DEPARTMENT OF ELECTRICAL ENGINEERING

SOLUTION & MARKING SCHEME

(Semester 1, 2015/16)

SUBJECT (Code & Title) : EE512 / EE512A Electric Vehicles

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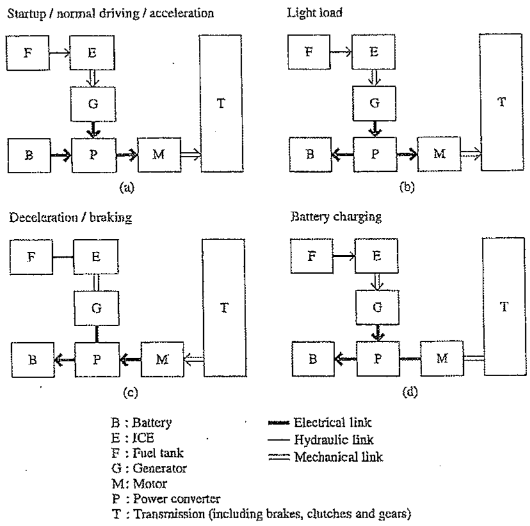
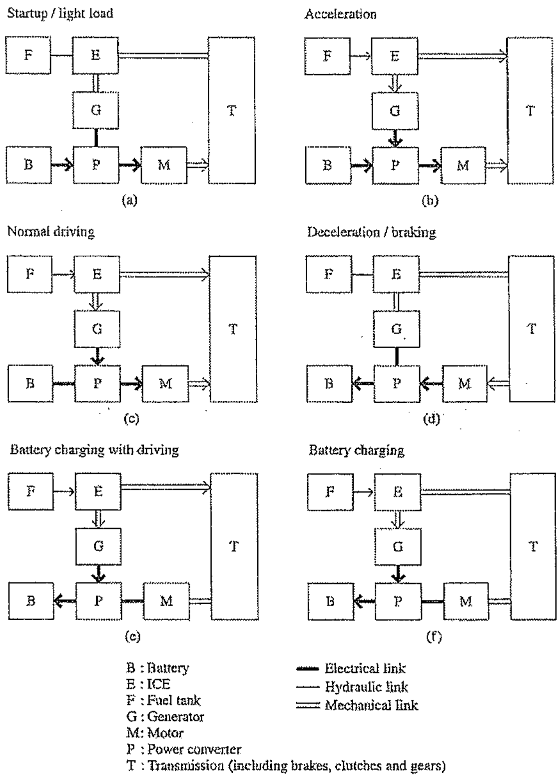
SUBJECT MODERATOR	E Cheng

QUESTION NO. ( )	SOLUTION	MARKS
Q1 (a)	A: The car is accelerating from low speed to medium speed. In this area, the driver's accelerator is hard pressed to the maximum, and the motor power is giving out its maximum torque. Many dots in this area mean that the driver is always the car to perform hard acceleration.	2
	B: The car's motor is giving out its maximum negative torque. This happens when the motor is having regenerative braking. Also, the regenerative braking is already at its maximum peak from medium speed to zero speed. Many dots in this area mean the driver always performs hard deceleration.	2
	C: The car is cruising along at low speed. Many dots show that the car is driving in the urban area when the speed is predominately low (i.e. 50km/hr).	2
	D: The car is cruising along at high speed. This happens when the speed limit is 70 ~ 100 km/hr, in high way or non traffic light roads.	2
(b) (i)	Mild Hybrid Electric Vehicle (Mild HEV) and Full Hybrid Electric Vehicle (Full HEV) Both types do not have charging facility. The car needs to fill up the tank. Mild HEV means that the vehicle is predominately an ICE car, but it includes an electric motor to assist its performance during acceleration and deceleration. Full HEV means that the vehicle is powered mostly by the electric motor, with the ICE assisting in the electricity generation, and constant speed cruising.	6
(b)(ii)	Plug-in Hybrid Electric Vehicle (PHEV) and Range extended Electric Vehicle (REV) Both types contain a small oil tank and a charging socket. PHEV can be series hybrid or parallel-series hybrid. If it functions as an EV, it has a range of 50~70 km. Beyond that range the ICE kicks in. REV is designed as a pure EV, with around 150km range. However, if the user needs to go beyond this range, he can fill up a small petrol tank and start up the electricity generator, as a back up battery power for extended range.	6

QUESTION NO. ( )	SOLUTION	MARKS
Q2 (a)	*Differential Gear* (a) Contains differential gear. Therefore it is more complicated mechanically. But differential gear has a well proven safety record. (b) Contains no differential gear. Structurally it is more simple. However, the two wheels need to be synchronized, by an intelligent controller and software. With no mechanical link, it seems that the safety issue is not well proven.	3
	Motor Attachment (a) Motor is attached to the car chassis, and there is a complicated mechanical link to the wheels. It is mechanically more complicated. However the motor will not subject to vibration (b) Motor is built into the wheels. Mechanically it is more simplified the motor needs to be subjected to shock vibration and dirty environments.	3
	Number of motors (a) One – therefore a mechanical link is need to link the two wheels (b) Two – no mechanical links needed. However, the synchromization between the two wheels is complicated.	2
	Gear ratio (a) Gear reduction present. Therefore a smaller motor size can be used. (b) Direct drive – The motor diameter needs to be bigger to create adequate torque.	2
(b)	  Fig. 4.7. Electric-heavy series–parallel hybrid operating modes. Main Differences: During hard startups and normal driving, series-parallel can be powered by the motor and ICE. But series hybrid can only be powered by the motor. When the car is moving, parallel –series hybrid can use the ICE to drive the car and charge the battery at the same time. But series hybrid needs to rely on the generator to charge the battery and power the motor to move the car.	10

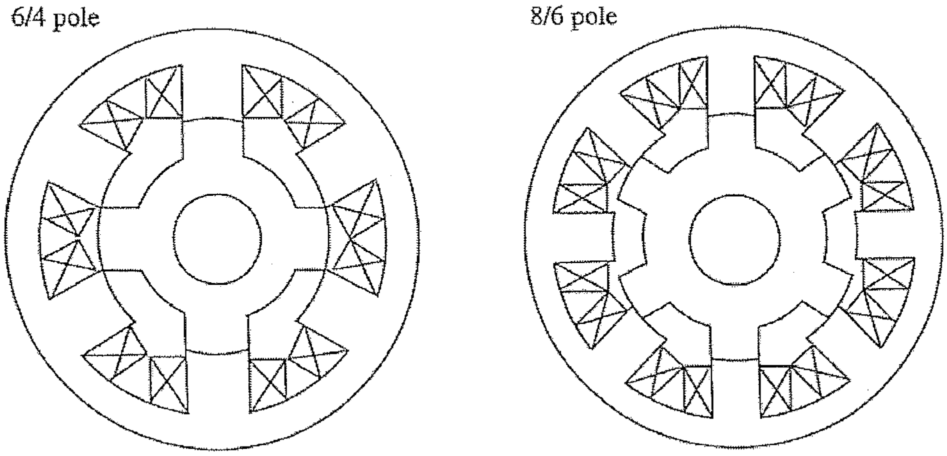
QUESTION NO. ( )	SOLUTION	MARKS

Q3

(a) — 7 marks

Structure:

6/4 pole　　　　8/6 pole

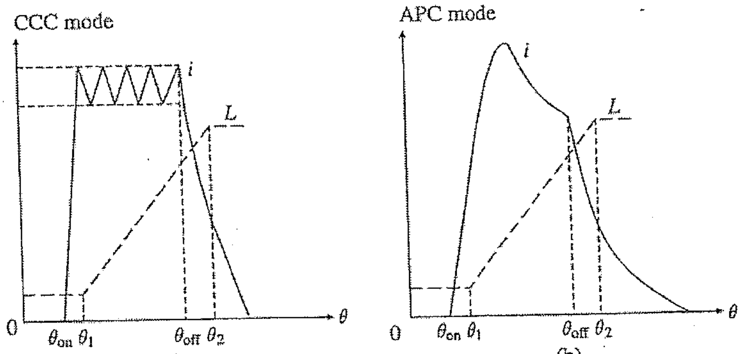


(a)　　　　(b)

* no brush, no permanent magnet, no commutator, simple construction
* rugged, highly reliable, can work in extreme temperature range, can withstand shock vibration
* efficient, high torque at low speed

(b) — 8 marks

CCC mode　　　　APC mode



(a)　　　　(b)

CCC: regulate the current supplied to the coil through feedback control (for low speed use)
APC: switch on and switch off current supply at particular positions (for high speed use)

At low speed the controller's speed is fast enough to regulate the current of the coil through feedback control. Therefore current shaping is used. At high speed the controller cannot catch up with the speed of the turning rotor, therefore on/off control is used. However, at such high speed, due to the inertia of the rotor, the motor will turn very smoothly with no irregularities.

(c) — 5 marks

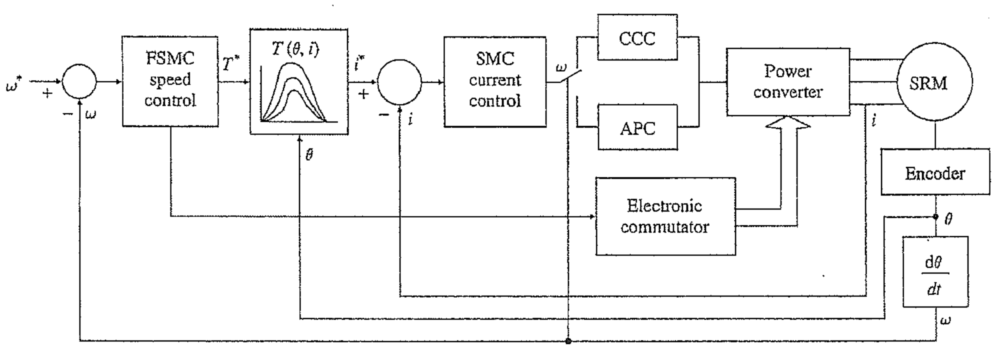


Fig. 5.66. FSMC system of a SR motor drive.

Add some explanation to the diagram above.

QUESTION NO. ( )	SOLUTION	MARKS
Q4	Fuel cell has high energy storage capacity, but low power output capability	3
(a)	Ultra-Cap has high output capability but low energy storage capability	
	By combining the two, and by intelligently manage the two power sources, the EV power pack can have both high energy capacity, and high power output capability.	3
(b)		
(i)	*Energy management for hard braking:* Brake >> Energy generated by the motor >> Store in Ultra Cap >> Use by motor during acceleration or cruising Therefore it is a good practice to discharge the ultra cap when the EV speed is high. Note: Fuel Cell cannot be recharged electrically.	7
(ii)	*Energy Management for Fast acceleration from rest* Fuel Cell supply energy >> store in ultra cap >> use by motor during acceleration Therefore it is a good practice for ultra cap to charge up when EV is at rest.	
(iii)	Constant high speed driving Fuel Cell >> directly supply power to the motor	
(c)	(figure and text below)	7

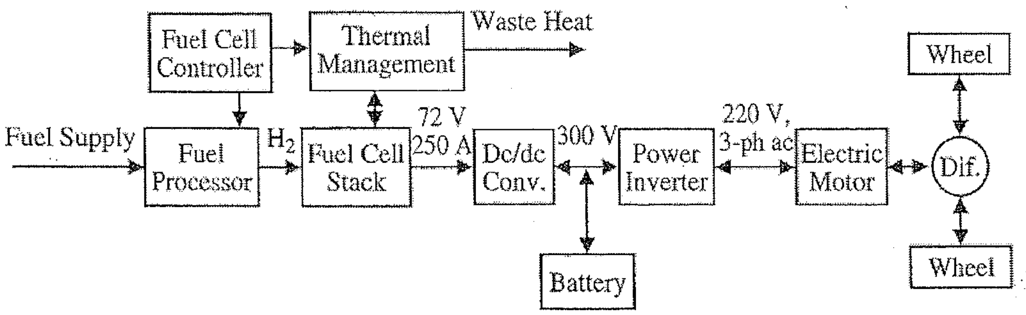


FIGURE 4.3 Fuel-cell-based EV.

Why FCEV is more complicated than Pure EV

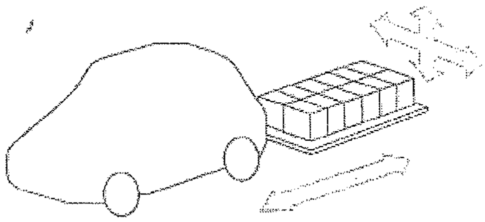
* Need to regulate the amount hydrogen fuel to the cell for optimum power output
* Need to manage a high temperature environment for reaction to take place
* Need fuel tank and other storage equipment for safety storage of the hydrogen fuel

QUESTION NO. ( )	SOLUTION	MARKS

Q5 (a) — Marks: 8

Public Battery Swapping Stations

Instead of charging the batteries immediately, we have another way to refuel the energy source of EVs—mechanically swapping the discharged batteries with those fully charged batteries. Of course, all these batteries should be owned by the service station or battery company while the EV driver is only a battery borrower.



Changes that need to take place in HK for battery swapping:
* Infrastructure – need to build battery swapping stations, with robot handling assistant
* Commercial – need one or more private companies to own and hire EV batteries
* Standardization – need to unified battery electrical and mechanical standard for the batteries
* Adaptation – need to be attractive in cost for all the above things to happen

(b) — Marks: 12

There is no standard answer.

Marks will be assigned as follows:

1. Local Practicality (25%) – How practical is it to implement in HK? Do you have to change a lot of things in HK?

2. Cost (25%) – The overall cost should not be too high, otherwise both the bus company and the consumers will have no incentive to change.

3. Technology maturity (25%) – Is the technology already mature, or is it still under scientific research?

4. Other Details (25%) – Is the plan well thought through? Any things missing or overlooked?

Q6 (a) — Marks: 5

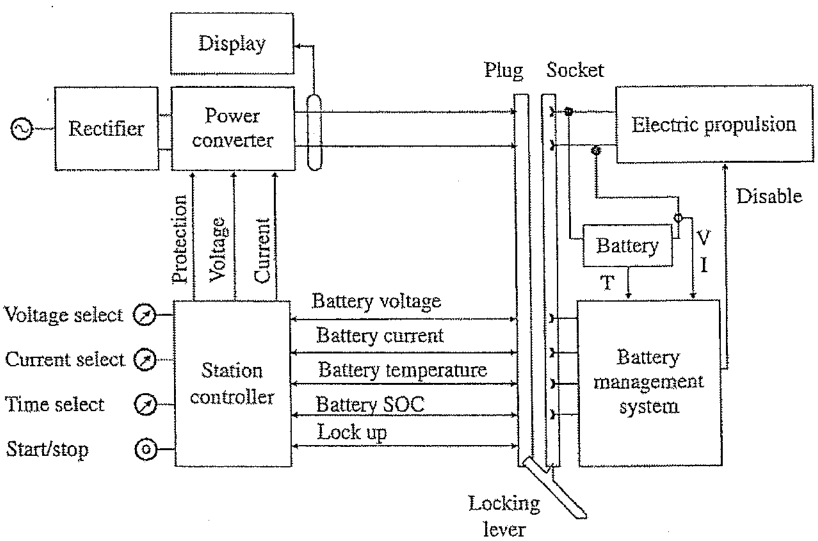


Fig. 7.16. Arrangement of an off-board conductive charger.

QUESTION NO. ( )	SOLUTION	MARKS
	hand, the off-board charger is designed with a high charging rate, and has virtually no limitation on its weight and size. Since the off-board charger and the BMS are physically separated, they should have a reliable communication by wiring cables or wireless radios. Based on the information of the battery's type, voltage, temperature and SOC supplied by the BMS, the off-board charge will adopt a proper charging method to charge the battery without any excessive overcharge and overheating.	3
(b)	(i) A car has 4 wheels, the electric motor is usually connected to two wheels only, and the other 2 wheels use friction brakes. Even the electric motor connected wheels need to add a tradition brake to guarantee failsafe. Therefore the regenerative braking energy is always a fraction of the total brake energy.	4
	(ii) At very low speed the motor, acting as a generator, will generate little to no energy output. At very high speed, the braking energy is too high for the electric motor to absorb, and a majority of energy dissipation is passed onto the friction brakes.	4
	(iii) The generated power cannot be larger peak power rating of the motor (which acts as a generator). Therefore there is a plateau for the regenerative braking power output.	4