OVERVIEW OF ELECTRIC VEHICLES - CLEAN AND ENERGY EFFICIENT URBAN TRANSPORTATION

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Abstract. In a world where energy conservation and environmental protection are growing concerns, the development of electric vehicle technology has taken on an accelerated pace. The dream of having commercially viable electric vehicles (EVs) is becoming a reality. This paper provides an overview of the present status and future trends in electric vehicle technology, with emphasis on the key issues and the impact of rapid development of electric motors, power electronics, microelectronics, and new materials. Comparisons are made among various electric drive systems and various battery systems. The potential electric vehicle impacts and market size are also addressed.

Keywords. Electric vehicles, electric drives.

WHY ELECTRIC VEHICLES?

The first societal reason for electric vehicle is the energy issue. Presently transportation sector uses over 60% of oil demand in advanced countries. As the resources of oil is limited, this problem becomes the issue of national security and dependence. Figure 1 shows that electric energy can be generated from comprehensive prime energy resources including fossil, hydro, nuclear, wind, solar geothermal, tidal and wave. Moreover, the energy efficiency of electric vehicle (EV) is about 15% and 30% higher than natural gas vehicle (NGV) and gasoline/internal combustion engine vehicle (ICE) respectively. The range of energy saving depends on the driving cycle condition and the efficiency of power plant. The energy saving of electric vehicles in city driving is more significant as compared with that in highway driving, since electronic controlled variable-speed electric drive is more efficient than conventional gear shift ICE drive. In short, electric vehicle complies with the national energy strategy should be secure, efficient and environmentally sound.

The second societal reason for electric vehicle is the environmental issue, which is the prime driving force of today's electric vehicle development. Due to the growing concern for air quality and the possible consequences of the greenhouse effect, some cities have set aside emission-free zones and have enforced stricter emissions regulations encouraging the promotion of EVs. In October 1990, the California Air Resources Board established rules that mandates 2% of all vehicle sold in California in 1998 to be Zero Emission Vehicles (ZEV), and by 2003, ZEV sales quota will be 10%. Figure 2 shows the comparison of emissions of gasoline-powered minivan and electric minivan, taking into account the emission of the power plant. This comparison is based on drive test in California. Similar study has been done in Hong Kong which showed similar result.

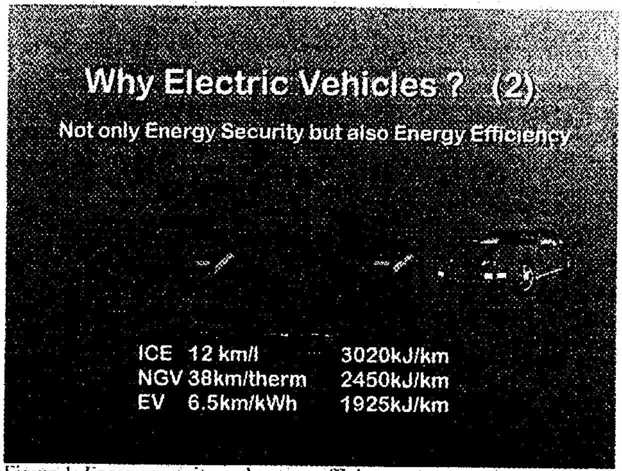
The third societal reason for electric vehicles is that electric vehicle is more intelligent so that it can contribute to reduce traffic jam and enhance driving safety by the aid of intelligent navigation system, radar system for crash prevention, etc. These electronic information technologies can be readily implemented in electric vehicle system, since the vehicle is already electrified.

KEY ISSUES

The key issues in successfully commercialize and promote electric vehicles lie in how to produce low cost good performance electric vehicles; how to leverage the initial investment; and how to provide efficient infrastructure.

System integration and optimization is a prime factor in achieving low cost good performance electric vehicles. Since the energy density of present battery is much lower than that of gasoline, every effort should be made in optimizing the energy utilization for increasing driving range. The rating of the power train should be designed in accordance with the torque-speed demand of the vehicle; the major components should be carefully selected for optimum matching.

The electric vehicle system is an integration of vehicle body, electric propulsion, energy storage battery, and energy management. The technologies involved are diversified, which include electrical and electronic engineering, mechanical and automotive engineering, and chemical engineering. The philosophy and architecture of the system are of prime consideration. System integration and optimization enables perfect matching among subsystems, bearing in mind that the components used in EV are working in mobile and severe temperature conditions. The key technology required includes : (1) light weight, rigid, low aerodynamic and low rolling resistance chassis and body technology, (2) high power density and high operating efficiency motor drive technology, (3) high energy density, high power density and long cycle life battery/energy storage technology, (4) intelligent energy management system, and (5) high efficiency, high reliability battery charger and infrastructure facility technology.

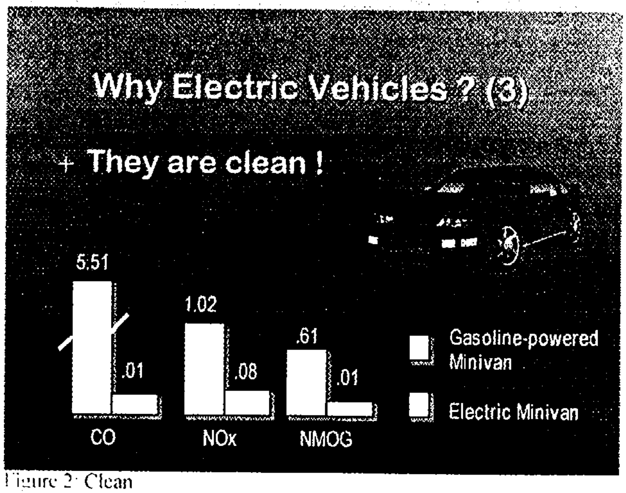


Why Electric Vehicles ? (2)

Not only Energy Security but also Energy Efficiency

ICE 12 km/l 3020kJ/km
NGV 38km/therm 2450kJ/km
EV 6.5km/kWh 1925kJ/km

Figure 1: Energy security and energy efficiency



Why Electric Vehicles ? (3)

+ They are clean !

Figure 2: Clean

In Summary, a ground up design philosophy should be adopted for commercially viable EVs, although some components and facilities can be chosen from existing ones. Since the characteristics of an internal combustion engine is inherently different with that of a motor drive, the special merits of electric motor control should be fully utilized. EV design concepts should include : (1) Technologies which enhance the performance of EV should be selected from state of the art of automobile, electrical, electronic and material technologies, (2) Special designs particularly suitable for EVs should be adopted, and (3) Construction techniques specific to an electrically powered vehicle should be adopted. The EV concept can be summarized as Table 1.

TABLE 1 - EV CONCEPT

☐ EV is not just a car, but a new society system
☐ EV system can be an intelligent system and can be integrated with other electric transportation systems
☐ EV design is the integration of art and engineering
☐ EV operating condition and duty cycle must be defined
☐ EV users' expectation must be studied and appropriate education must be conducted

ELECTRIC PROPULSION

The electric propulsion system of an EV is responsible to convert electric power to mechanical power to propel the vehicle to overcome aerodynamic drag, rolling resistance drag and kinetic resistance as showm in Figure (3) The driving characteristics of a conventional internal combution engine car is shown in Fig (4), since the torque-speed characteristic of an internal combution engine is only within narrow bandwidth, the required torque-speed performance of the vehicle have to be achieved through gear charging. However, in modem motor drive, high constant torque region and constant power over wide speed range can be achieved through electronic control. Figure (5) shows typical torque-speed characteristics required for different size of vehicles.

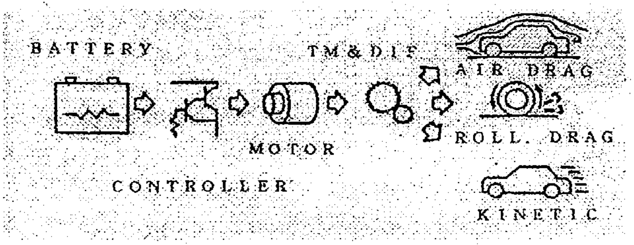


Figure 3 : EV Propulsion

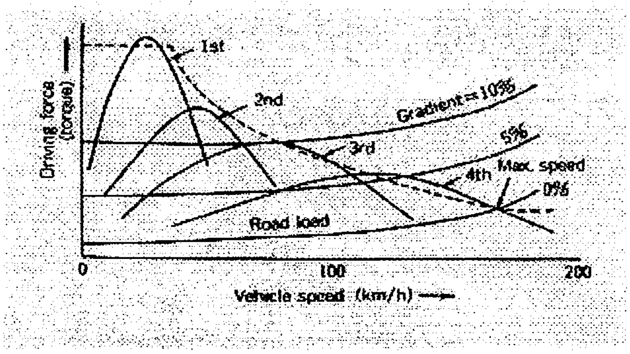


Figure 4 : ICE Driving Characteristics

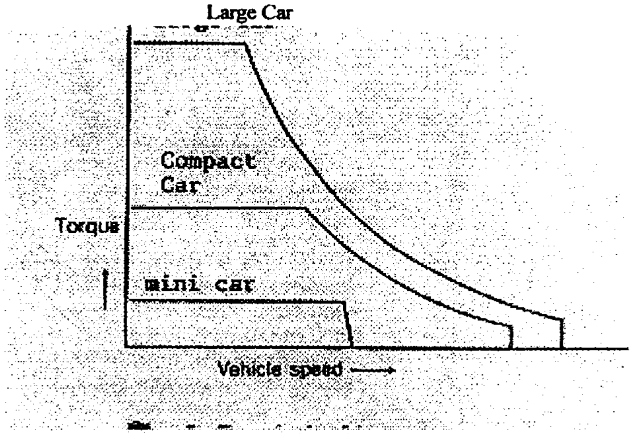
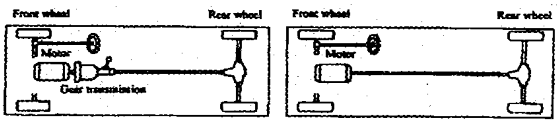
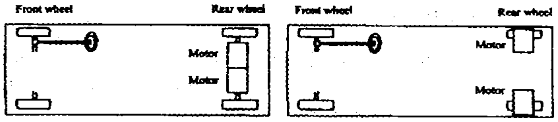


Figure 5 : Characteristics of various Vehicles

In an EV, the electric propulsion design can be more flexible, the propulsion system can be designed with single motor or multi-motors, with or without reduction gear, with or without differential gear, with shaft motor or wheel motor. Figure 6 shows various possible arrangements. Table 2 summarized the main requirements for EV motors drives.



(a) Conventional (b) Without gear transmission



(c) Without differential gear (d) Wheel motor

Figure 6 : Possible EV propulsion arrangement

TABLE 2 - **Main Requirements for EV Motor Drives**

☐ Power Rating
  ◆ High instant power
  ◆ High power density
☐ Torque - speed characteristics
  ◆ High torque at low speed for starting and climbing
  ◆ High speed at low torque for cruising
  ◆ Very wide speed range including constant torque region and constant power region
  ◆ Fast torque response
☐ High efficiency over wide speed and torque ranges
☐ High reliability and robustness to meet vehicle operating conditions (eg. at high and low temperatures, bad weather, road vibration, etc)
☐ Resonable Cost

Figure 7 illustrates the functional block diagram of a typical EV propulsion system, where the arrow-headed thick and thin lines represent the power and signal flows, respectively. Due to the availability of regenerative braking, the power flow is reversible. Depending on the control strategy and driver's command, the electronic controller provides proper control signals to the power converter. These signals are amplified via a driving circuitry to switch proper power devices. Finally, the motor interfaces with wheels via the transmission device.

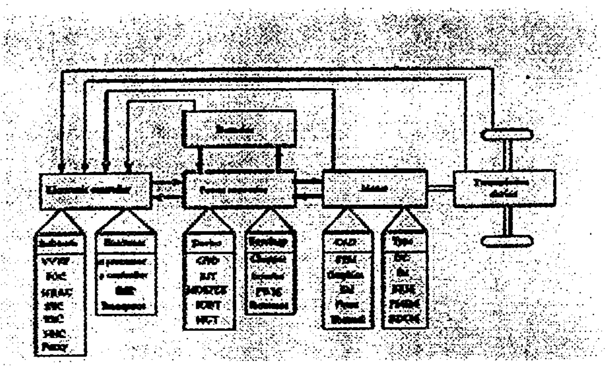


Figure 7: Functional diagram of EV propulsion

A classification of motors for electric propulsion is shown in Figure 8, where the shaded motor types have been accepted for EVs. Both the GM Impact/Impact 4 and Nissan FEV employ the induction motor, while both the BMW E1/E2 and U2001 use the PM brushless DC motor. The dual induction motors in the Nissan FEV possess a rated output of 20 kW and starting torque of 95.5 Nm, while the PM brushless DC motor in the BMW E1 has 32 kW and 150 Nm. On the other hand, the other motor types are also employed in EVs, such as the PM synchronous motor in the Ford/GE ETX-II, the switched reluctance motor in the Chloride Lucas, the DC series motor in the Daihatsu Hijet, the DC shunt motor in the Mazda Bongo, the DC separately excited motor in the Fiat 900E/E2, and the PM DC motor in the Suzuki Senior Tricycle.

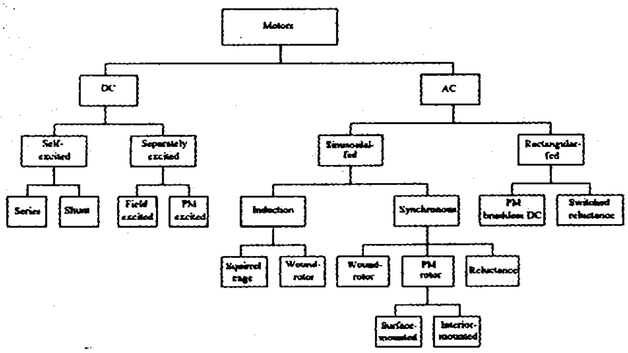


Figure 8: Classification of EV motors

Despite DC motor drives traditionally had been used for traction propulsion, but DC motor needs careful maintenance due to its communtator and brushless. With the advent of advanced power electronic devices and converters, powerful microelectronic products, new materials and motor topologies, and modern control algorithms, AC drives offer several definite advantages over their DC counterparts-namely, high efficiency, high power density, efficient regenerative braking, robustness, reliability, and almost no maintenance.

Among AC drives, vector controlled induction motors are popular and mature, however conventional vector controlled induction motor has low efficiency at light load ranges, hence it is not perfectly matched the EV driving requirement. Therefore, maximum efficiency control should be incorporated as shown in Figure 9, where the ratio of torque current component and flux current component is controlled over EV operating range. It was reported that by using maximum efficiency control, the driving range of EV is increased (10 ~ 20)%. Moreover, 6-phase pole charging induction motor drive can be used to increase the speed and torque range at constant power region as shown in Figure 10. The pole changing is implemented by reversing the winding current through the triggering of 6-phase inverter, hence mechanical change over switch is not necessary

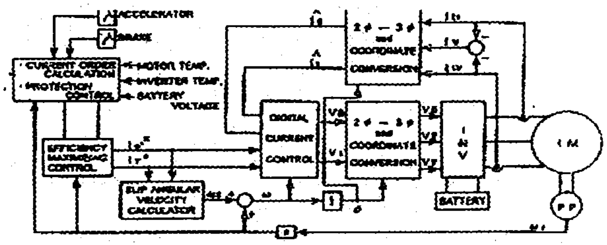


Figure 9 : Block diagram of maximum control of IM

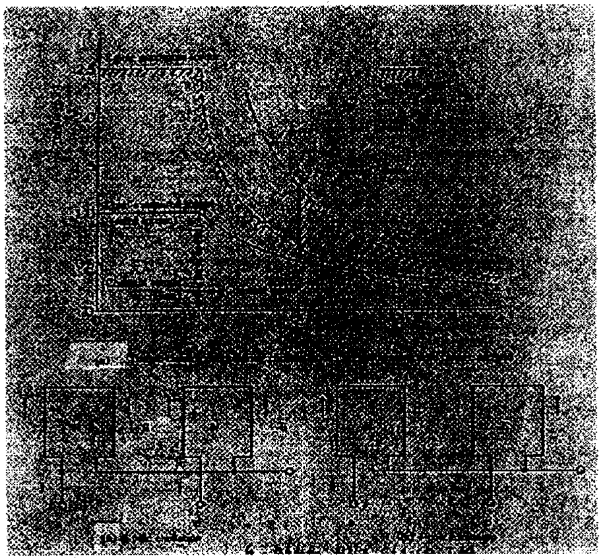
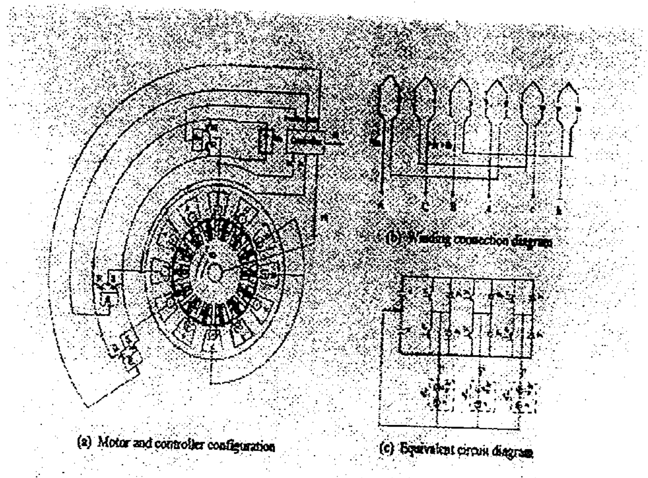


Figure 10 : 6-phase pole change IM

PM brushless DC (PMDBC) motors possess highest power density as compared with other AC drives. There are many types of PMBDC motors, Figure 11 is a PMBDC motor developed in the University of Hong Kong. However PM brushless DC motor needs new control algorithm to increase its speed range over constant power region. The author has developed a unique control algorithm to solve this problem by adjusting the friing angle of the inverter to obtain negative $\frac{di}{dt}$ during conducting period, hence the motor's emf and speed are increased [12] . Alternatively, a PM hybrid (PMH) motor can be selected. In a PMH motor, an auxillary DC field winding is incorporated, hence the airgap flux is the total of the PM flux and field winding flux, each of them has its own magnetic path. Figure 12, shows the construction of a PM hybrid motor developed in the University of Hong Kong [15]



(a) Motor and controller configuration

(c) Equivalent circuit diagram

Figure 11 : Novel PM Brushless DC motor

(a) motor and controller configuration
(b) winding connection diagram
(c) equivalent circuit diagram

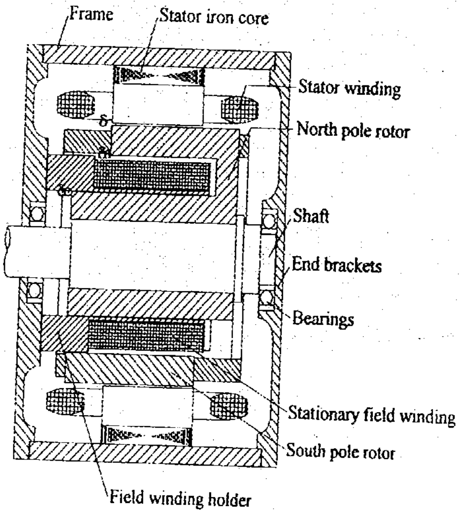


Figure 12 : Construction of PM hybrid motor

Switched reluctance motor (SRM) drives offer promising features for EV applications because of its simplicity and reliability in motor construction and power converter, high starting torque, wide speed range at constant power region, favourable thermal distribution, "limp home" capability, i.e. it runs following loss of phase(s) and efficient regenerative braking. The author is developing SRM drive for the Japan P-Start EV

The use of conventional gearing as the transmission device can no longer satisfy the needs of EVs. Recently, planetary gearing has been accepted as the transmission device of latest EVs, such as the GM Impact/Impact 4, Nissan FEV, BMW E1/E2 and U2001, because of high gear ratio and high transmission efficiency. The planetary gear set of the Nissan FEV is 12 to 1, while the ratio of the U2001 is 11 to 1. By using planetary gearing, the concept of motorized wheels can be easily realized. On the other hand, by abandoning the transmission device or gearing, these motorized wheels can be realized directly using outer-rotor wheel motors. Recently, the Tepco IZA has employed four gearless motorized wheels, where each of them is an outer-rotor PM brushless DC motor of 6.8 kW at 288 rpm. Figure 13 shows the wheel motor used in the Eco EV Japan.

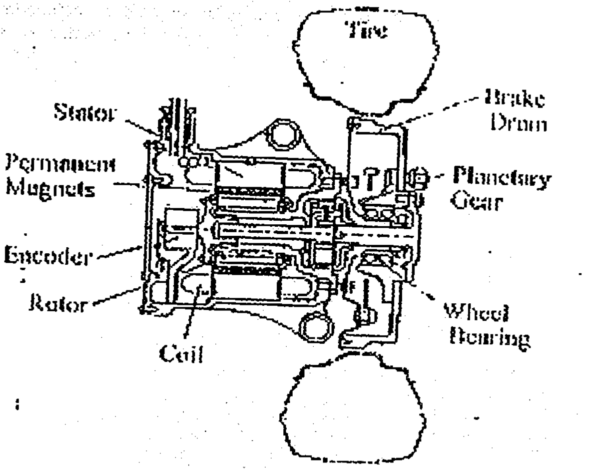


Figure 13: Wheel motor

An evaluation of power devices for electric propulsion is given in Table 3 in which a grading system is so adopted that each of the device characteristics is graded from 0 to 5 points. Although it seems that the IGBT provides the best performance, the power MOSFET has also been accepted for many electric propulsion systems, especially for relatively low-power electric bikes and electric tricycles. When the MCT becomes commercially available at reasonable cost, it is likely to be the best. The IGBT-based inverter in the Nissan FEV has a maximum output of 60 kVA and switching frequency of 10 kHz, while the MCT-based inverter in the Ford/GE ETX-II has 87.3 kVA and 5 kHz. It should be noted that the MCT-based inverter is only 45% of the BJT-based inverter volume and weighs 28% less than the BJT-based inverter

TABLE 3 - Power devices for EV propulsion

	GTO	BJT	MOSFET	IGBT	MCT
Voltage rating	5	4	3	4	4
Current rating	5	4	0	4	3
Switching freq.	0	1	5	3	3
Conduction loss	2	4	2	3	5
Switching loss	1	2	5	4	4
Leakage current	1	3	5	5	5
Easy of drive	2	3	5	5	4
Input impedance	2	2	5	5	5
Turn-on gain	3	4	5	5	5
Turn-off gain	1	4	5	5	5
Turn-on time	1	2	5	4	4
Turn-off time	0	1	5	4	4
dv/dt capability	2	3	4	4	5
di/dt capability	1	2	5	4	5
Operating temp.	3	4	4	4	5
Ease of parallel	2	2	5	3	4
Ease of protect.	3	3	3	4	5
Ruggedness	3	3	5	5	5
Cost	4	5	2	4	1
Availability	4	4	4	4	0
Total	45	60	82	83	81

Conventional linear control such as PID can no longer satisfy the stringent requirements placed on high-performance EVs. In recent years, many modern control strategies, such as model-referencing adaptive control (MRAC), self-tuning control (STC), variable structure control (VSC), fuzzy control and neural network control (NNC), have been proposed. Both MRAC and STC have been successfully applied to EV propulsion. Using sliding mode, VSC has also been applied to motor drives. By employing emerging technologies of fuzzy logic and neural networks to realize the concept of intelligent controllers, fuzzy control and NNC have promising applications to EV propulsion. In order to implement these modern control, powerful micro electronic devices are necessary. The state-of-the-arts include the Pentium microprocessor, 80960 microcontroller, i860 digital signal processor and T9000 transputer.

Figure 14 shows induction motor drive with novel sliding mode controller [11]. Figure 15 shows PM brushless DC motor with novel advanced angle wide speed range controller [12] and Figure 16 shows switched reluctance motor drive (SRM) with novel fuzzy sliding mode controller [13].

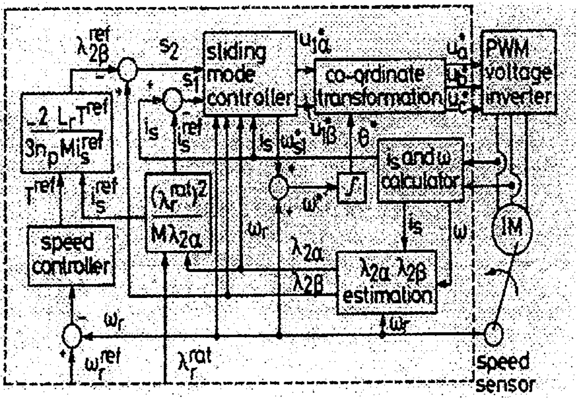


Figure 14: Novel sliding mode control of induction motor drive

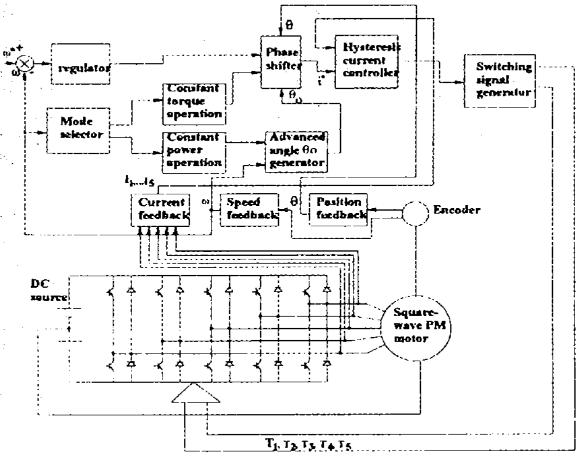


Figure 15: Novel wide speed range control of PM brushless DC motor

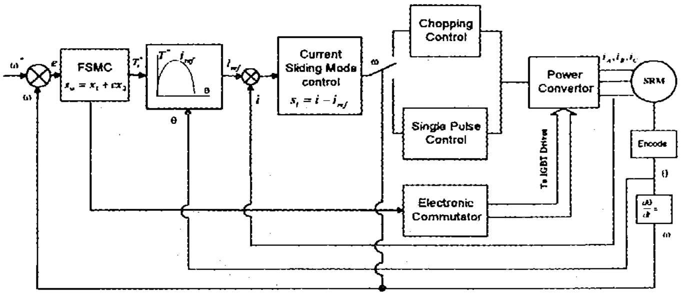


Figure 16: Fuzzy sliding mode control of SR motor drive

In summary, induction motors (IM) are popular and mature, while PM brushless DC motors possess highest power density, PM hybrid (PMH) motors offer optimum efficiency over very wide speed range, and SR motors are most robust. Table 4 shows the basic comparison among these motor drives with grading from 0 to 5 points for each item. Figure 17 shows the recent progress of motor drives in pursuit of compact and lightness.

TABLE 4 - Comparison of motor drives

	IM	PM	PMH	S12
Power Density	2.5	5	4	3
Torque-speed characteristics	5	5	5	5
Efficiency over EV operating range	3	4	5	3
Robustness	4	4	4	5
Thermal management	4	5	4	5
Popularity/maturity	5	4	3	3

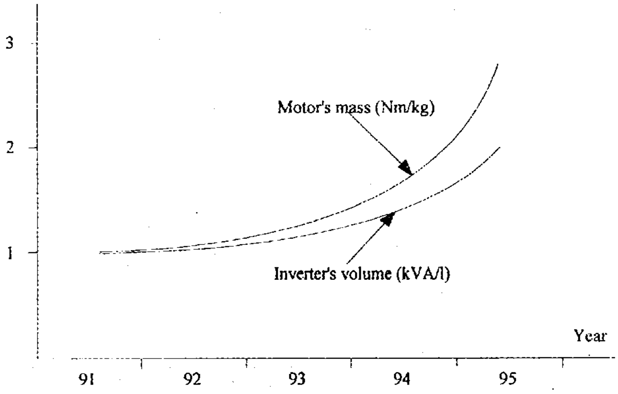


Figure 17 Progress in pursuit of power density

BATTERIES

Because the energy and power densities of batteries are generally much smaller than those of gasoline, a large number of batteries are required to assure a desired level of power performance. However, mounting a vehicle with a large number of batteries suffers from several shortcomings: the reduction of interior and luggage spaces, the increase in vehicle weight and cost, and the degradation of vehicle performances. Until now, the most mature battery technology suitable for EVs has been Pb-Acid. For the benchmark Pb-Acid batteries with energy and power densities of 33 Wh/kg and 93 W/kg, respectively, a comparison with latest advanced batteries is shown in Table 5. Moreover, recent commercially available batteries for EVs are given in Table 6, where the power density is at 80% of DOD, and the cycle life is at 100% of DOD. Until now, Pb-Acid batteries are most popular in EVs, such as the GM Impact/Impact 4, EPRI/GM G-Van, Mazda Bongo, Suzuki Cervo, Daihatsu Hijet, Mitsubishi Mini-Cab, and Nissan EV Guide II. Ni-Cd batteries are also commonly used in EVs, such as the Nissan FEV, U2001, Renault Zoom, and Tepco IZA. Na-S batteries are used in the BMW E1/E2, Ford Ecostar, and LADWP/SCE LA301. Ni-Fe batteries are used in the EPRI/Chrysler TEVan, and Nissan March EV-II. Zn-Br batteries are used in the Toyota EV-40.

Development of Al-Air batteries for EVs has continued at an accelerating rate over last few years. Since Al can not be electrodeposited from aqueous solutions, it can only be mechanically replaced to offer refuelability. Although the peak power density of Al-Air batteries is exceptionally low, the very high energy density of 360 Wh/kg, about 10-fold better than Pb-Acid, enables them to be excellent as EV range extenders.

Many researchers are excited by the idea of coupling batteries with electric flywheels or ultracapacitors, which can deliver surges of power. Recently, an ultrahigh-speed flywheel, known as an electromechanical battery (EMB), has been reported. This EMB can deliver a whooping 5000-10000 W/kg, which is orders of magnitude higher than anything achievable by an electrochemical battery or even an internal combustion engine.

TABLE 5 - Advanced batteries

	Energy density	Power density	Range	Energy eff. (%)
Pb-Acid	1.0	1.0	1.0	68
Ni-Fe	1.5	1.2	2.0	58
Ni-Cd	1.6	1.9	2.1	80
Ni-Zn	1.9	1.9	2.1	76
Ni-MH	1.7	2.1	2.3	76
Zn-Br	2.2	0.6	2.1	75
Na-S	2.5	1.1	3.4	91
$Li-FeS_2$	4.0	4.0	4.0	80
Li-Polymer	4.0	3.5	4.0	85

TABLE 6 - Latest EV batteries

	Manuf.	Model	Weight (kg)	Energy (Wh/kg)	Power (W/kg)	Cycle life
Pb-Acid	Johnson Controls	GC12550	18.6	23.7	120	500
Pb-Acid	Sonnenschein	DF6V180	30.2	29.3	80-100	700
Pb-Acid	Electrosource	Horizon	27	50	>300	900
Ni-Cd	SAFT	STM5.140	23.2	45.3	260	2000
Na-S	ABB	B-11	253	81	152	600
Na-S	Silent Power	PB-MK3	29.2	79	90	800
Ni-MH	Ovonics	OBC	17.1	80	245	1000
Ni-Fe	Eagle-Picher	NIF200	25	51	99	920
Zn-Br	Sea	ZBB-5/48	81	79	40	350

BATTERY CHARGERS

The challenge of transforming EVs from concept to reality is to make it safe, convenient and easy for consumers to charge batteries. To improve convenience and increase charging efficiency, a number of charging schemes have been proposed: home charge, regenerative charge, solar charge, park-and-charge (PAC), and move-and-charge (MAC). Figure18 shows a multiple charging system aiming to charge batteries using various charging schemes simultaneously.

Instead of using plugging type power transfer, an inductive power transfer system has recently been developed for charging EV batteries. As shown in Figure 19, the inductive charging system features an inductive coupler with a coil that is completely encased in a plastic covered paddle. The vehicle is equipped with a charging port that also incorporates a coil. When the paddle is inserted into the charging port, the corresponding magnetic fields intermingle to complete the circuit. The incoming power is then converted by an AC-DC converter to charge batteries. This inductive charging system is inherently safe under all-weather operation. In order to have a light-weight and compact inductive charging port, low mass magnetic cores and high-frequency AC-DC converter are necessary. Typically, this system can handle power levels from 1.5 to 25 kW with overall efficiency of better than 90%, while the power transfer frequency is 40-350 kHz.

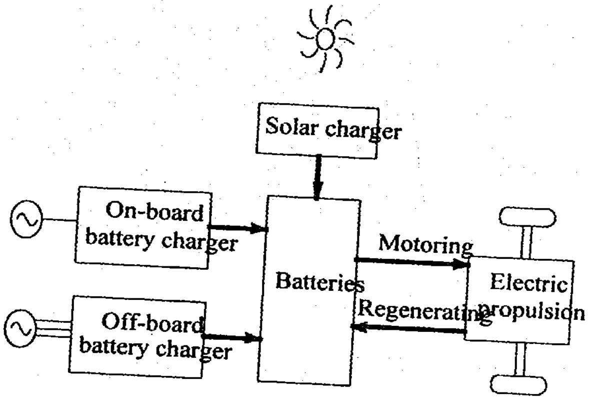


Figure 18: Multiple charging system

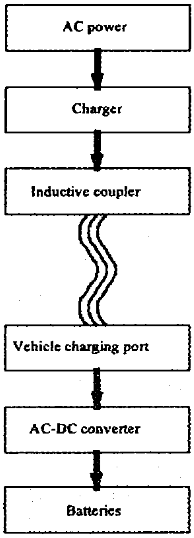


Figure 19: Inductive charging

POWER & ELECTRONIC AUXILIARIES

A thermoelectric variable temperature seat (VTS) has recently been proposed, which is a highly energy-efficient means of providing vehicle occupant heating and cooling. Typical energy requirement for a VTS is 100 W per occupant compared with 1-4 kW per vehicle for standard automotive air-conditioning units. Since the energy requirement of an existing air-conditioning unit may reduce the driving range of an EV by 20-30%, this energy-efficient VTS is particularly suitable for EVs. Its high energy efficiency is achieved by using heating and cooling energy to directly heat and cool the occupant rather than to heat and cool the surrounding space and interior vehicle surface. The temperature effect is produced by a combination of conduction to the occupant through the seat rest and back rest, and through convection of conditioned air escaping through the surface of the seat. Since heating and cooling are provided by a thermoelectric heat pump and blower contained within the seat, it contains no refrigerants - environmental friendliness. This new idea stimulates the development of efficient, low-weight and compact thermoelectric heat pumps and blowers.

In order for power steering to be feasible in EVs, extremely efficient high-power controllers are necessary to provide needed performance without sapping precious battery reserves. Recently, an adaptable inverter fitting most 3-phase AC induction motors has been developed for power steering. A DSP is employed to perform VVVF control. The input power of this unit is about 900 W.

An auxiliary power converter (APC) is used to convert battery power into regulated power for all vehicle accessories. These power accessories include power seats, power windows, power antenna, power door locks, brake vacuum pumps, radios, windshield defoggers, de-icers, headlamps, air bags, CRT display, and the energy management system. This is usually accomplished by using a full-bridge PWM DC-DC converter. To reduce heat sinking requirement and improve operating performance, it is operated at high frequency and ZVS condition. Thus, it can run reliably with inexpensive forced air cooling. Typically, the output power of this unit is about 1.6 kW.

Maximizing energy usage and monitoring energy capacity are critical to attaining acceptable performance in EVs. As shown in Figure 10, the energy management system (EMS) making use of sensory inputs from sub-systems of the vehicle predicts range for standardized driving profiles, controls the energy usage of vehicle sub-systems, suggests more energy efficient driving behavior, directs regenerated energy from braking to batteries, selects battery charging algorithm based on battery state-of-charge and cycle life history, modulates climate control in response to current driving conditions, and adjusts lighting brightness.

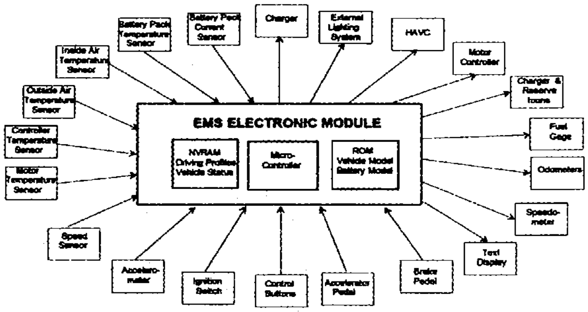


Figure 20: Energy management system

The Audio Navigation System (ANS) shown in Figure 21 is a low-cost route finder that utilizes a voice interface. The driver's voice is used for input while speech stored on CD is used for output. The driver is prompted to spell his destination and current location. After the best route has been calculated, the system instructs the driver to follow this route. When the EMS is coupled with the ANS, it can plan energy efficient routes, locate charging facilities for extended trips, and modify range prediction and energy efficiency of route predictions on the basis of traffic conditions.

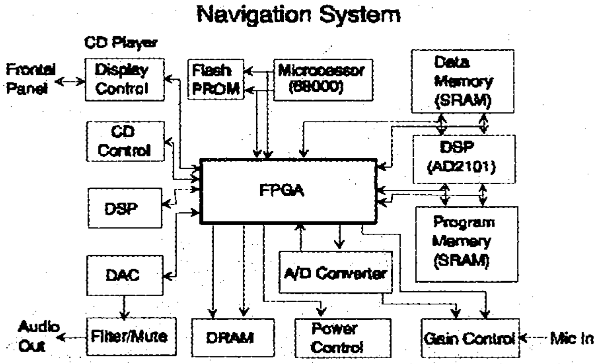


Figure 21: Audio navigation system

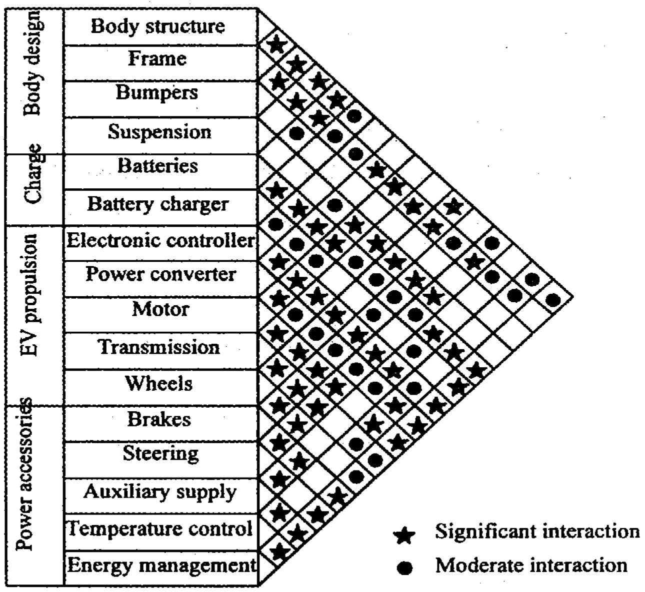


Figure 22: Subsystem interactions

TABLE 7 - Latest flagship EVs

	GM Impact 4	Nissan FEV	BMW E1/E2	HKU U2001
Curb weight (kg)	1348	900	915	1973
Drag coefficient	0.185	0.19	0.32	0.34
Rolling coefficient	0.0048	0.005	0.008	0.0044
Top speed (km/h)	128	130	120	110
Acceleration (km/h, s)	0 → 96, 8.5	0 → 40, 3.6	0 → 50, 6	0 → 48, 6.3
Range (km, km/h)	193, 89	160, 72	155, 80	176, 88
Battery type	Pb-Acid	Ni-Cd	Na-S	Ni-Cd
Battery weight (kg)	395	200	265	792
Voltage level (V)	312	280	180	264
Energy capacity (kWh)	16.8	11.6	28.8	37
Motor type	Induction	Induction	PM brushless DC	PM brushless DC
Transmission. type	Planetary	Planetary	Planetary	Planetary
Converter type	IGBT	IGBT	IGBT	IGBT

Due to the multidisciplinary nature of EVs, the process of identifying the preferred features and packaging options for EV integration should be carried out at the system level. Figure 22 illustrates typical sub-system interactions in EVs. The impact of these sub-system interactions affects the vehicle cost, performance, and safety. The flagship EVs of GM (the Impact 4), Nissan (the FEV) and BMW (the E1/E2), as well as the U2001, jointly developed by the University of Hong Kong, Amerigon and Honda, are compared in Table 7 to illustrate latest EV technologies.

Figure 23 shows the U-2001 show piece electric vehicle. This show piece vehicle in incorporated most advanced technology of power drive, energy management, navigation and novel air-conditioning system. It is a testimony to close collaboration between university and industry, as well as between east and west.

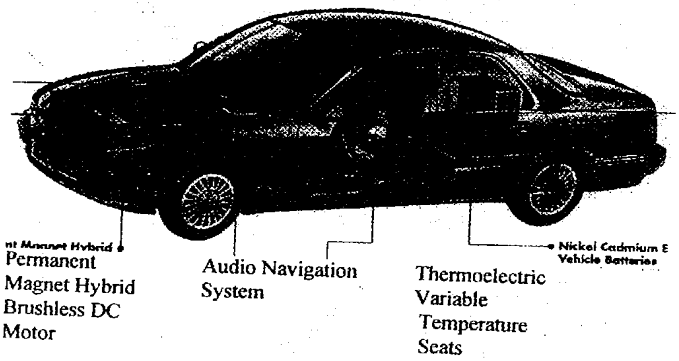


Figure 23: Show piece U2001

EV DEVELOPMENT IN CHINA, TAIWAN AND HONG KONG

The region of China, Taiwan and Hong Kong is enjoying exceptional advantages for the development of EVs. These advantages are listed as follows.

1. This region is almost the fastest growing region in economic development in the world and has great real and potential demands for EVs.
2. The vehicle performance required by the region is quite different from other regions in the world because of its high population density. The mainly pursued objectives and concerns for vehicles used in this region may not be high speed and large range but reliability and cost.
3. The cheap labor in China may greatly reduce the production cost of EVs, making them more affordable.
4. Throughout Asia, about 60% of all electricity comes from relatively clean sources (oil and gas) or emission-free sources (nuclear and hydro), the introduction of EVs is a logical strategy for reducing air-pollutant emissions and greenhouse gas emissions. Even using electricity exclusively from coal, EV-related emissions are less than those from gasoline or diesel vehicles.

Therefore, this region can play a unique role in the development and widespread of EVs. There have been many attempts to promote applications of EVs by adopting technical, financial and policy supports in this region.

In China, the development of EVs has been accelerated. Several R&D projects of EVs have been listed as the key R&D plans by the Chinese State Planning Commission and Chinese State Commission of Science and Technology. The overall EV development goal in Mainland China can be summarized as follows :

1. By the year of 2000, develop 3 types of concept EVs, with unique Chinese character and advanced international standard, thus to prepare for commercialization in 21st century.
2. By the year of 2000, produce 3000-5000 units of economic and practical conversion EVs.
3. By the year 2000, develop 2 to 3 EV demonstration zones, including EV infrastructure, operating, regulations, maintenance services, etc., thus to integrate the R & D, production and marketing.
4. By the year of 2000, to establish EV operating regulations, incentive policy, EV and components technical standard, and EV information database.

EVs have great market potential in China. As the highway has not been popularized, the driving speed in most cities is controlled at 30-50 km/h, which is the most achievable and economical speed for EVs. The performance requirements of EVs in China are quite moderate as compared with those in North America and Europe.

In Taiwan, the number of motorcycles has exceeded 10 million units. These motorcycles have become the most popular transportation vehicles and caused a severe environmental pollution. Therefore, the Government strategy is to give priority to develop motorcycles. The Government has funded the R & D of electric motorcycle and regulated the production of conventional motorcycle. The Government has recently held Electric Vehicle International Symposium inviting experts worldwide including myself to assist the Government in drawing strategic plan and road map towards commercializaiton of electric motorcycle. The Government committed to subsidize the purchase of electric motorcycle. Several leading companies also committed the investment. Taiwan is aiming to be centre of excellence in production of electric motorcycle. In addition, Taiwan is also looking for the possibility of using electric/hybrid buses.

In Hong Kong, the role of EV development is multi-aspects. One role is an active EV user. Another important role is to link up the western advanced technology with the cheap labor of eastern countries, especially in China for the promotion and commercialization of EVs. Kong. The feasibility of using electric minibus, electric bus and electric taxi are being explored. The China Light & Power Co Ltd and the Hong Kong Government have electric vehicle fleets in operation.

CALIFORNIA ZEV MANDATE UPDATE AND GLOBAL EV MARKET POTENTIAL

Table 8 shows the check list of EV Commercialization

TABLE 8 - EV COMMERCIALIZATION

☐ Why?
  Environment? Energy? Politic? Economic? Social?
☐ When?
  1998? 2003? 2010? when energy crisis?
☐ Where?
  North America? Europe? Japan? China? India?
  Southeast Asia?
☐ What?
  High end product? Low end product? Public transportation?
  Passanger cars? Commercial vans? Buses?
☐ Who?
  Government? Industry? Start-up company? R & D?

Last November, the US Big Three, Toyota, Honda and Nissan made proposals to the California Air Resource Board (CARB) to produce 5,000 EVs in late 1996 and 1997, and 14,000 in 1998, while about 22,000 vehicles must be zero emission in 1998 according to the mandate. The companies also stated to manufacture advanced batteries for EVs in 1998. If the painful incubation start up would reduce, it is estimated that the global annual EV market size in next decade will be around 1.5 million.

CONCLUSIONS

This paper has presented the present status of electric vehicles and has discussed their major advantages, key issues, key technology and market potential. Electric vehicles provide a clean, energy-efficient urban transportation alternative. The next decade is likely to be the decade in which the long-awaited commercially viable electric vehicles will begin to take their place on the roads.

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