Power Management System for Hybrid and Solar Electric Vehicles

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***Abstract*– The world is trying to face the problem of energy sources running out, so, this situation requires making use of renewable sources of energy such as sunlight. In the field of automotive engineering, ICE vehicles production reduces and the electric vehicles production increases.**

Power management strategies have been developed in EVs since the first introduced one in early 1900s. Vehicles can be operated by a single source of power or by a combination of multiple sources (such in HEV) and propelled by a single or a combination of several systems. Charging technique for solar electric vehicles can be achieved by mounting solar panels on their roof, electric batteries of these cars can be recharged. These solar panels work on the PV technology.

This paper reviews two main parts

--- The first is an overview on hybrid and solar electric vehicles, batteries and solar panels suitable for EVs, power management.

---The second is an application of the power management on a small project.

Keywords— power management, solar panels, batteries, Hybrid electric vehicles, solar electric vehicles

I. INTRODUCTION

Nowadays, the world need a renewable source of energy because all sources of energy will run out, especially in the field of automotive engineering, Scientists look for alternatives for internal combustion engine vehicles.

Internal combustion engines have a several problems that affect the environment due to the emissions, which come from their engines.

In EV, the internal combustion engine is replaced by an electric motor, which gets energy from rechargeable batteries through a controller that regulates this amount of power.

There are two techniques for charging batteries, the first technique is done using a power station for fully electric vehicles, and the second technique is done by an embedded source of energy within the vehicle.

EVs have many advantages:

- they are more efficient.
- they produce low emissions; more friendly cars.
- they require less maintenance.

They have also many disadvantages:

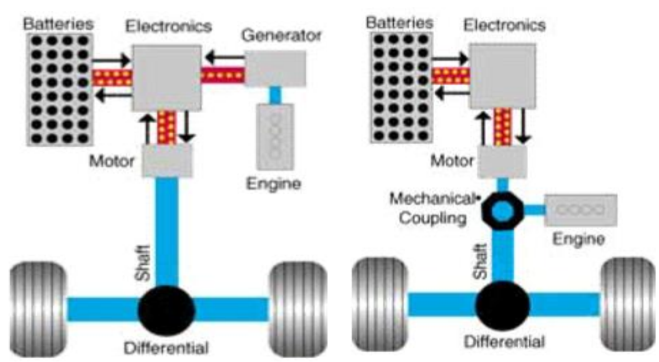
- they have a high production cost.
- Needed to be charged for long periods.
- Move for a short distance.

Electric vehicles paved their way into public use as early as early as the middle of the 19th century, even before the introduction of gasoline-powered vehicles.

In the year 1900, 4200 vehicles were sold, out of 40% were stream powered, 38% were electric powered, and 22% were gasoline powered. However, the invention of the starter motor, enhancements in mass production technology of gas powered vehicles and disappearance of EVs in the early 1900s.

In 1970, the first hybrid type of photovoltaic devices and electric vehicles were manufactured. To generate more publicity and research interest in solar powered transportation, Hans Tholstrup organized an 1,865 mi (3.000 km) race across the Australian outback in 1987.General Motors (GM) won the event by a large margin, achieving speeds over 40 mph with their Sunraycer vehicle.

II. HYBRID ELECTRIC VEHICLE



(a) (b)

Fig.1 types of hybrid electric vehicles according to way of connection (a) series, (b) parallel.

The hybrid electric vehicle is a vehicle propelled by either of two sources of motive energy. There are many types of hybrid systems, which may combine fuel cells, gas turbine diesels, gasoline engines, batteries, ultra-capacitors and solar panels.

For military applications we may use unmanned electric vehicle to walk a long distance for investigation and discovery; this requires combat vehicles that are smaller, lighter and achieves better fuel economy yet, are more lethal, survivable and more mobile.

By developing new vehicle propulsion methods and using alternative fuels, the general requirement of combat capability,

as well as the economic and mobility enhancement aims can be achieved.
Electric Hybrid Vehicles are used in military applications like reconnaissance vehicles – unmanned vehicles.

Types of hybrid electric vehicles
Hybrid electric vehicles can be classified according to:

A) Driveline Topologies

1. series hybrid electric vehicle:
Using the assist source of power as a source for charging the batteries only, not for directly driving the car.
2. parallel hybrid electric vehicle:
We can switch between the available sources of power embedded within the vehicle according to driver's demand or it could be controlled as shown in figure 1

B) Degree of hybridization

1. Full Hybrid Electric Vehicles:
This type of vehicles can run using the engine or the batteries or a combination of them. The batteries used in this type of vehicles require having large and high capacity.
2. Assist Hybrid Electric Vehicles:
This type of vehicles differs from the full hybrid type as
   a. Engine only used when torque is high.
   b. Always uses large motor.
   c. Small pack of batteries is used.

OTHER TYPES OF HYBRID ELECTRIC VEHICLES

A. Plug-In Hybrid Electric Vehicle (PHEV):
This type is considered as a full hybrid vehicle, when running using the batteries on the batteries only, it can be recharged using electric power grid or it could be recharged using the engine.

B. In-Wheel Motor Hybrid EVs:
This type of HEVs uses a small electric motor at each wheel. This configuration makes it easy to control the torque and speed without using transmission and complex mechanical components, this reduces the vehicle overhaul weight and consequently the efficiency improved

III. SOLAR ELECTRIC VEHICLES

Solar EVs is powered completely by direct solar energy. This is performed using solar panels installed on the vehicle body. These solar panels are usually consisting of photovoltaic cells, which converts the solar energy into electric energy to charge batteries throw a charge controller. This vehicle operates when it is exposed to a direct sunlight such as golf cart. The main disadvantage of using this vehicle that it cannot be used in shaded days or nights. To solve this problem, it is recommended to use a battery pack, which ensures continuous and extended range of driving. Nowadays, SEVs are found all over the world as a clean, environmental car and as a replacement source of energy to the natural that facing a great demand and a runout problem. Many competitions of SEVs take place to promote for manufacturing and enhancement of this car for example The German Power Core Sun cruiser, Japanese Kaitu II and the Australian eve are the most remarkable solar race cars, the TINDO project that is operating as free public transport service in Australia.

In this paper, we mainly concentrate on hybrid electric vehicles that use solar energy as an alternative source of energy for charging the batteries as shown in figure 2.

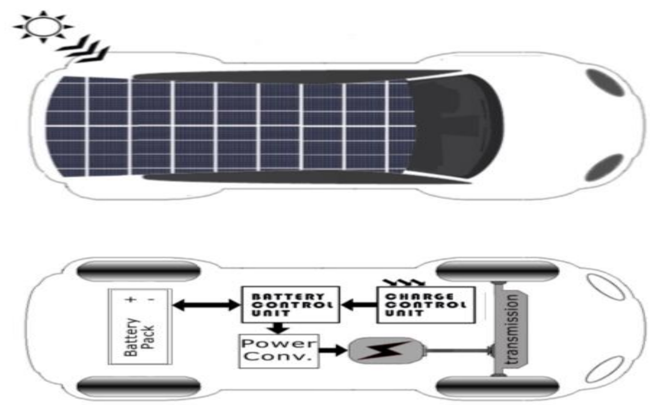


Fig.2 Solar Electric Vehicle drives train with battery pack.

IV. BATTERIES

Battery: is main power source for any electronics wireless devices, which can be used in electric cars, that is electrical energy is converted to mechanical energy.
The scientific definition is: the arrangement of electrochemical cells connected in series, which can be used as a source of DC. That is arranged in series to increase the voltage and in parallel to increase the current. Batteries used are Lead Acid, Nickel Iron, Nickel Cadmium, Lithium Polymer, Lithium Iron and Sodium Sulphur.

Required characteristics for choosing batteries:

a) The price
b) Power capacity and specific energy.
c) Voltages and Amp Hour Efficiency
d) Safety: There are two types of batteries as:
   1) LI-ION: More safe
   2) LI-POLYMER: dangerous even if it is discharged.
e) Number of Life Cycles and Recharge Rates.
f) Light and compact.
g) Energy density

Some types of batteries used in hybrid electric vehicles:

a) **Lead acid battery:** That contains (3 to 6) cells to get 6 to 12V, contain fiberglass separator for electrolyte to be kept in place, resist vibrations, spill-proof and withstand rougher use. Lead is the anode and Pbo2 is the cathode.

That it has the following properties:

1. 1-2 years of daily use.
2. Need 3 to 15 hours to completely recharge.
3. Driving ranges greater than 30-50 miles.
4. Cheap and easily rechargeable.

b) Nickel-Cadmium battery: That is a cadmium anode and NiO2 acting as a cathode. The electrolyte is KOH**.**

That it has the following properties:

1. Higher charging cycles.
2. More expensive, it is smaller and lighter.
3. Easy to recharge.
4. Contains toxic metal.

c) Nickel-Zinc battery:

1. Is a low weight battery.
2. It is environmentally friendly and be reliable to be up to 600 cycles (deep charge) and 11,000 cycles (low charge).
3. More expensive than other batteries.

d) Lithium battery: It is a solid-state battery because solid electrolyte is used, that is a polymer. The electrolyte allows ions to pass but not the electrons. It contains lithium anode and TiS2 as a cathode.

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battery vehicle (EV, PHEV, HEV) production, the Li-ion battery demand from 2012 to 2020. That EVs sales are increasing gradually and the production growth will continue due to the demand of electric vehicles, the lithium supply for batteries also rises as EV sales increase.

It has the following properties:

1. Its cell voltage is high, 3V.
2. The battery constituents are solids, so there is no leakage.
3. Variable sizes and shapes and lightweight.
4. Higher energy density.

Table.1 comparison between different types of batteries.

P.O.C	LEAD-ACID	NI-CAD	NIMH	LITHIUM
AMP-HR. (20HR)	2.5	4	6.5	7.5
CELL VOLTAGE	2	1.2	1.2	3.6
MAX C RATE	40	25	11	40
AH/25C	0.5	3	5	6

V. SOLAR ENERGY

A solar cell is an electronic device that converts sunlight into electricity. Shining the solar cell will produce both a current and a voltage. The conversion of PV energy in solar cells consists of two important steps. First, a material, which absorbs light, produces an electron hole pair required to generate electrical power. Secondly, PV energy conversion uses semiconductor materials in the form of a p-n junction. There are two main types of solar cells, crystalline silicon solar cells and thin film solar cells. PV modules consist of a number of interconnected solar cells. The purpose of connected solar cell is to protect them and connection of wires from the environmental effects in which they are used and prevent mechanical damage to the solar cells and to prevent water or water vapour from rusting the electrical connections.

Types of solar cells:

1. Monocrystalline solar panels are the most common for residential solar installations (High efficiency higher cost).
2. Polycrystalline solar panels are popular for designing a solar system on a budget (Low cost Lower efficiency).
3. Thin film solar panels are not the best option for home solar (Flexible and lightweight extremely low efficiency). They are solid black, without the normal silicon cell outlines you see on the face of a crystalline solar panel.

Advantages and disadvantages of flexible solar panels

Most type of solar panels that can be stablished on the roof of the car is the flexible one.

Advantages:

- Serve as eco-friendly energy sets (battery needed).
- Lightweight and movable.
- Easy on most pockets.
- Bendable enough and multi-functional, as compared to conventional solar panels.

Disadvantages:

- Size matters, so limited power generation and storage. Even with an efficiency of up to 25%, you only get up to 300-watt flexible solar panels.

- Less durable than solar panels and a high-quality solar panel from Renogy comes with a 5-year product warranty.

Connection of solar cells

a) Series Connection

Connecting the panels in series increases the voltage of the system, so the two panels produce double the voltage as compared to one panel. This high voltage can cause damage to the battery and could cause a safety issues, to connect panels in series, connect the negative (-) plug of panel (1) to the positive (+) plug of the panel (2). See Figure 4.

b) Parallel Connection

Connecting the panels in parallel increases the current of the system, so the two panels produce double the current as compared to one panel. This high current may cause damage to the battery and the by-pass diode in the junction box and cause a safety issue.

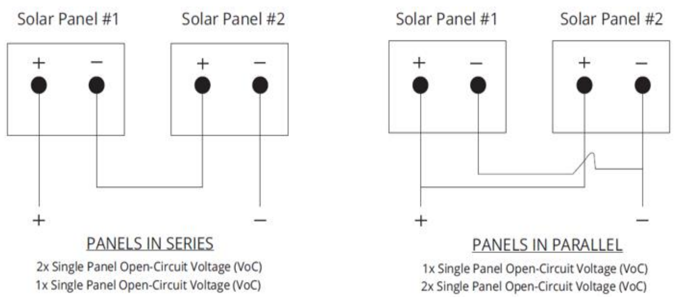

Fig 4: Schematic of two panels in series and parallel.

To connect panels in parallel, connect the positive (+) plug of panel (1) to the positive (+) plug panel (2) Connect the negative (-) plug of panel (1) to the negative (-) plug of panel (2).

V. POWER MANAGEMENT

Control strategies for hybrid and electric vehicles generally target several simultaneous objectives. Reduction of the vehicle fuel consumption, also aims to minimize emissions and to improve drivability. Nowadays, two layers; High-level software-based supervision and low-level hardware-based control form the power management (PM) system in EVs, which can be divided into two control layers, low-level component and low-level control. Both hardware and software control layers works together to optimize PM system in EVs.

Main challenge of energy management system (EMS) in an electric vehicle is to guarantee optimum use and restoration of the total energy in the vehicle. Regardless of number of sources, the powertrain configuration, at any time and for any vehicle speed, the control strategy has to determine the power distribution between different energies. When two storage techniques or two fuel converters are available additional power distribution between the RESSs and between the fuel converters has to be determined. These decisions are controlled by two factors. Firstly, the motive power demanded by the driver must always be assured up to a maximum power demand. In addition, charge status must be provided, allowing the vehicle to charge continuously.

VI. APPLICATION ON A SMALL PROJECT

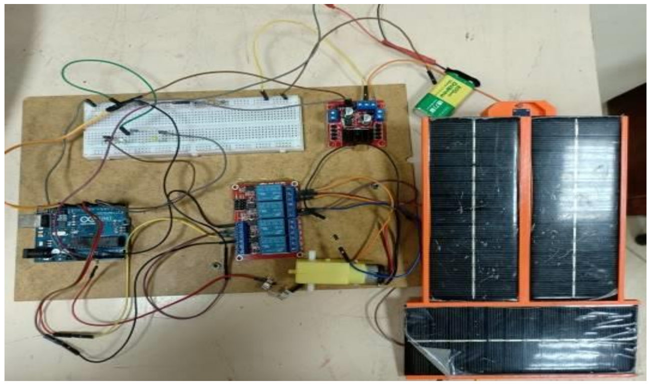

Fig.5: small solar model.

Hanging on the pervious information about solar and hybrid electric vehicles and their power management strategies,
Fig 5 shows an application on a small simple prototype similar to the hybrid electric vehicle working strategies using an Arduino as a controller for switching between the two sources of energy for running the car motor and using solar energy for charging the batteries.

Main circuit components:

1. motor driver (L298N Driver)
2. Arduino (UNO)
3. Battery (9V)
4. Small dc motor (9v, 200mah for max rpm)
5. solar cell (12V, 5.2 watt)
6. Relay (2/4 channel)

In this circuit, there exist two sources of power (batteries and solar panels) for driving the dc motor that is similar to the dc motor in the full-scale car model, which drives the wheels with the use of differential.

We use an Arduino for achieving the power management strategies according to batteries and environment status and according to driver's command.

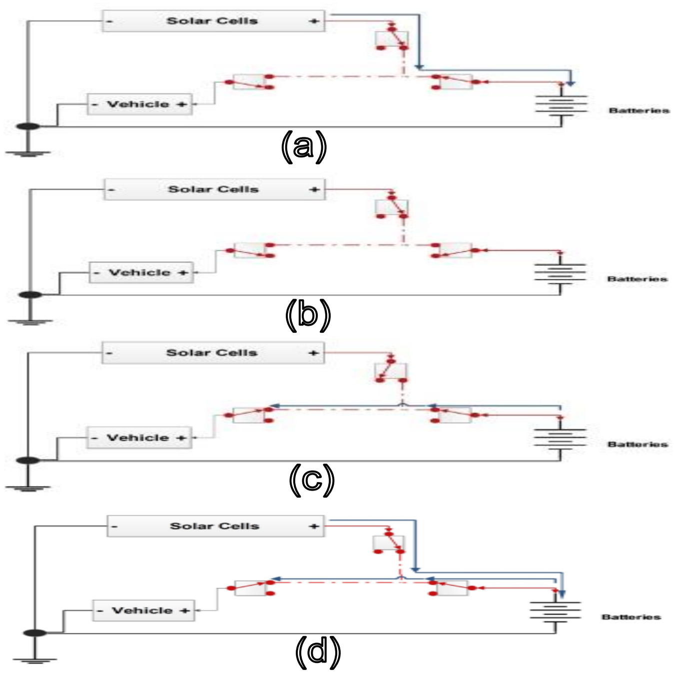

Fig.6 Power management flow diagrams

Power management flow diagrams shown in figure 6 illustrate:

- Case (a): No driver command and high solar voltage. Action: Solar cells are charging the batteries.

- Case (b): No driver command and low solar voltage. Action: Batteries are disconnected from solar panels to prevent self-discharge of batteries.

- Case (c): Driver command and low solar voltage. Action: Vehicle is powered by batteries and solar cells are disconnected.

- Case (d): Driver command, high solar voltage and low battery voltage. Action: Vehicle is powered by batteries and solar cells are charging the batteries.

➢ **battery calculation:**

  - battery:9v, 800mAh, lithium.

  - motor: 9v, 200mAh.

  - Time taken for full battery discharge = 4hrs.

➢ **solar panels calculation:**

  - battery:9v, 800mAh, lithium.

  - solar: 5.2 watt, 12 V.

  - Time needed for full battery charge using one solar sheet = 3.918 hrs. Of direct sunlight.

  - Using three solar sheets = 2.64 hrs. of direct sunlight.

VII.CONCLUTION

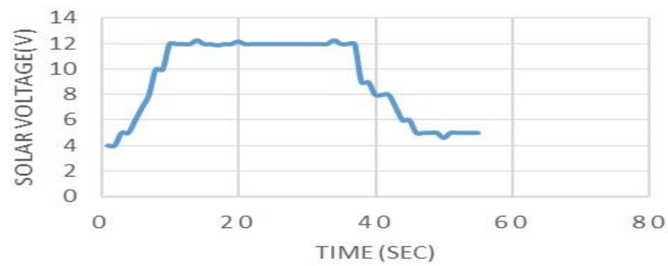

Fig.7 solar voltage readings in sunlight

After using solar panels, we increase the working time nearly twice and accordingly the distance travelled.

VIII. ABBREVIATIONS AND ACRONYMS

- ICE: Internal Combustion Engine
- HEV: Hybrid Electric Vehicle
- EV: Electric Vehicle
- SEV: Solar Electric Vehicle
- PHEV: Plug-In Hybrid Electric Vehicle
- PM: Power Management
- RESSs: rechargeable energy storage systems

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