sensors and communication.
- Modular energy architectures - the possibility of adding a secondary source (e.g. H_2 + battery).
- Fast charging stations and automated docking systems - to increase the continuity of work.
- Implementation of safe lithium iron phosphate cells ($LiFePO_4$) in medical collaborative service robots (CSR) due to lower fire hazard and safety in operating modes.
- Application of micro fuel cells and hybrid power units with supercapacitors (Fuel Cell + SC) for robots with a long duty cycle.

A large part of these development trends have already been implanted in real systems powering collaborative service robots. And these are not just laboratory samples, but real systems that perform the most complex service activities by relieving the heavy or monotonous work of people, for example, in healthcare.

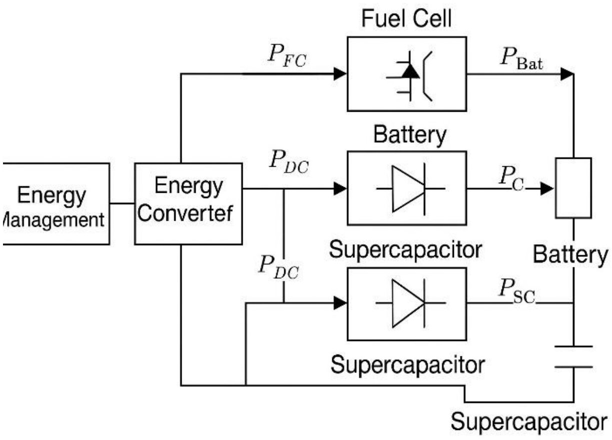

Fig.1. Schematic diagram of a combined power supply with a hybrid block.

The modern development of these systems implies increasingly complex and user-friendly new implementations that will lead to significant help to human society.

Figure 1 shows an exemplary schematic diagram of a combined power supply with a hybrid energy block with supercapacitors and a battery (H2 Fuel Cell + Batt.+ SC) for robots with a long duty cycle. Such a configuration involves the use of the advantages of a micro-hydrogen fuel cell with the ability to store part of the energy in a battery. In a situation where significant power is required for a short time, the supercapacitors block is used, through which significant energy can be introduced for a very short time and thus increase the torque of the motors to a value required to overcome the obstacle that has arisen. Such a power supply system is suitable for robots with off-road capabilities in order to perform a task of transporting a seriously injured patient from a random area.

Fig.2. Modern Collaborative Robot - Full-face view.

Figure 1 and Figure 2 show a modern collaborative robot with hybrid power supply, a micro hydrogen fuel cell as a hybrid power unit with supercapacitors (H2 Fuel Cell + SC) for robots with a long duty cycle. It is a wheeled platform equipped with a rich sensor system, including two types of laser interferometers (LIDAR), with the help of which it orients itself in space and is able to move to any point.

Fig.3. Modern Collaborative Robot - Profile view.

Various executive devices can be mounted on this platform, for example, a manipulator with seven degrees of mobility so that it can carry out certain orders, for example, in the middle of a hospital [5].

6. Conclusion

The type of power supply for collaborative service robots is determined by the mission, the operating environment and safety requirements. The most flexible solutions are hybrid systems (battery + supercapacitors or battery + fuel cell), which provide an optimal balance between energy density, peak capacity and operational reliability. In future developments, the trend is towards "smart" power modules that self-optimize according to the load and allow collaborative work in a dynamic environment without interruption.

Based on the above, the following conclusions can be drawn:

- For mobile collaborative robots: $LiFePO_4$ is preferred due to safety and stability.
- For high-performance platforms or long autonomous missions: the hydrogen fuel cell is an excellent choice.
- For high peak loads and recuperation: supercapacitors are often combined with batteries (hybrid power supply).

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