CMR/INSTITUTE OF TECHNOLOGY

USN

Internal AssessmentTest -III

Sub:	**Electric Vehicles**							Code:	21EE752
Date:	14/12/2024	Duration:	90mins	Max Marks:	50	Sem:	7th	Branch:	OE-ECE, CIVILCSE, AIML

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1	Explain with a block diagram of the torque control of the BLDC motor.	10	CO4	L2

Control of BLDC Motor Drives

- In vehicle traction application, the torque produced is required to follow the torque desired by the driver and commanded through the accelerator and brake pedals. Thus, torque control is the basic requirement.
- The desired current I* is derived from the commanded torque T* through a torque controller. The current controller and commutation sequencer receive the desired current I* position information from the position sensors, and perhaps the current feedback through current transducers, and then produces gating signals.
- These gating signals are sent to the three-phase inverter (power converter) to produce the phase current desired by the BLDC machine.

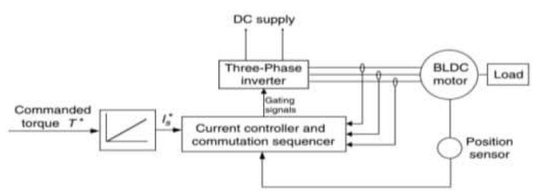
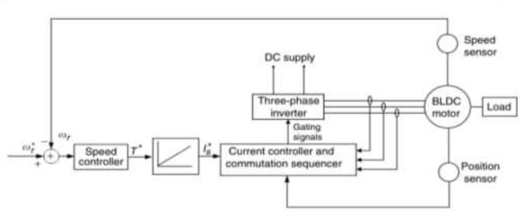


FIGURE 6.51
Block diagram of the torque control of the BLDC motor

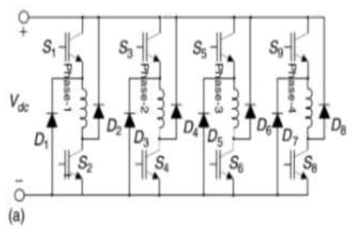
- In traction application, speed control may be required, Many high-performance applications include current feedback for torque control. At the minimum, a DC bus current feedback is required to protect the drive and machine from over currents.
- The controller blocks, “speed controller” may be any type of classical controller such as a PI controller, or a more advanced controller such as an artificial intelligence control. The “current controller and commutation sequencer” provides the properly sequenced gating signals to the “three-phase inverter” while comparing sensed currents to a reference to maintain a constant peak current control by hysteresis (current chopping) or with a voltage source (PWM)-type current control.
- Using position information, the commutation sequencer causes the inverter to “electronically commutate,” acting as the mechanical commutator of a conventional DC machine.



		Marks	CO	RBT
2	Explain in detail different inverter topologies for SRM drives.	10	CO4	L2

SRM Drive Converter

- The torque developed by the motor can be controlled by varying the amplitude and the timing of the current pulses in synchronism with the rotor position.
- In order to control the amplitude and pulse width of the phase current, a certain type of inverter should be used.
- The input to the SRM drive is DC voltage, which is usually derived from the utility through a front-end diode rectifier or from batteries. Unlike other AC machines, the currents in SR motors can be unidirectional.
- Hence, conventional bridge inverters used in AC motor drives are not used in SRM drives.



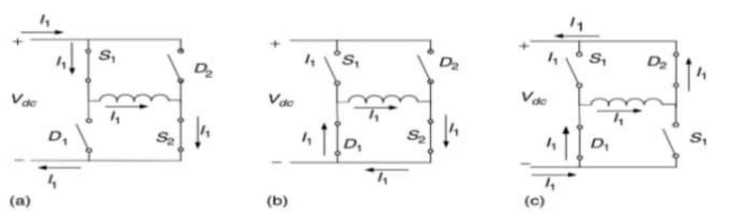


FIGURE 6.63
Modes of operation for the classic converter: (a) turning on phase mode; (b) zero voltage mode; and (c) turning off mode

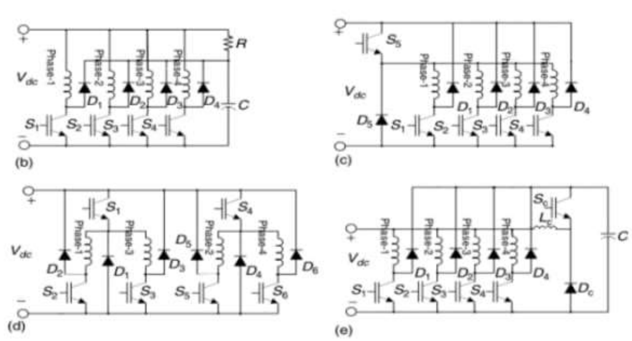


FIGURE 6.62
Different inverter topologies for SRM drives: (a) classical half bridge converter; (b) R-dump; (c) n+1 switch (Miller converter); (d) 1.5n switch converter; and (e) C-dump

Modes of Operation

- For SRM, there is a speed at which the back EMF is equal to the DC bus voltage. This speed is defined as the base speed.
- The phase current amplitude can be regulated from 0 to the rated value by turning the switches on or off.

$$W_f' = \int_0^i \lambda \, di$$

W_f = Stored field Energy
λ = flux
W_f' = Co Energy

- Maximum torque is available in this case when the phase is turned on at an unaligned position and turned off at the aligned position, and the phase current is regulated at the rated value by hysteresis or PWM control.

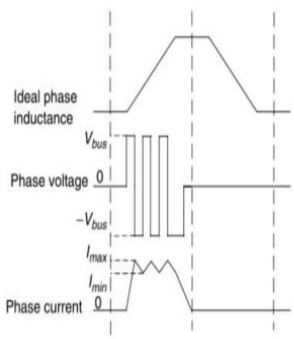


FIGURE 6.64
Low-speed (below the base speed) operation of SRM

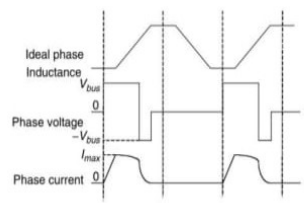


FIGURE 6.65
High-speed (above the base speed) operation of SRM

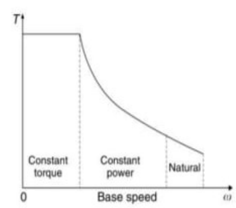


FIGURE 6.66
Torque–speed characteristic of SRM

3	Discuss about Design of PPS in series hybrid electric drive train.	10	CO5	L2

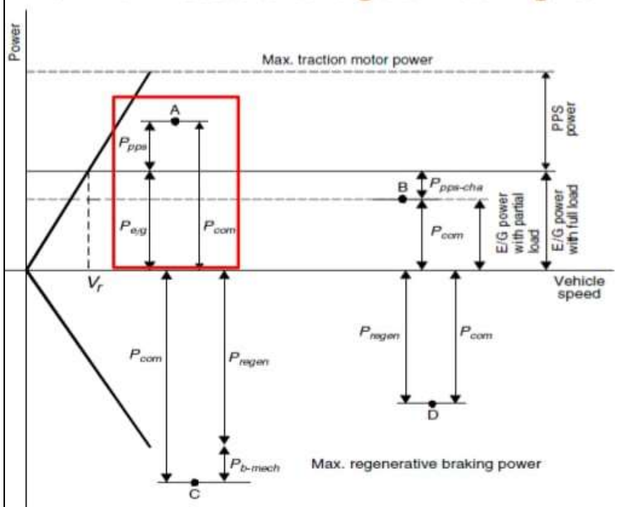
Maximum State-of-charge Of Peaking Power Source Control Strategy

The main aim of this control strategy is to meet the power demand commanded by the driver and, at the same time, maintain the SOC of the PPS at its high level.

This control strategy is considered to be the proper design for vehicles for which the performance relies heavily on the peak power source.

This includes vehicles with frequent stop–go driving patterns, and military vehicles for which carrying out their mission is the most important. A high SOC level will guarantee the high performance of the vehicles at any time.

Maximum State-of-charge Of Peaking Power Source Control Strategy



A — Hybrid traction mode
P_{com} — Commanded power
P_{pps} — Power of the peaking power source
$P_{e/g}$ — Power of engine/generator

B — Engine/generator-alone traction mode or PPS charging mode
$P_{pps\text{-}cha}$ — PPS charging power

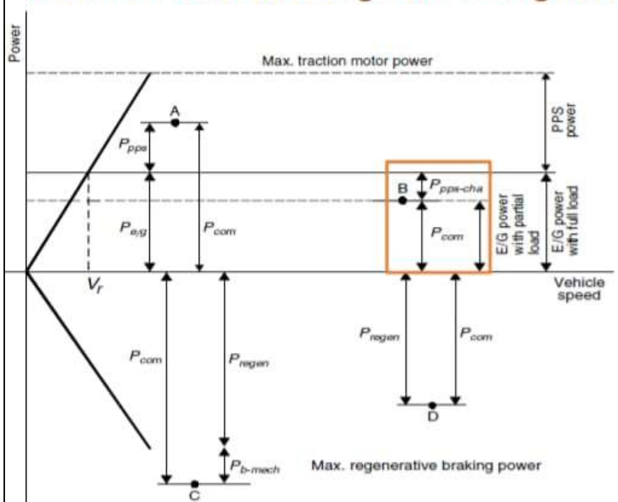
C — Hybrid braking mode
P_{regen} — Regenerative braking power
$P_{b\text{-}mech}$ — Mechanical braking power

D — Regenerative braking mode

Point A represents the commanded traction power that is greater than the power that the engine/generator can produce.

In this case, the PPS must produce its power to make up the power shortage of the engine/generator.

Maximum State-of-charge Of Peaking Power Source Control Strategy



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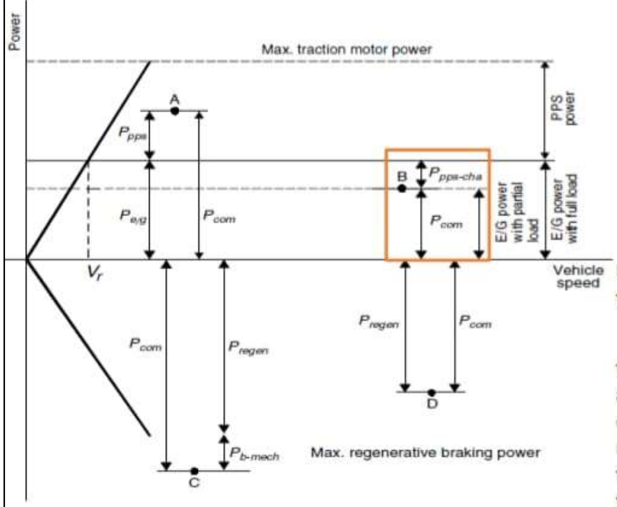
$P_{pps\text{-}cha}$ — PPS charging power

C — Hybrid braking mode
P_{regen} — Regenerative braking power
$P_{b\text{-}mech}$ — Mechanical braking power

D — Regenerative braking mode

Point B represents the commanded power that is less than the power that the engine/generator produces when operating in its optimal operation region.

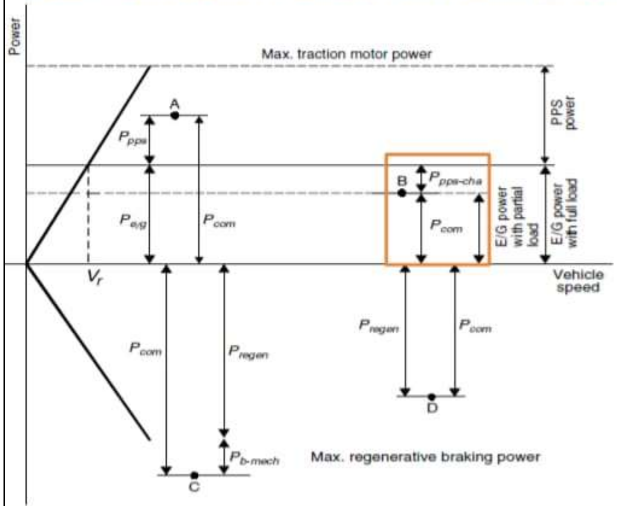
Maximum State-of-charge Of Peaking Power Source Control Strategy



In this case, two operating modes may be used, depending on the SOC level of PPS.

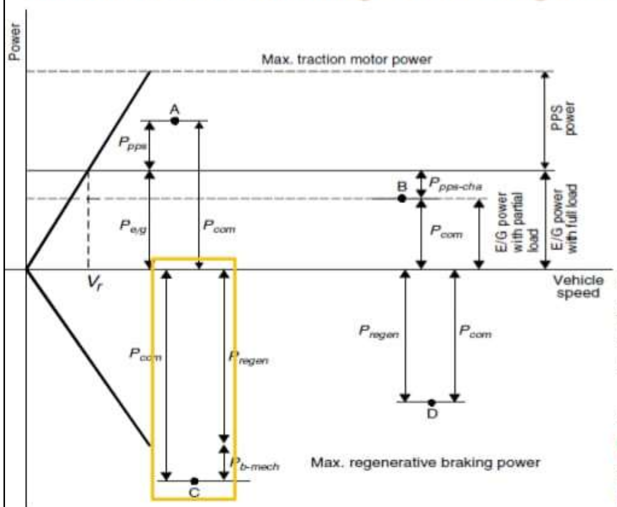
If the SOC of the PPS is below its top line, the PPS charging mode is applied, i.e the engine/generator is operated within its optimal operating region and part of its power goes to the traction motor to propel the vehicle and the other part goes to the PPS

Maximum State-of-charge Of Peaking Power Source Control Strategy



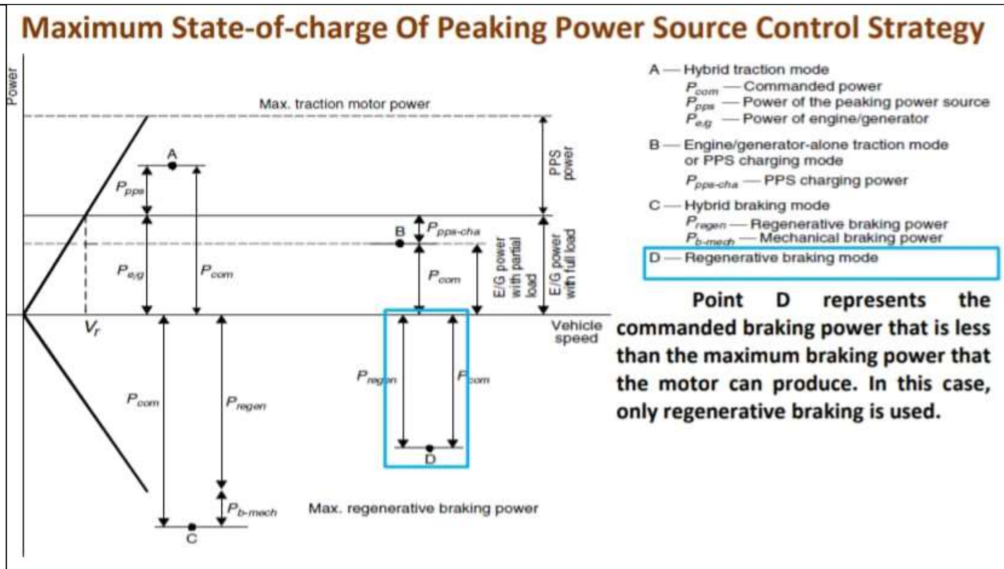
On the other hand, if the SOC of the PPS has already reached its top line, the engine/generator traction mode alone is supplied, i.e. the engine/generator is controlled to produce power equal to the demanded power, and the PPS is set at idle.

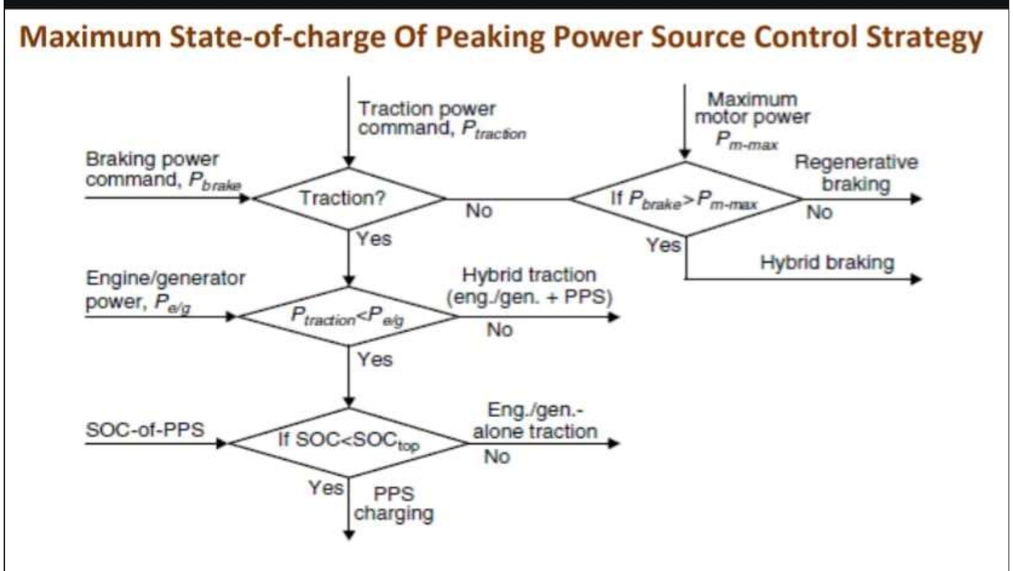
Maximum State-of-charge Of Peaking Power Source Control Strategy



Point C represents the commanded braking power that is greater than the braking power that the motor can produce (maximum regenerative braking power).

In this case, the hybrid braking mode is used, in which the electric motor produces its maximum braking power and the mechanical braking system produces the remaining braking power.





4	Explain about Design of Engine Power Capacity in parallel hybrid electric drive train.	10	CO5	L2

Design of Engine Power Capacity

- The engine should be able to supply sufficient power to support the vehicle operation at normal constant speeds both on a flat and a mild grade road without the help of the PPS.
- At the same time, the engine should be able to produce an average power that is larger than the average load power when the vehicle operates with a stop-and-go operating pattern.
- As a requirement of normal highway driving at constant speed on a flat or a mild grade road, the power needed is expressed as

$$P_e = \frac{V}{1000\eta_{t,e}}\left(M_v g f_r + \frac{1}{2}\rho_a C_D A_f V^2 + M_v g i\right)(\text{kW}).$$

- The average load power of a vehicle can be calculated by

$$P_{ave} = \frac{1}{T}\int_0^T \left(M_v g f_r V + \frac{1}{2}\rho_a C_D A_f V^3 + \delta M_v V \frac{dV}{dt}\right) dt.$$

- The average power varies with the degree of regenerative braking. The two extreme cases are the full and zero regenerative braking cases. Full regenerative braking recovers all the energy consumed in braking.
- However, when the vehicle has no regenerative braking, the average power is larger than that with full regenerative braking.
- The average power that the engine can produce with full throttle can be calculated as

$$P_{max\text{-}ave} = \frac{1}{T}\int_0^T P_e(v)\, dt,$$

5	Explain about Design of Electric Motor Drive Power Capacity in parallel hybrid electric drive train.	10	CO5	L2

Design of Electric Motor Drive Power Capacity

- In HEV, the major function of the electric motor is to supply peak power to the drive train. In the motor power design, acceleration performance and peak load power in typical drive cycles are the major concerns.
- It is difficult to directly design the motor power from the acceleration performance specified. It is necessary to make a good estimate based on specified acceleration requirements, and then make a final design through accurate simulation.
- As an initial estimate, one can make the assumption that the steady-state load (rolling resistance and aerodynamic drag) is handled by the engine and the dynamic load (inertial load in acceleration) is handled by the motor.
- With this assumption, acceleration is directly related to the torque output of an electric motor by

$$\frac{T_m i_{t,m} \eta_{t,m}}{r} = \delta_m M_v \frac{dV}{dt},$$

- where Tm is the motor torque and δm is the mass factor associated with the electric motor.

- the motor power rating is expressed as

$$P_m = \frac{\delta_m M_v}{2\eta_{t,m} t_a}(V_f^2 + V_b^2).$$

- The average power of the engine, used to accelerate the vehicle, can be expressed as

$$P_{e,a} = \frac{1}{t_a - t_i}\int_{t_i}^{t_a}(P_e - P_r)\,dt,$$

- where Pe and Pr are the engine power and resistance power, respectively.
- It should be noted that the engine power transmitted to the driven wheels is associated with the transmission, that is, the gear number and gear ratios.

6	Explain about Transmission Design and Energy Storage Design of parallel hybrid electric drive trains.	10	CO5	L2

Transmission Design

- Since the electric motor supplies the peak power and has high torque at low speed, single-gear transmission between the electric motor and the driven wheels can produce sufficient torque for hill climbing and acceleration.
- However, a multigear transmission between the engine and driven wheels can indeed enhance the vehicle performance.
- The use of multigear transmission, can effectively increase the remaining power of the engine. Consequently, the vehicle performance (acceleration and gradeability) can be improved.
- On the other hand, the energy storage can be charged with the large power of the engine. The vehicle fuel economy can also be improved, since the use of proper gears of the multigear transmission allows the engine to operate closer to its optimal speed region.
- Furthermore, the large remaining power of the engine can quickly charge the energy storage from low SOC to high SOC.
- However, multigear transmission is much more complex, heavier, and larger than single-gear transmission.

Energy Storage Design

- The energy storage design mainly includes the design for the power and energy capacity. The power capacity design is somewhat straightforward.
- The terminal power of the energy storage must be greater than the input electric power of the electric motor, that is,

$$P_s \geqslant \frac{P_m}{\eta_m},$$

- where Pm and ηm are the motor power rating and efficiency.
- During the acceleration period, the energies drawn from energy storage and the engine can be calculated along with the calculation of the acceleration time and distance by

$$E_s = \int_0^{t_a} \frac{P_m}{\eta_m}\, dt \qquad E_{eng} = \int_0^{t_a} P_e dt,$$

- where Es and Eeng are the energy drawn from the energy storage and the engine, respectively, and Pm and Pe are the powers drawn from the motor and engine, respectively.

- The energy capacity of the energy storage must also meet the requirement while driving in a stop-and-go pattern in typical drive cycles. The energy changes of the energy storage can be obtained by

$$E_c = \int_0^{t} (P_{sc} - P_{sd})\, dt,$$

- where Psc and Psd are the charging and discharging power of the energy storage.
- The energy capacity of the energy storage can be obtained as

$$E_{cs} = \frac{E_D}{SOC_t - SOC_b},$$

- where Ed is the energy discharged from the energy storage, and SOCt and SOCb are the top line and bottom line of the SOC of the energy storage.

CI **CCI** **HOD**