DEPARTMENT OF ELECTRICAL ENGINEERING

SOLUTION & MARKING SCHEME

(Semester 2, 2011/12)

SUBJECT (Code & Title) : EE543 Hybrid and Electric Car Technology

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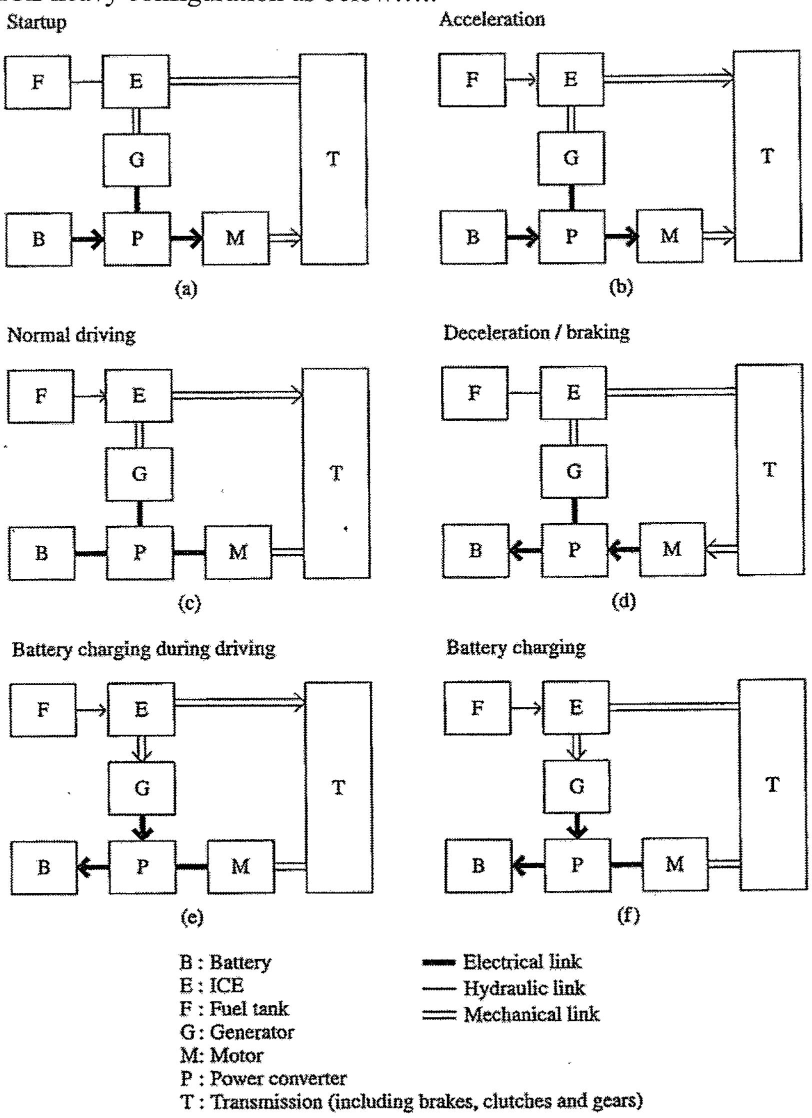
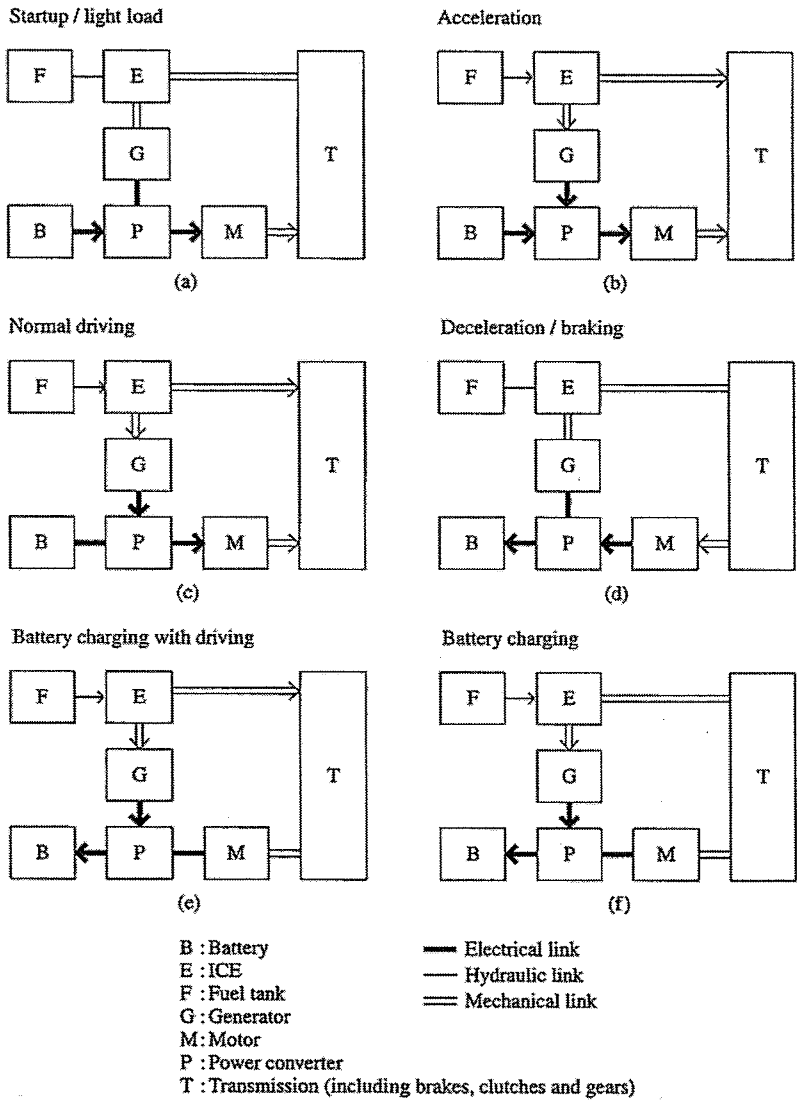
INTERNAL MODERATOR	W.C. Lo

QUESTION NO. ( )	SOLUTION	MARKS
Q1 (a)	With Differential Gear 1. Traditional and standard mechanical component 2. Proven Technology Safe even if the motor drive fails 3. More mechanical component, increase cost & weight 4. Needs one set of high power motor drive	3
	Two motors and no differential gear 1. The two motors need to synchronize electronically, complicate controller configuration 2. If one motor fails, the power drive is unbalance, and may cause the car to turn or spin 3. Less mechanical linkage, but needs an extra synchronize circuit. 4. Needs two sets of lower power motor drives	3
(b)	F_d: Aerodynamic drag force, caused by the head wind opposing the car's forward motion, especially when it is travelling at high speed.	2
	F_r: Rolling Force due to the deformation of the tyre and the road surface. Factors which affect this figure include tyre pressure, temperature, and thread size, and the number of tyres.	2
	F_c: Climbing Force, the downward force for a vehicle to climb up an incline.	2
(c)	$F_d = 0.5\rho \cdot C_d \cdot A(v + v_0)^2$	2
	75km/hr = 75 x 1000 / 60 X 60 ----- convert to m/s = 20.833 m/s	2
	$F_d = 0.5 \times 0.48 \times 1.23 \times 2.8 \times (20.833)^2$ $= 358.7$ N	2
	$F_r = M \cdot g \cdot C_r$ $= 1800 \times 9.81 \times 0.13 = 2295.5$N	2
	$F_c = Mg \sin\theta$ $= 1800 \times 9.81 \times \sin 20° = 6039.4$N	2
	$F_l = 358.7 + 2295.5 + 6039.4 = \underline{8693.6\text{N}}$	2

QUESTION NO. ( )	SOLUTION	MARKS
Q2	For Series Hybrid	
(a)	1. Can run at full power for short distance (45km) under pure battery, with plug-in charge. 2. The ICE can run at single speed (usually high speed) at its maximum efficiency for electricity generation. 3. Regenerative braking, gear box structure is very simple (1 to 2 gears and no clutch)	3
(b)	For Parallel Hybrid 1. Can cut down the size and weight of engines, because total power output is the addition of power of ICE and electric motor. 2. Use intelligent power sharing to ensure that the ICE is running at high efficiency, buy using the electric motor to share out the uneven load. 3. Use regenerative braking to provide extra energy.	3
(c)	EITHER --- ICE heavy configuration as below…..	



QUESTION NO. ( )	SOLUTION	MARKS
(c) cont.	OR --- Electric heavy configuration as below…	14



ALSO add explanations to the energy flow diagram

QUESTION NO. ( )	SOLUTION	MARKS

Q3 ANSWER: YES 1

(a) 1. Electric motor must be small size, light weight with high power, due to the load and size restriction inside a EV. 4
2. Electric motor must be highly reliable with fail safe mechanism, especially in the case of dual motor drive with no differential gears.
3. Must be able to provide uniform power under a large speed range, because modern EV wishes to reduce the complexity of gears changing.
4. Must be able to withstand large temperature range, rugged, and dusty environment.

(b) Three major advantages
1. Fail safe: Even if one phase fails, it will continue to operate under reduced power mode.
2. Simple construction: therefore it is rugged and highly reliable, requires very little maintenance, and has a low manufacturing cost.
3. No magnets: therefore the overall material cost for the motor is low. Without the magnet, the motor can maintain uniform performance under extreme temperatures. 3

(c)

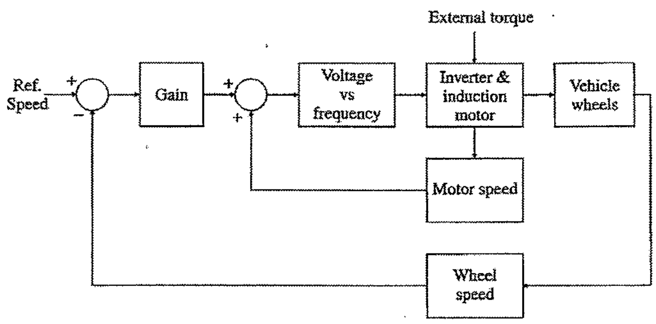


Fig. 5.28. VVVF control of induction motor drives. 6

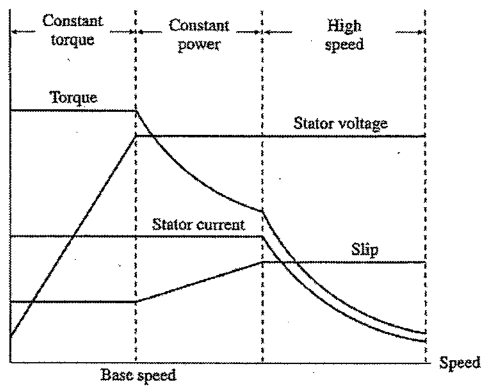
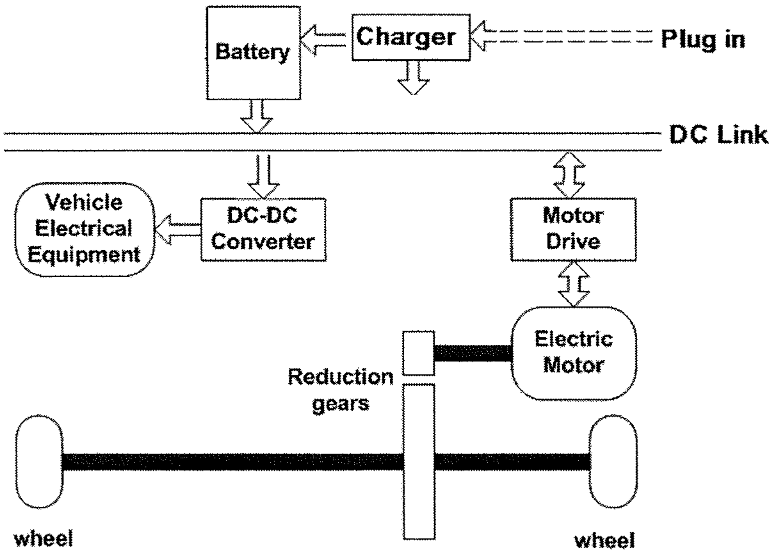
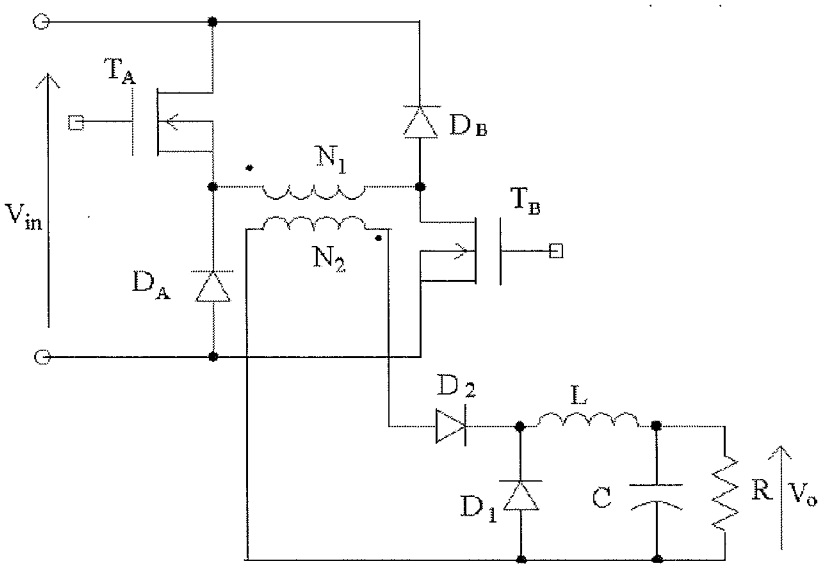
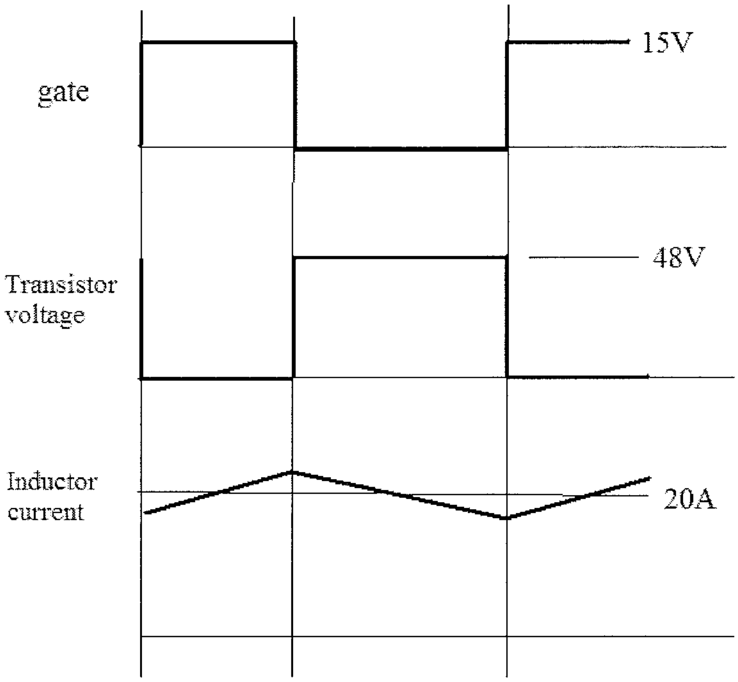
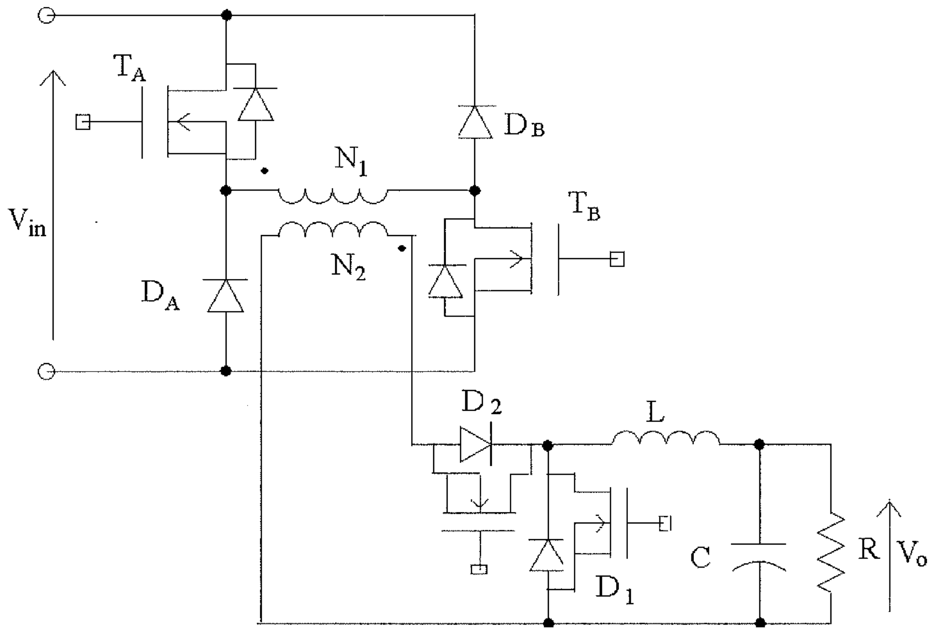


Fig. 5.29. Characteristics of induction motor drives. 6

OPERATION:

Constant Torque: constant slip, constant current (max value), while increasing the V.
Constant Power: under const and max V and I, increase the slip to max value.
High speed: Decrease the current under max slip will decrease the power, but increase the speed, under field weakening mode.

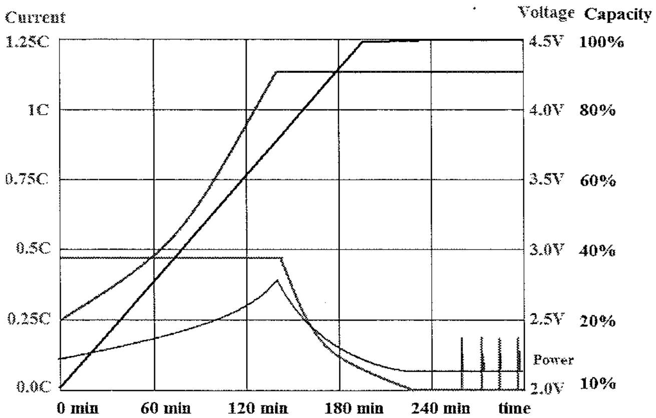
QUESTION NO. ( )	SOLUTION	MARKS
Q4 (a)		4 marks
(b)	The suggested voltage 48V. Reasons: safety voltage, Only 4 times of vehicle voltage of 12V. Simple power conversion Low cost vehicle. Use 4 12V batteries.	4 marks
(c)	 TA, TB=48V DA, DB=48V D2, D1=12V C=12V	4 marks
(d)	Vo/Vin=12/48=D*N2/N1 => N2/N1=12/48/0.4=1.07	4 marks

QUESTION NO. ( )	SOLUTION	MARKS
		4 marks
(e)	Change the diode into transistor in the secondary side. i.e. the circuit is: 	
Q5		
(a)		5 marks

QUESTION NO. ( )	SOLUTION	MARKS

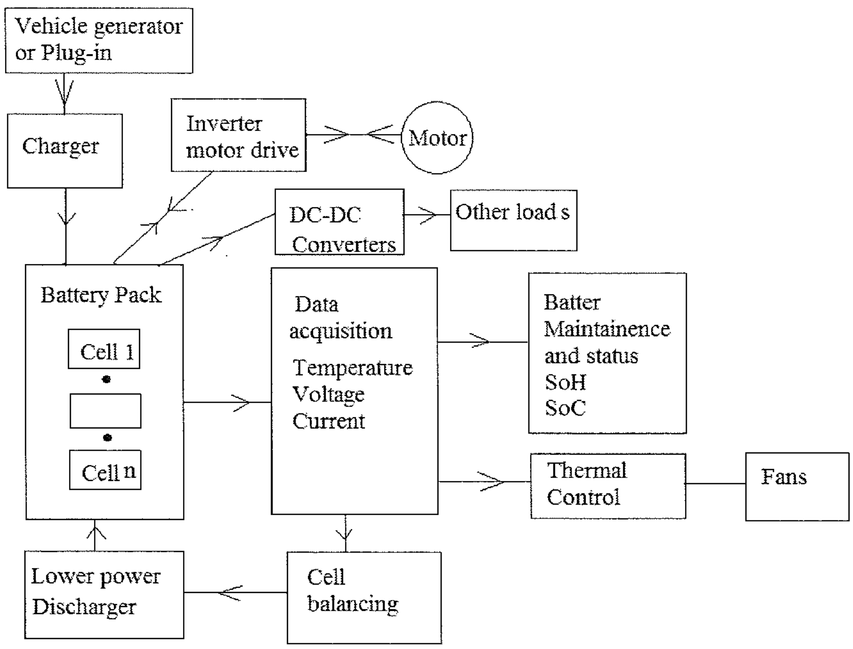
	Lead-Acid	Li-Ion
Specific Energy (Wh/kg)	30-45	90-130
Energy Density (Wh/l)	60-90	140-200
Specific Power (W/kg)	200-300	250-450
Cycle life (Times)	400-600	800-1200
Working Temperature(C)	-40~60	-40~60
Cost (US$/kWh)	150	>200

(b) 5 marks



CC mode CV mode Trickle

(c) 5 marks



The balancing:
It converts individual cell voltages, battery current and battery temperature at different points of the battery pack into digital values. All of these data is then used to estimate battery status in later stages.

QUESTION NO. ( )	SOLUTION	MARKS

All cell voltages are measured instead of measuring a group of cells in series. The advantage of measuring individual cell voltages justifies the added cost of hardware because it enables cell balancing and overcharge protection at cell level. Balancing is a separate protection circuit to enable the charger to float from one to another for equal voltage among the cell. The voltage, current and temperature are entered into some formulation and modeling to calculate the SoC.

(d)

i)	Cell volatge	3.7	V
	No of cells	100	
	Current hour	100	Ah
	Total energy content	37	kWh
ii) For 85% SoC,			
	Charging Current	100	A
	End of CC	85%	
	Time needed	51	min
iii) For 30 min		30	min
	Energy	18.5	kWh

5 marks

Q6 (a)

Design question: Typical answers are:

96V battery
Energy content: 15kWh
Motor power: 10kW
Charger: =15kWh/6h = 2.5kW
As the weight is low, Li-ion battery is needed.
Power converter only needs from 300V to 12V and 16V vehicle electronics

5 marks

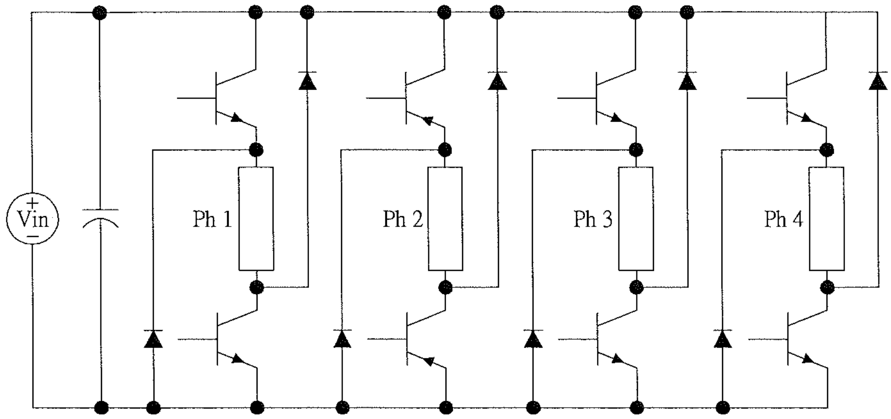
All power component voltage ratings are >96V

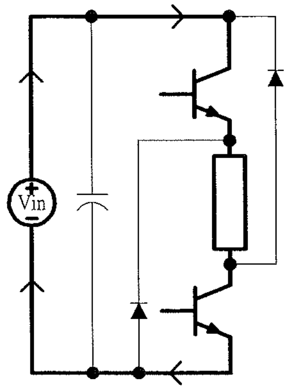
Weight distribution: battery: 130Wh/kg => 115kg
Motor weight: 10kW/ (0.25kW/kg) => 40kW
Charger: 2.5kW/ (1kW/kg) = 2.5kg

5 marks

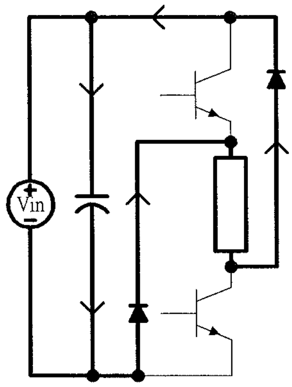
QUESTION NO. ( )	SOLUTION	MARKS

Q6
(b)

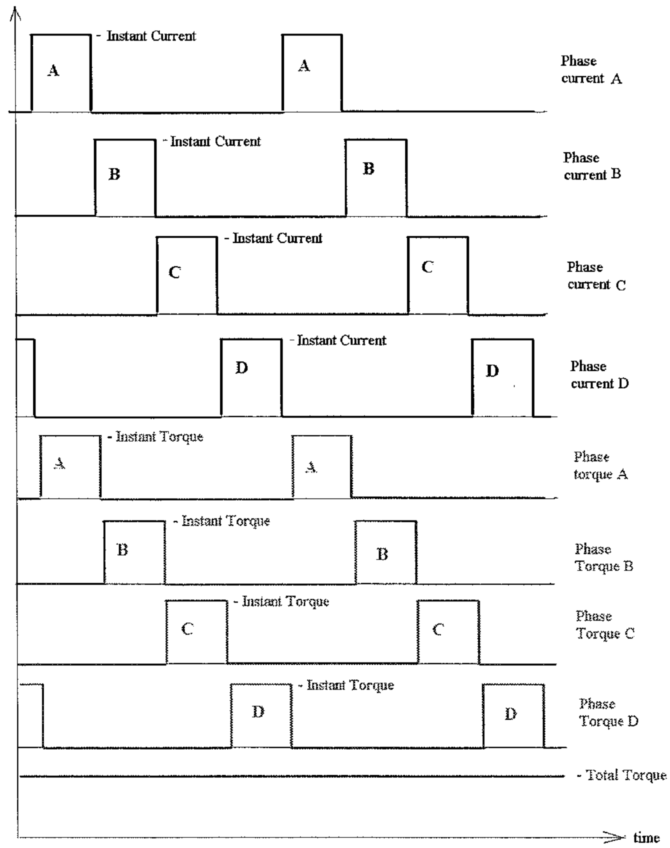




Motoring



regeneration



6 marks

QUESTION NO. ( )	SOLUTION	MARKS

No. of phase	4	
Vin	300	V
Torque	100	Nm
Speed	1000	rpm
	104.7197	rad/s
Mechanical power	10471.97	W
Efficiency	77%	
Input Elect Power	**13688.85**	**W**
Input current	45.629	A
Phase current (Average)	**11.407**	A

4 marks