電機控制實驗室 (Electric Machine Control Laboratory), Room 503, EECS Building

指導老師： 廖聰明 教授 (cmliaw@ee.nthu.edu.tw) (03) 5162188, (03) 5731142, EECS 503, Delta 817.

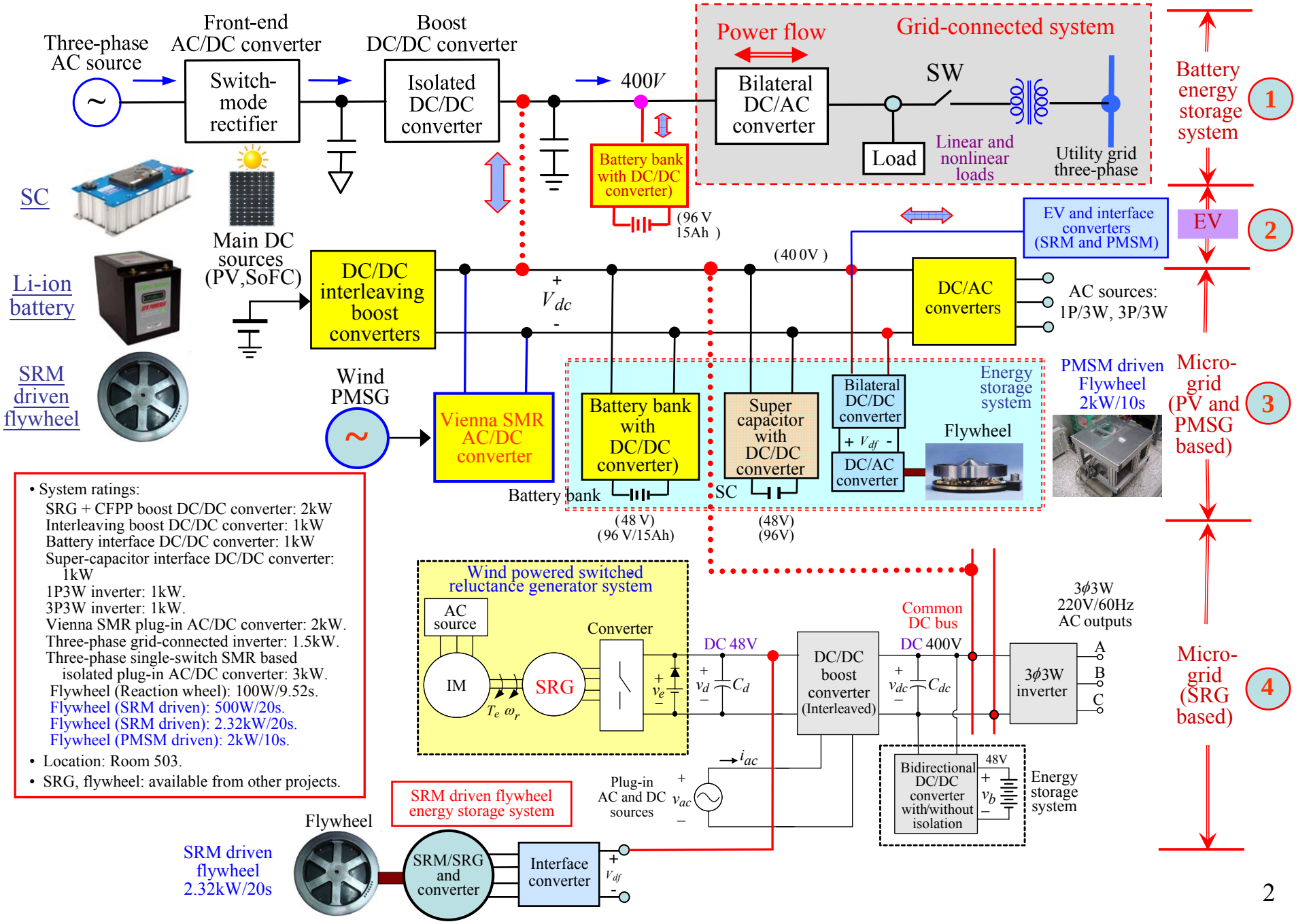
1. 馬達驅動系統

- 直流無刷馬達 (永磁同步馬達) 驅動系統：無位置感測控制、弱磁控制、PAM/PWM控制、換相調控、電流控制、速度控制、定位控制。電動車之驅動控制、再生煞車控制。
- 同步磁阻馬達驅動系統：換相調控、電流控制、速度控制。
- 開關式磁阻馬達驅動系統：無位置感測控制、弱磁控制、增壓控制、換相調控、電流控制、速度控制、噪音及振動消除控制、隨機PWM控制。電動車之驅動控制、再生煞車控制。
- 開關式磁阻發電機、同步發電機。
- 感應馬達：向量控制、弱磁控制、無感測控制、變頻器之PWM切換控制技術、噪音降低之PWM切換控制技術、實用先進控制技術。
- 馬達驅動系統之應用：電動車、空調機、冷凍冷藏設備、冰水機、散熱扇、家電設備、航太組件、風力發電機、飛輪儲能系統、原動機模擬器、G2V/V2H/V2G 操控、其他。

2. 轉換器系統

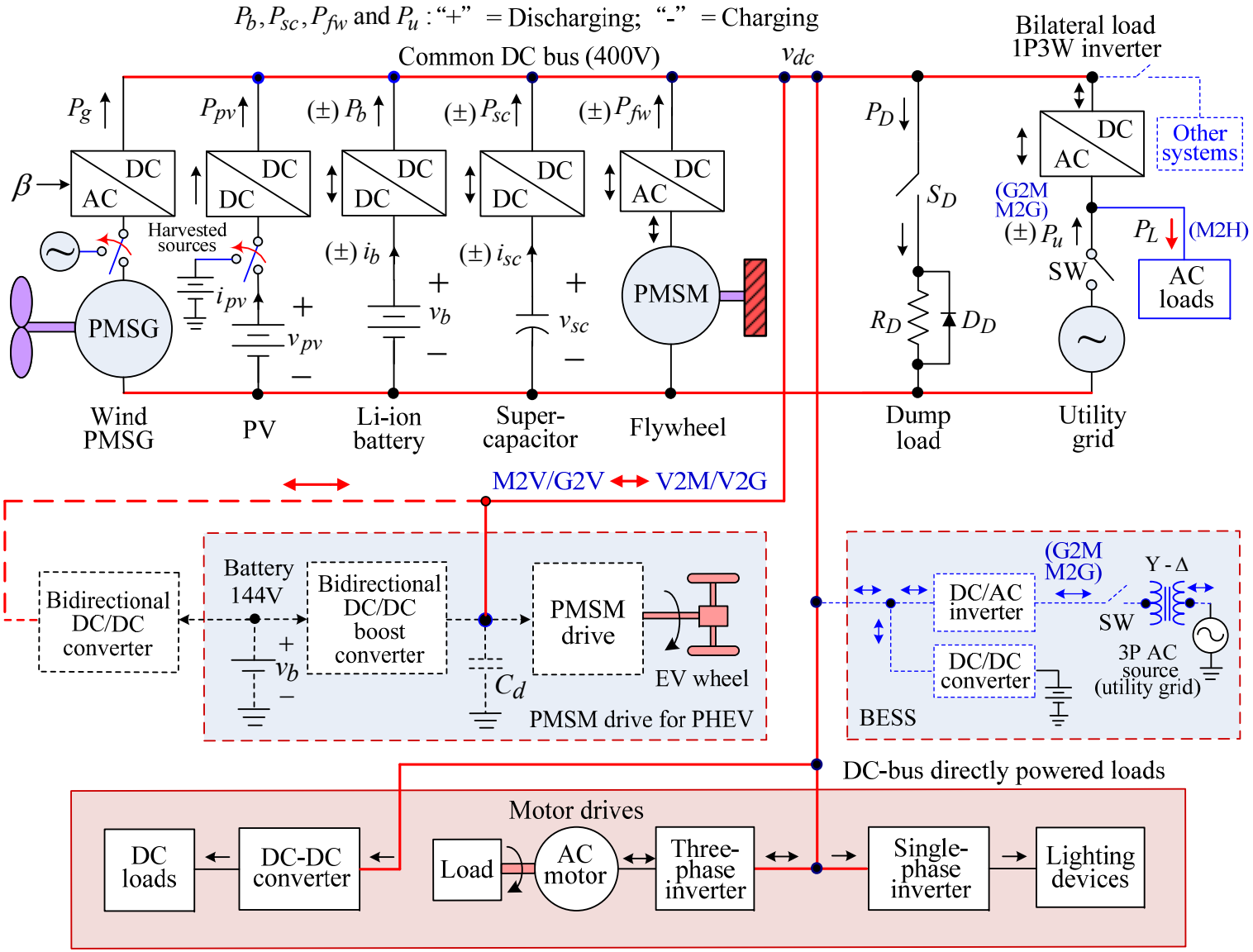
- 變頻器及其切換控制 (單相、三相、並聯)。
- 功因修正控制電路 (切換式整流器) (單相、三相、並聯)。
- 軟式切換轉換器。
- 轉換器之數位控制。
- 電動車輛之驅動系統、充電器及充電控制、UPS放電操控。
- 實用及先進控制技術。
- 切換式電源供應器。
- 電力濾波器。
- Photovoltaic cell and fuel cell powered auxiliary power units (APU)。
- 微電網及其組成電力電子轉換器。
- 儲能系統(蓄電池、超電容、飛輪)之建構及操控。
- 其他。

The established experimental common DC micro-grid and energy storage systems



- System ratings:
  - SRG + CFPP boost DC/DC converter: 2kW
  - Interleaving boost DC/DC converter: 1kW
  - Battery interface DC/DC converter: 1kW
  - Super-capacitor interface DC/DC converter: 1kW
  - 1P3W inverter: 1kW.
  - 3P3W inverter: 1kW.
  - Vienna SMR plug-in AC/DC converter: 2kW.
  - Three-phase grid-connected inverter: 1.5kW.
  - Three-phase single-switch SMR based isolated plug-in AC/DC converter: 3kW.
  - Flywheel (Reaction wheel): 100W/9.52s.
  - Flywheel (SRM driven): 500W/20s.
  - Flywheel (SRM driven): 2.32kW/20s.
  - Flywheel (PMSM driven): 2kW/10s.
- Location: Room 503.
- SRG, flywheel: available from other projects.

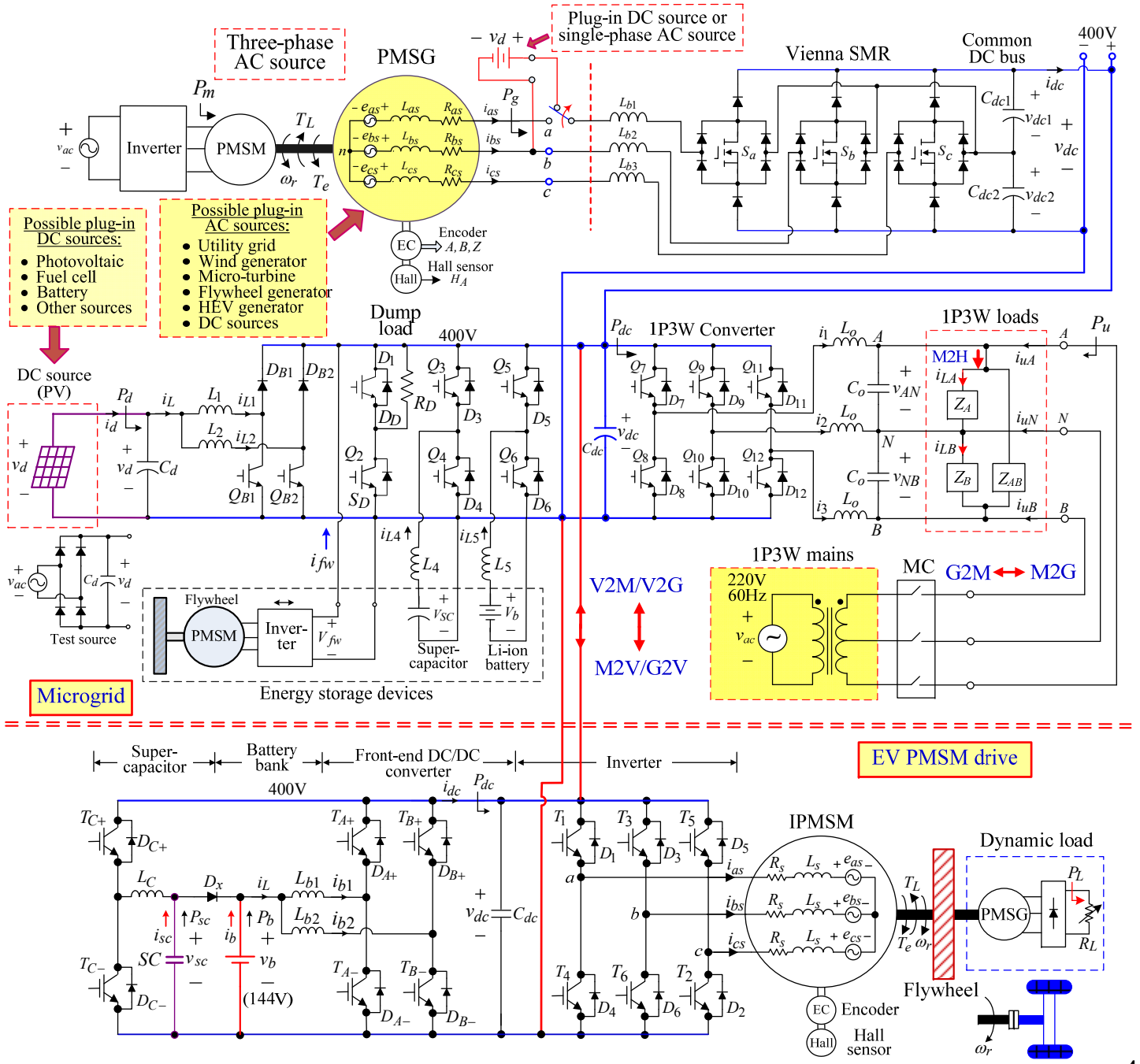
A micro-grid with multiple renewable sources and energy storage devices: incorporated operations with EV and grid, DC directly powered loads



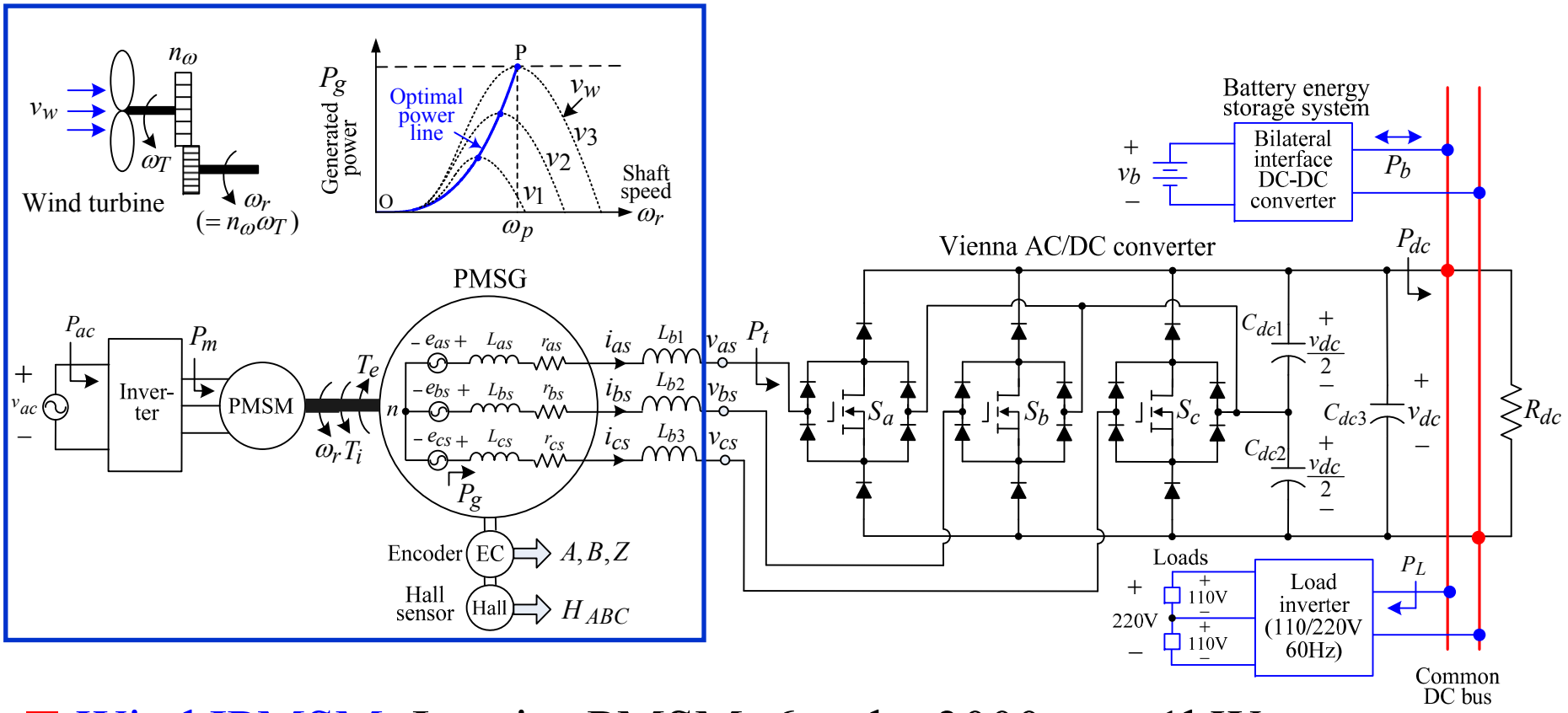
Wind generator and possible harvested AC and DC sources

DC microgrid

EV-IPMSM drive

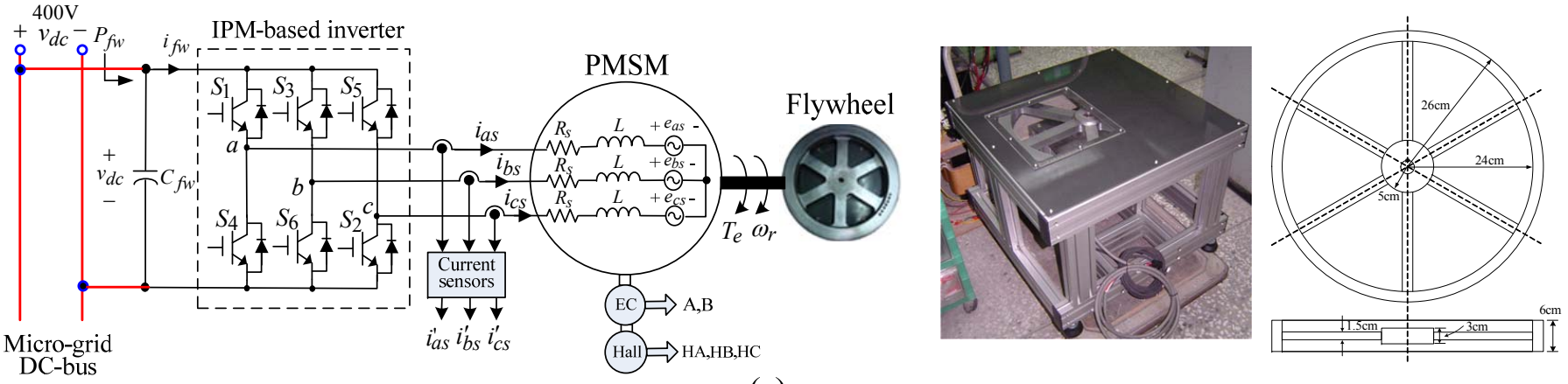


Wind IPMSG

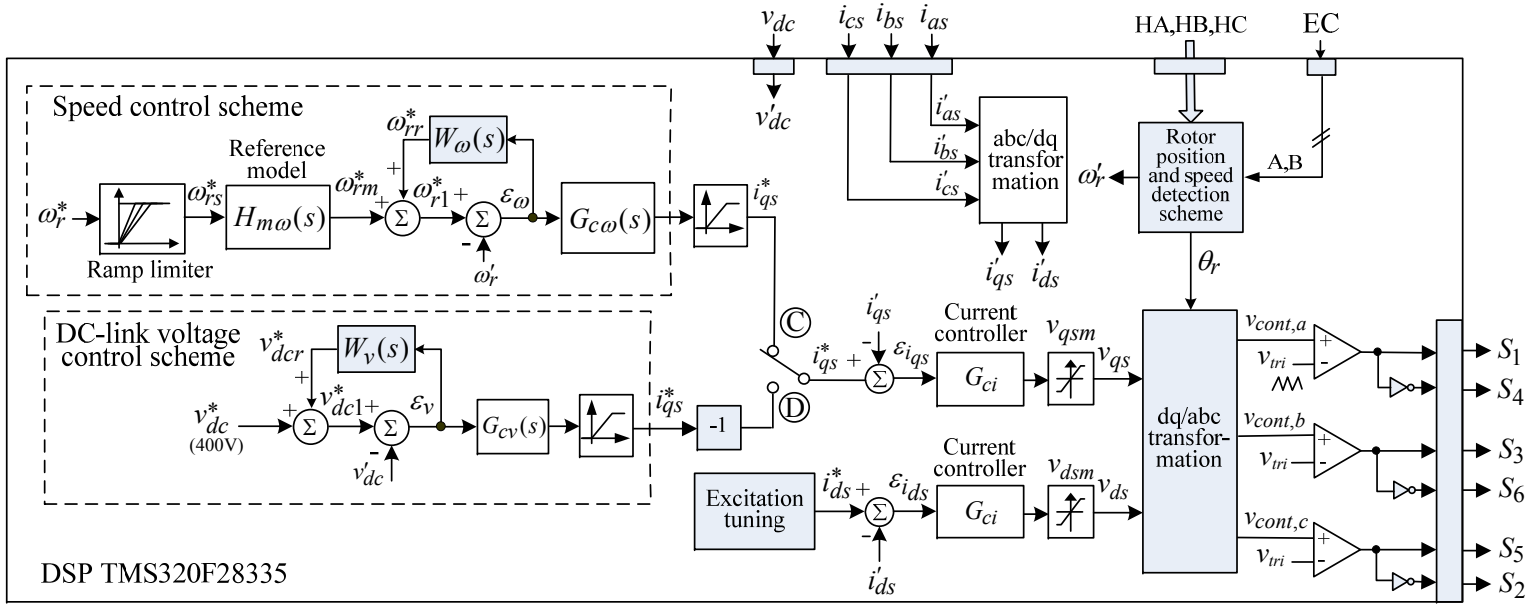


- Wind IPMSM: Interior PMSM, 6-pole, 3000rpm, 1kW
- SPMSM prime mover: SPMSM, 4-pole, 3000rpm, 2kW
- Power converter: The Vienna rectifier is established with three off-the-self modules (IXYS VUM 25-05E, $500V$, $35A$).

PMSM Driven Flywheel



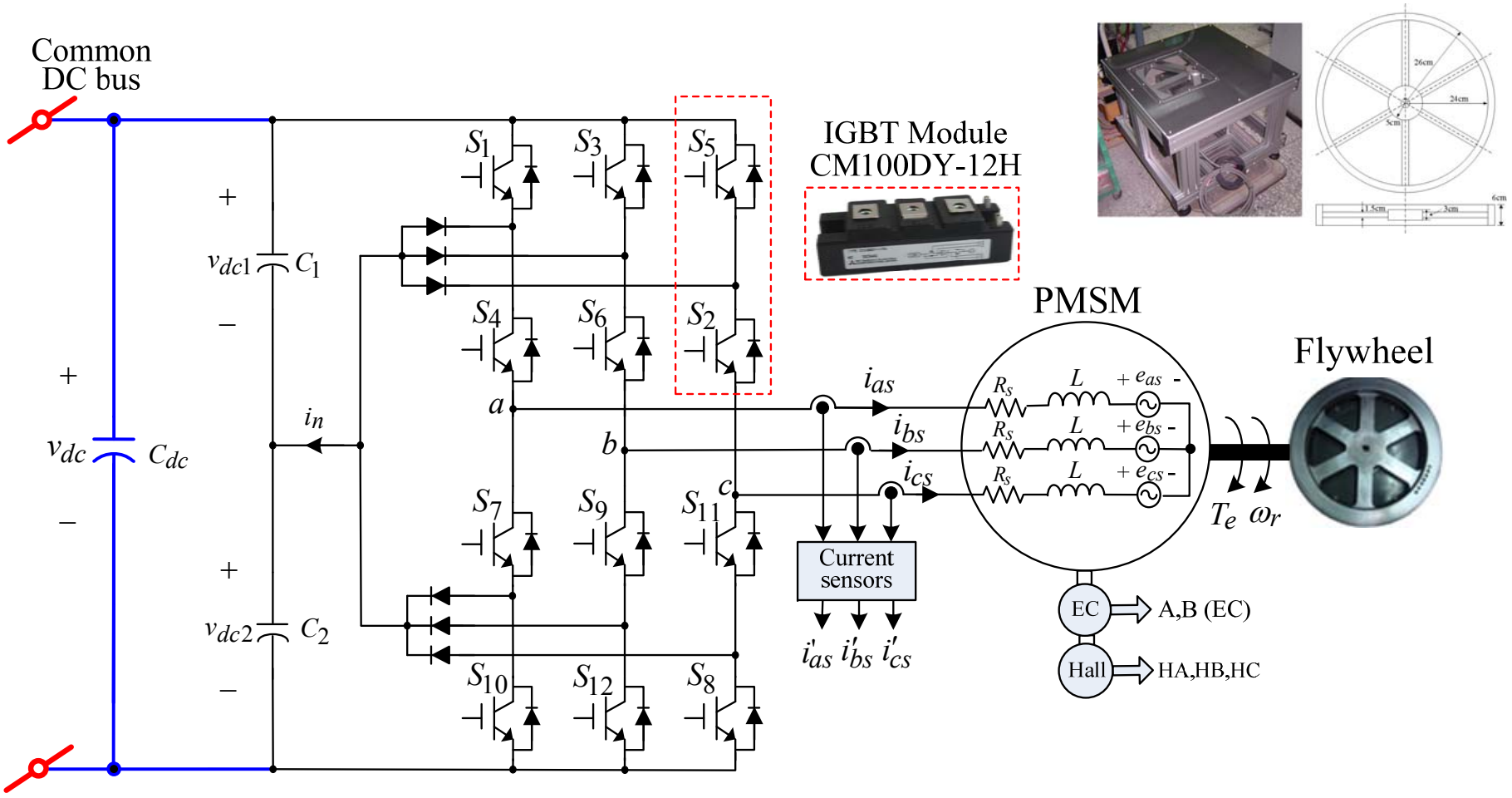
(a)



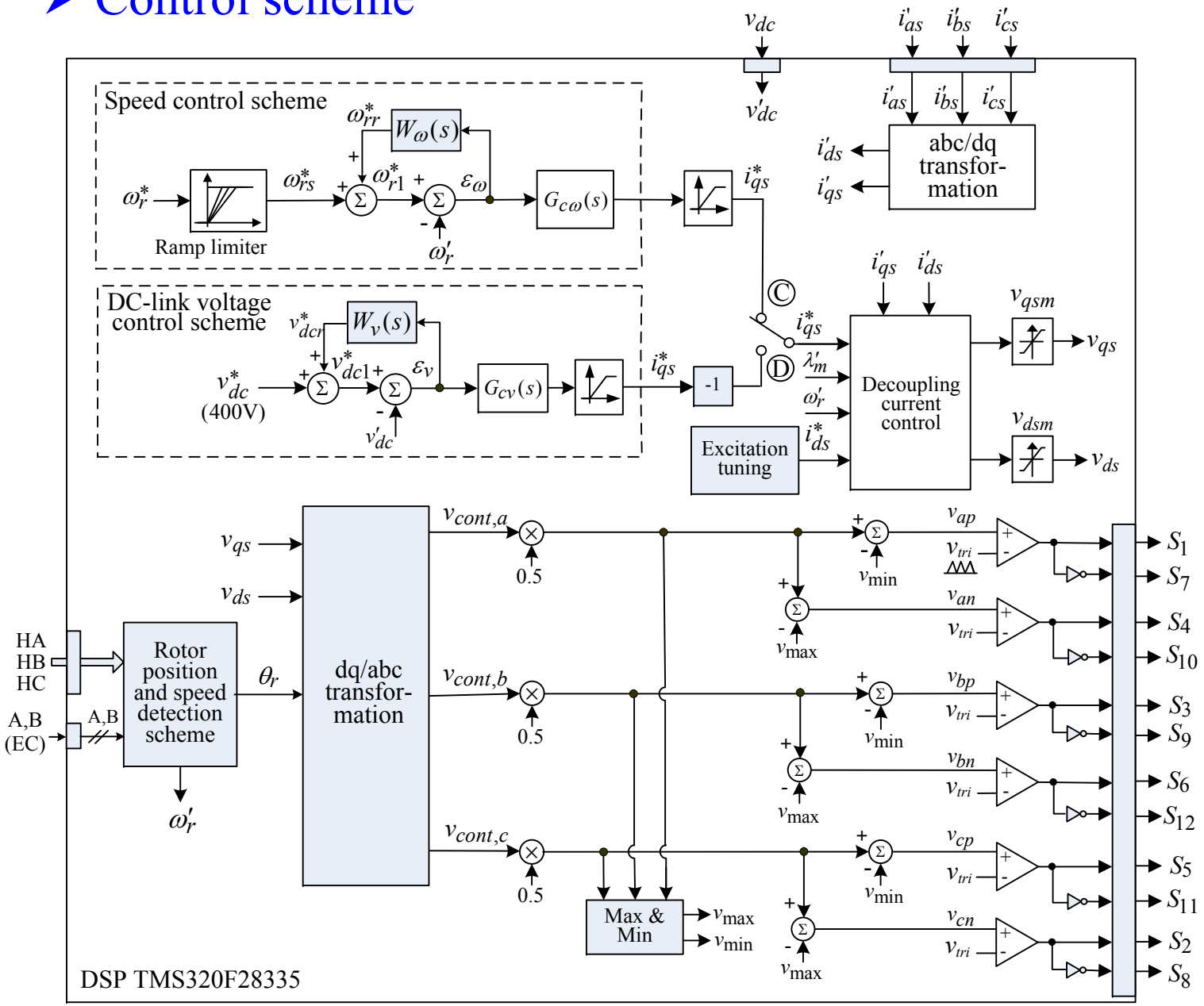
(b)

Three-level neutral-point clamped (NPC) inverter

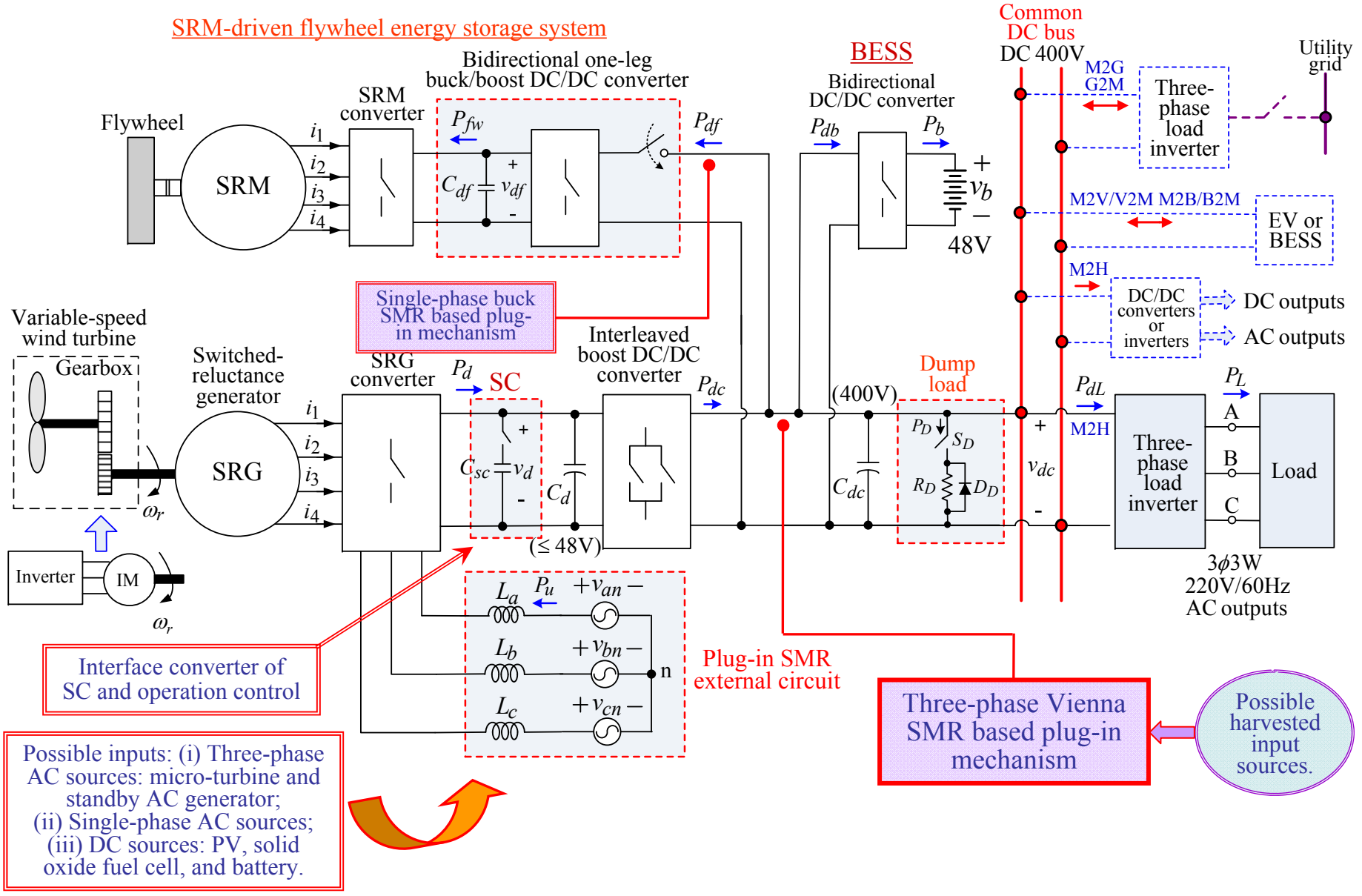
➢ Power circuit



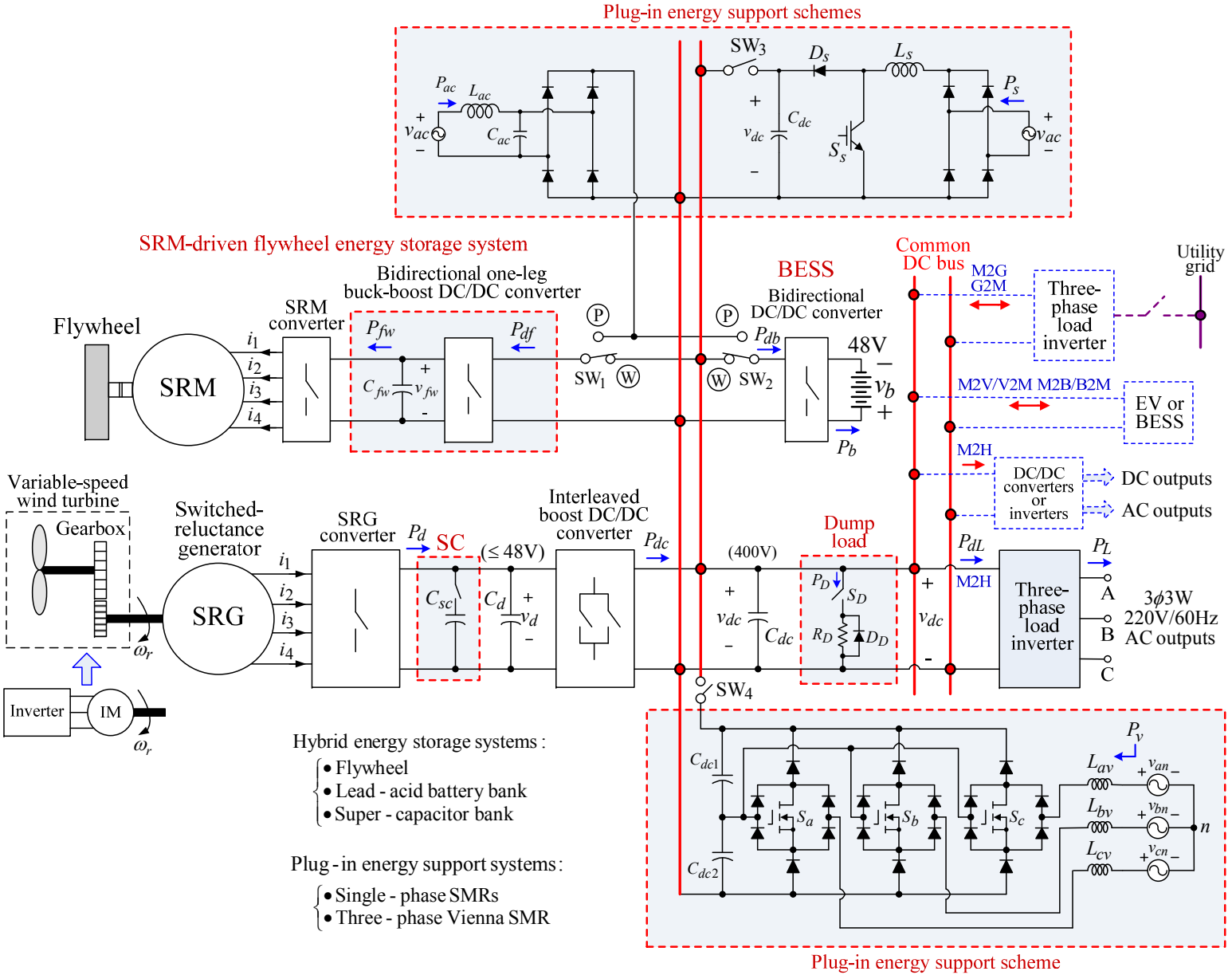
➢ Control scheme



Wind SRG-based DC micro-grid with the plug-in mechanism using three-phase bridgeless DCM SMR

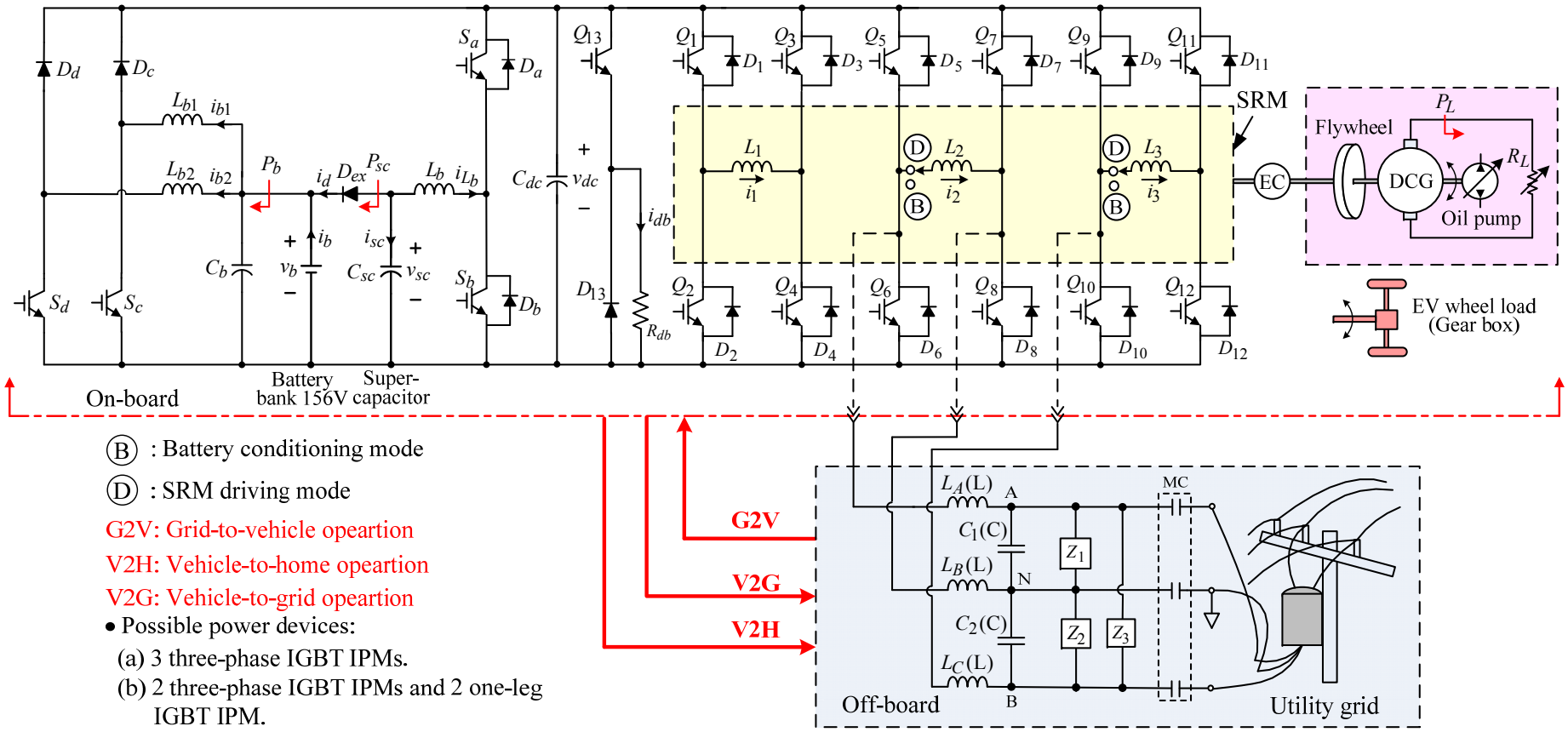


A wind SRG-based DC micro-grid with hybrid energy storage system and plug-in auxiliary energy support from utility grid or other possible sources



A battery/super-capacitor powered SRM driven vehicle with G2V/V2H/V2G functions

System configuration of the developed EV SRM drive with cascaded battery/SC



Ⓑ : Battery conditioning mode

Ⓓ : SRM driving mode

G2V: Grid-to-vehicle opeartion

V2H: Vehicle-to-home opeartion

V2G: Vehicle-to-grid opeartion

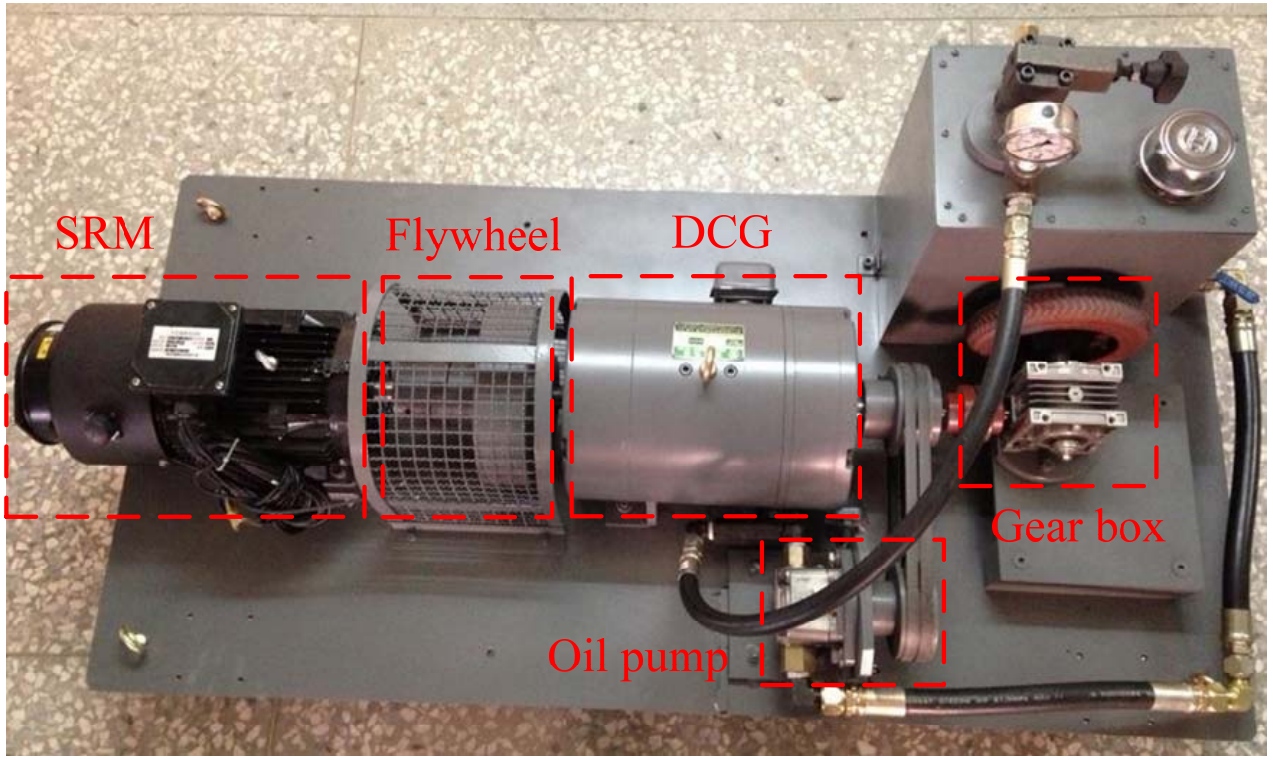
- Possible power devices:
  - (a) 3 three-phase IGBT IPMs.
  - (b) 2 three-phase IGBT IPMs and 2 one-leg IGBT IPM.

SRM driving: (S_c, D_c, S_d, D_d): form interleaving boost converter ($v_{dc}^* = 550\text{V}$) to establish 550V DC-link voltage.
(S_a, D_a, S_b, D_b): form interfaced one-leg bidirectional buck/boost DC/DC converter for super-capacitor ($v_{dc}^* = 560\text{V}$).

Regenerative braking:

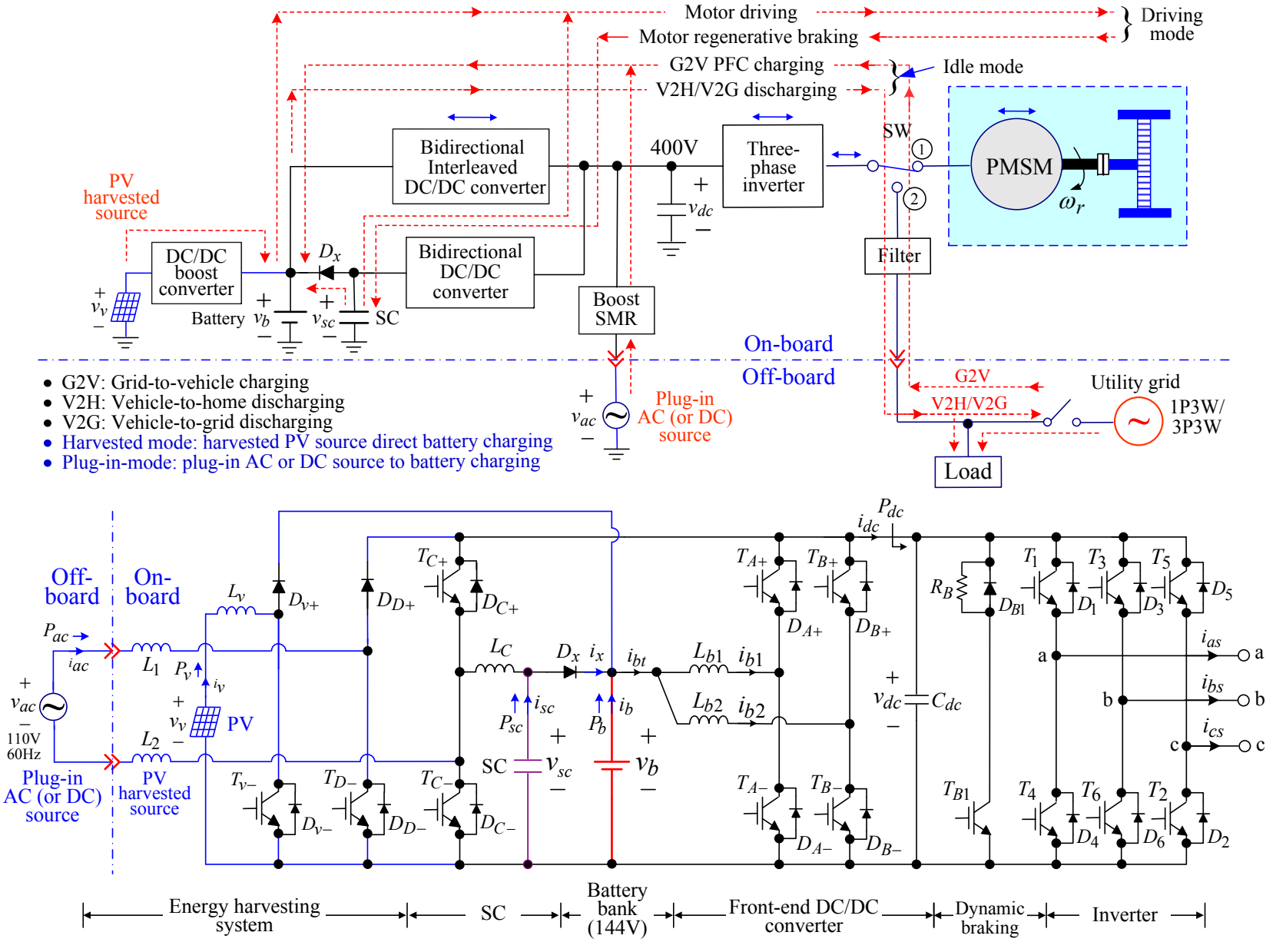
- By arranging the windings current on the inductance negative slope region and operating in hard free-wheeling, the SRM can be operated in regenerative braking. The components (L_b, S_a, D_b, C_{SC}) form a one-leg bidirectional buck/boost DC/DC converter to charge the super-capacitor. When the voltage of super-capacitor is over 156V, the battery will be charged via the diode(D_{ex}).

The constructed EV load test-bench

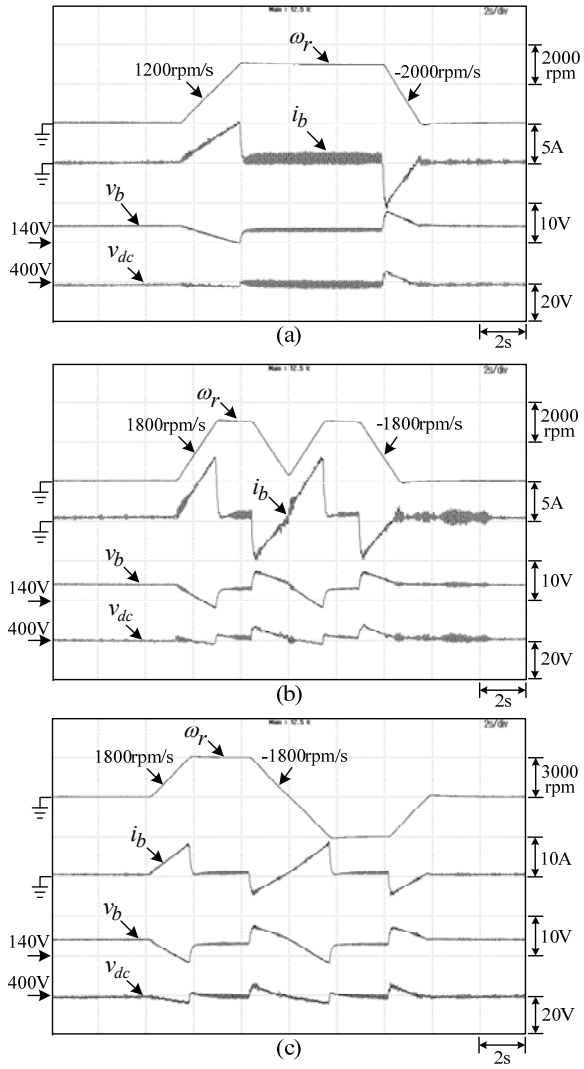


$$T_e = T_L + J\frac{d\omega_r}{dt} + B\omega_r = \frac{r}{G}\left[(\mu_{rr} + \sin(\psi))mg + (m + I\frac{G^2}{\eta_g r^2})\frac{dv}{dt} + \frac{1}{2}\rho A C_d v^2\right]$$

A battery/super-capacitor powered EV IPMSM drive with G2V/V2H/V2G and plug-in energy harvesting functions

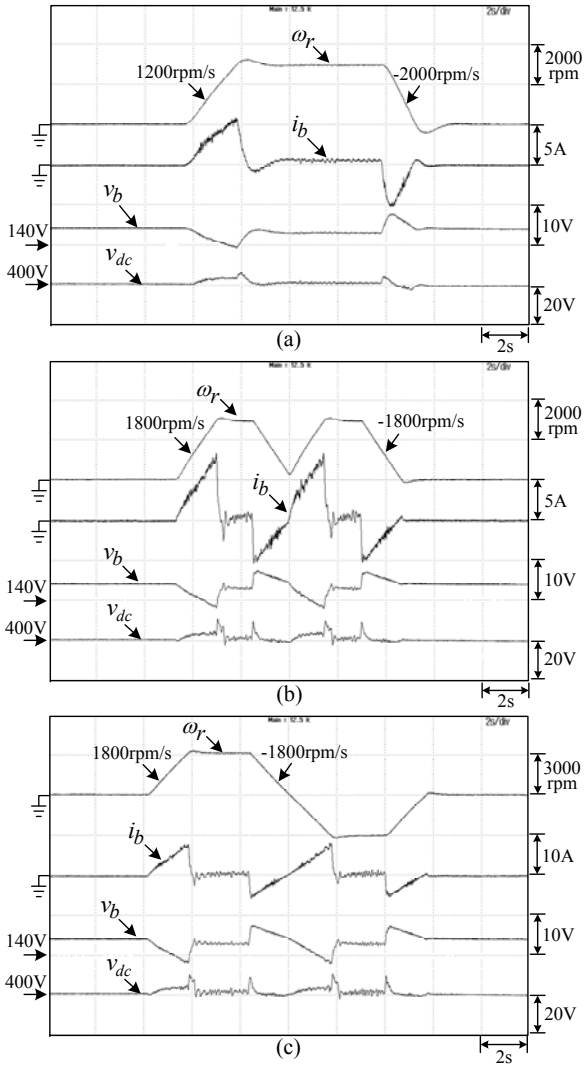


Standard control



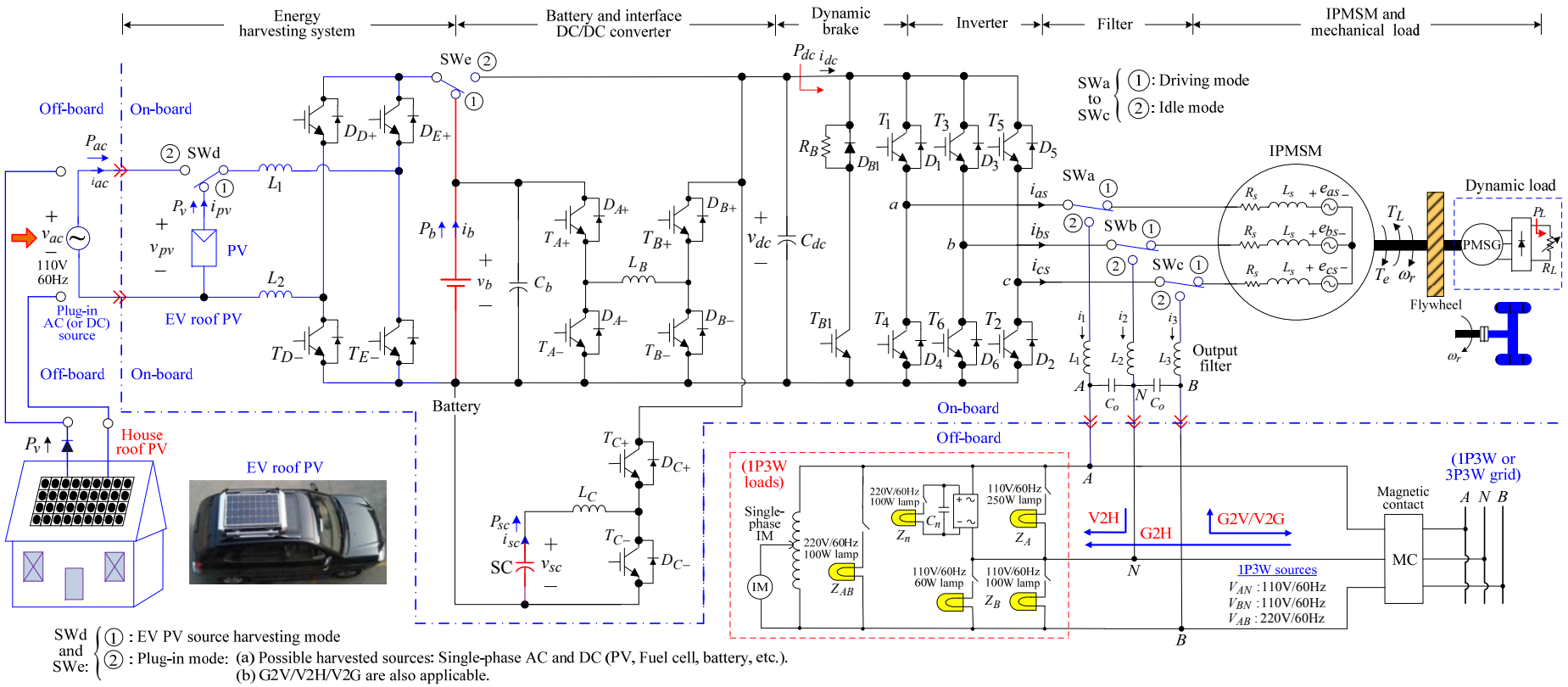
Measured (ω_r , v_{dc} , v_b , i_b) of the developed standard EV SPMSM drive powered by bidirectional DC/DC front-end converter due to the programmed speed rate profiles: (a) (1200rpm/s ↔ -2000rpm/s); (b) (1800rpm/s ↔ -1800rpm/s); (c) reversible operation with the speed rates of (1800rpm/s ↔ -1800rpm/s).

HFI sensorless control

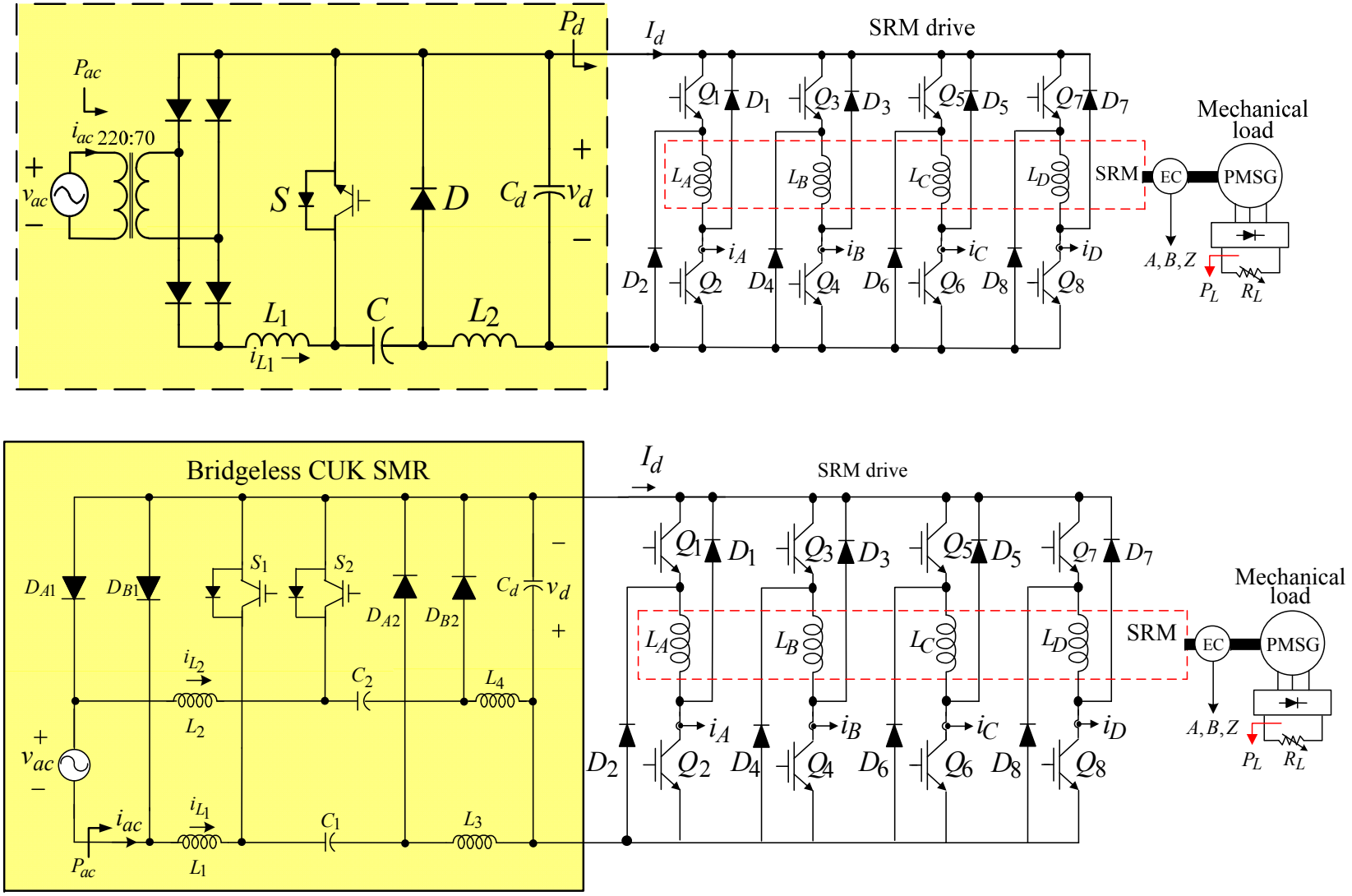


Measured (ω_r , v_{dc} , v_b , i_b) of the developed HFI sensorless EV SPMSM drive powered by bidirectional DC/DC front-end converter due to the programmed speed rate profiles: (a) (1200rpm/s ↔ -2000rpm/s); (b) (1800rpm/s ↔ -1800rpm/s); (c reversible operation with the speed rates of (1800rpm/s ↔ -1800rpm/s).

A battery/supercapacitor powered EV PMSM drive with grid connected and energy harvesting functions

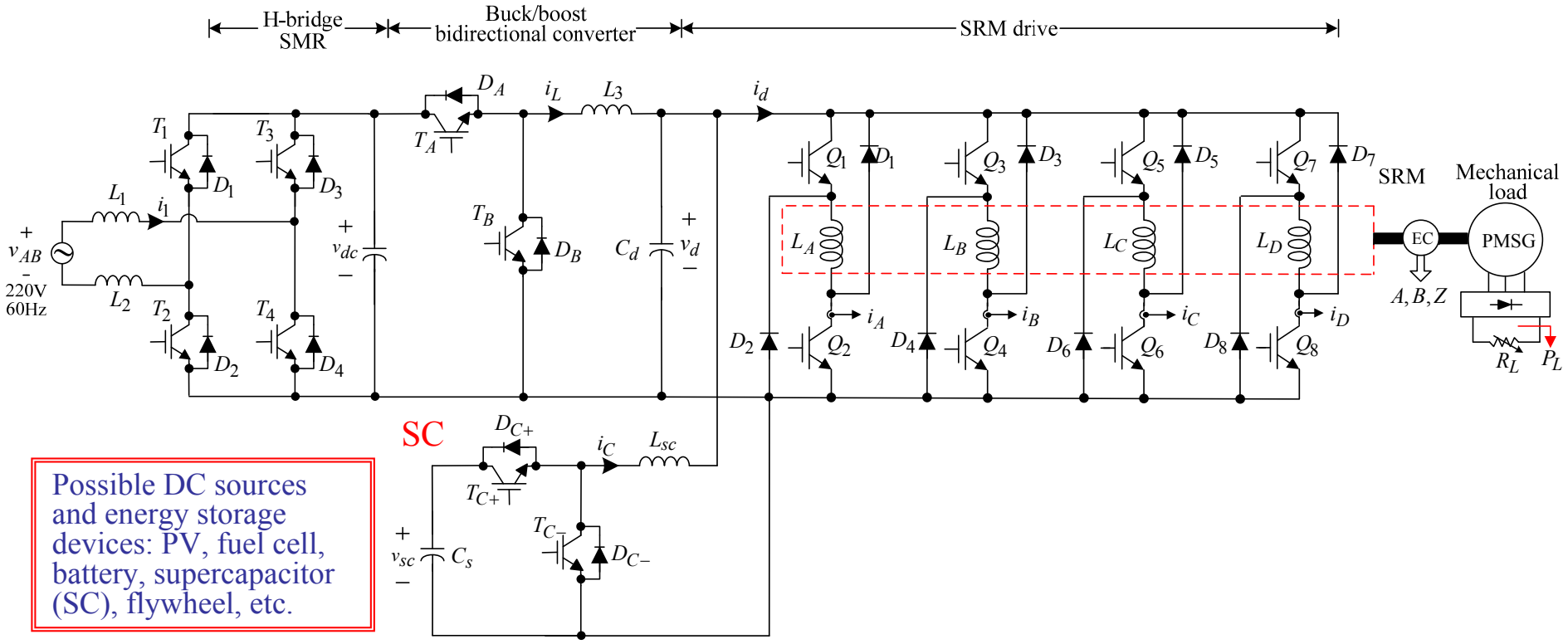


A switched-reluctance motor drive with standard and bridgeless Ćuk switch-mode rectifier front-ends



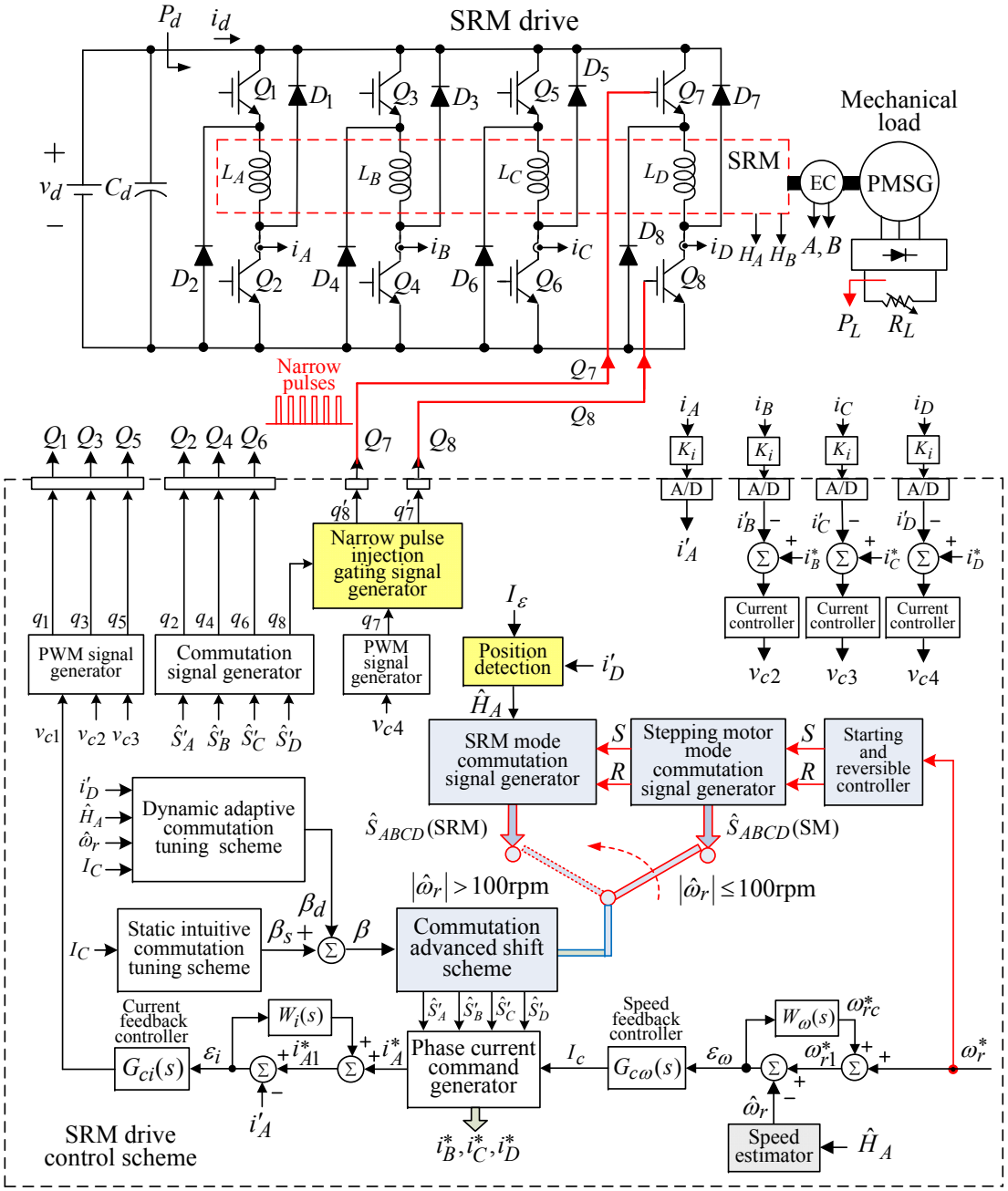
SRM drive with four-quadrant single-phase four-switch SMR

- Reversible running.
- Regenerative braking.
- Possible DC sources and storage devices interfaced to DC-link:
  PV, fuel cell, battery SC, flywheel, etc.

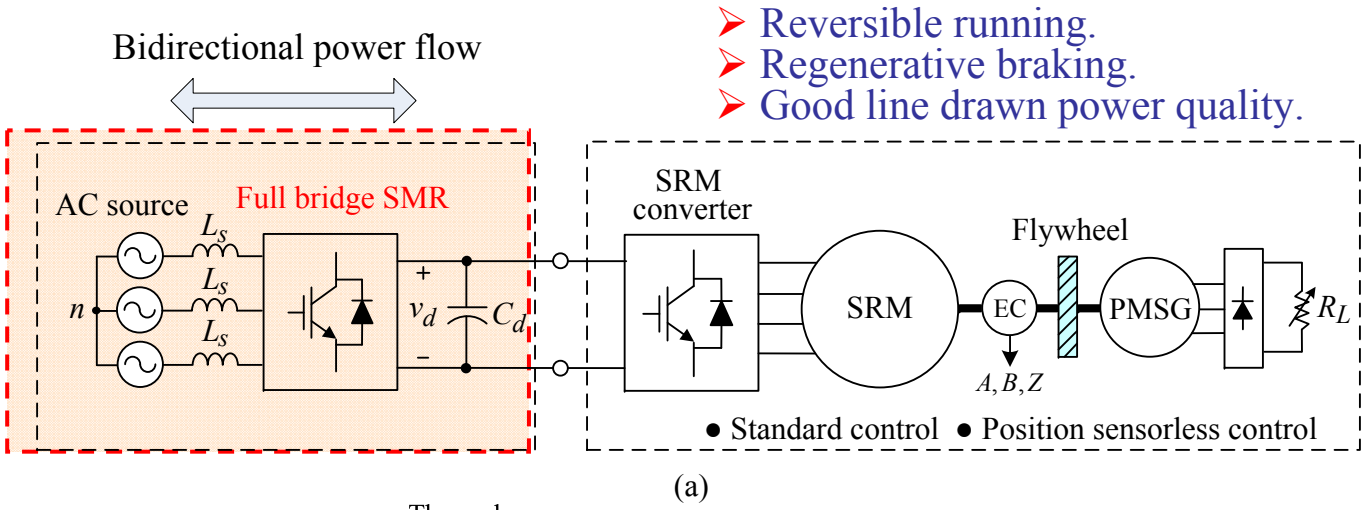


Possible DC sources and energy storage devices: PV, fuel cell, battery, supercapacitor (SC), flywheel, etc.

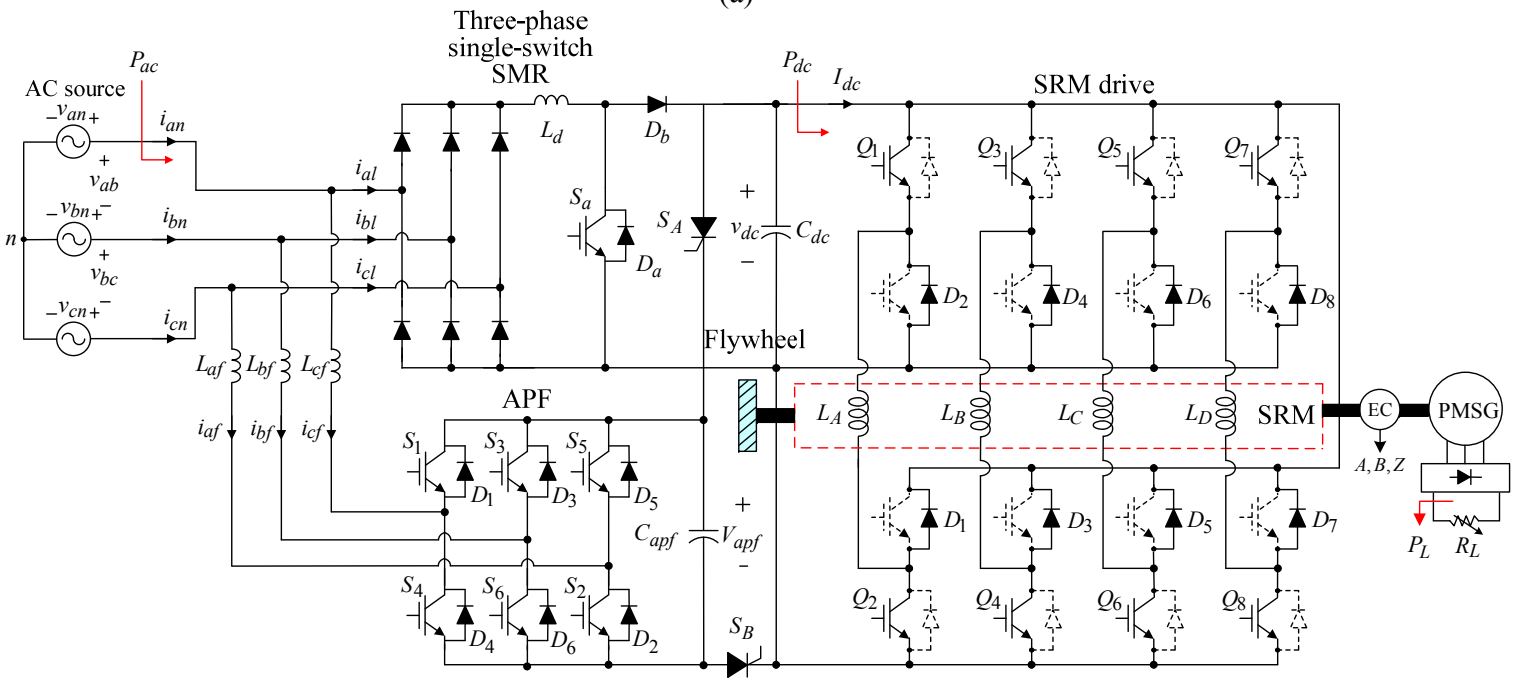
Position sensorless controlled SRM drive based on narrow voltage pulse injection



SRM drive with different types of AC-DC converter front-ends: (a) standard four-quadrant three-phase six-switch SMR; (b) three-phase single-switch SMR paralleled with active power filter.

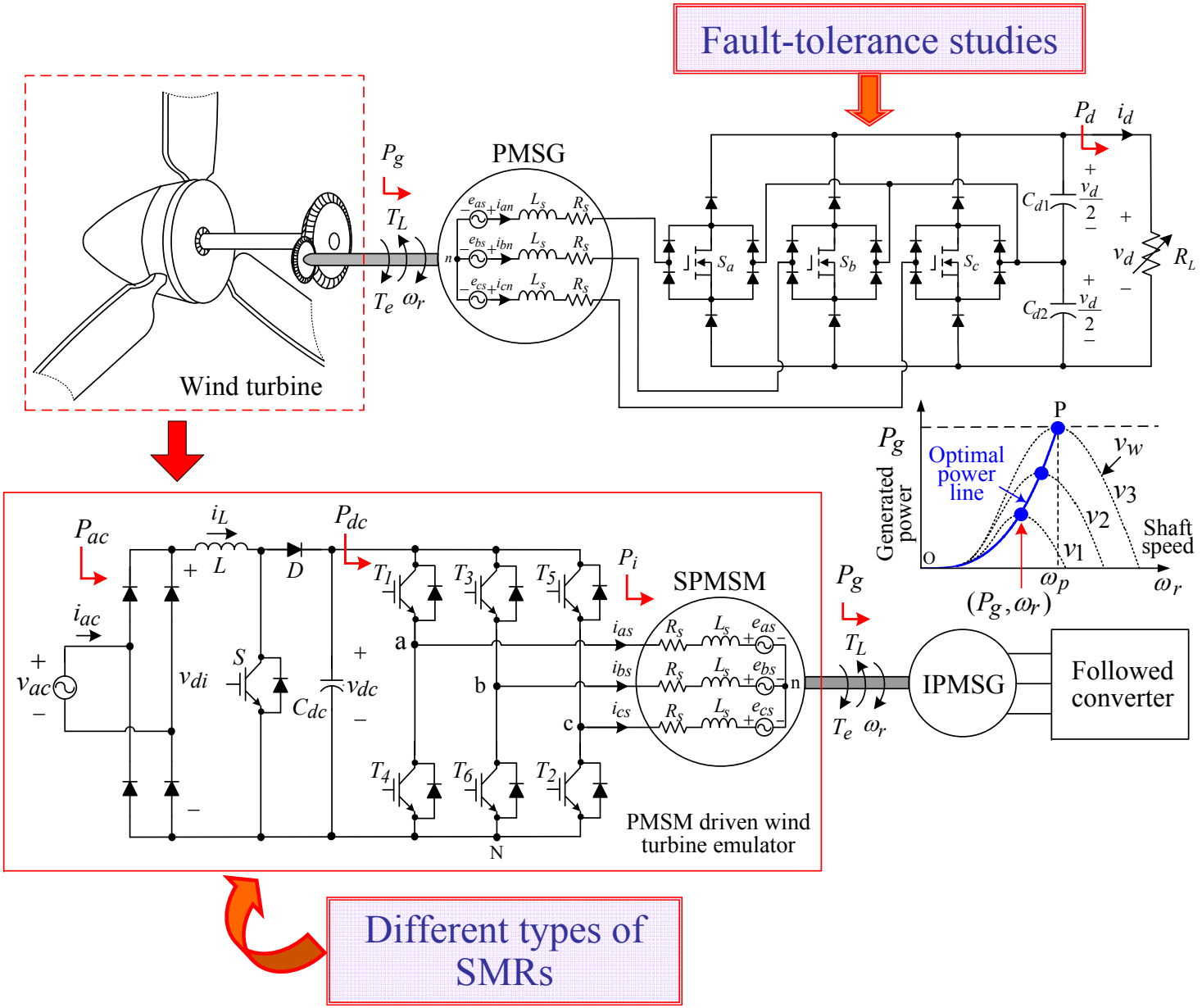


(a)

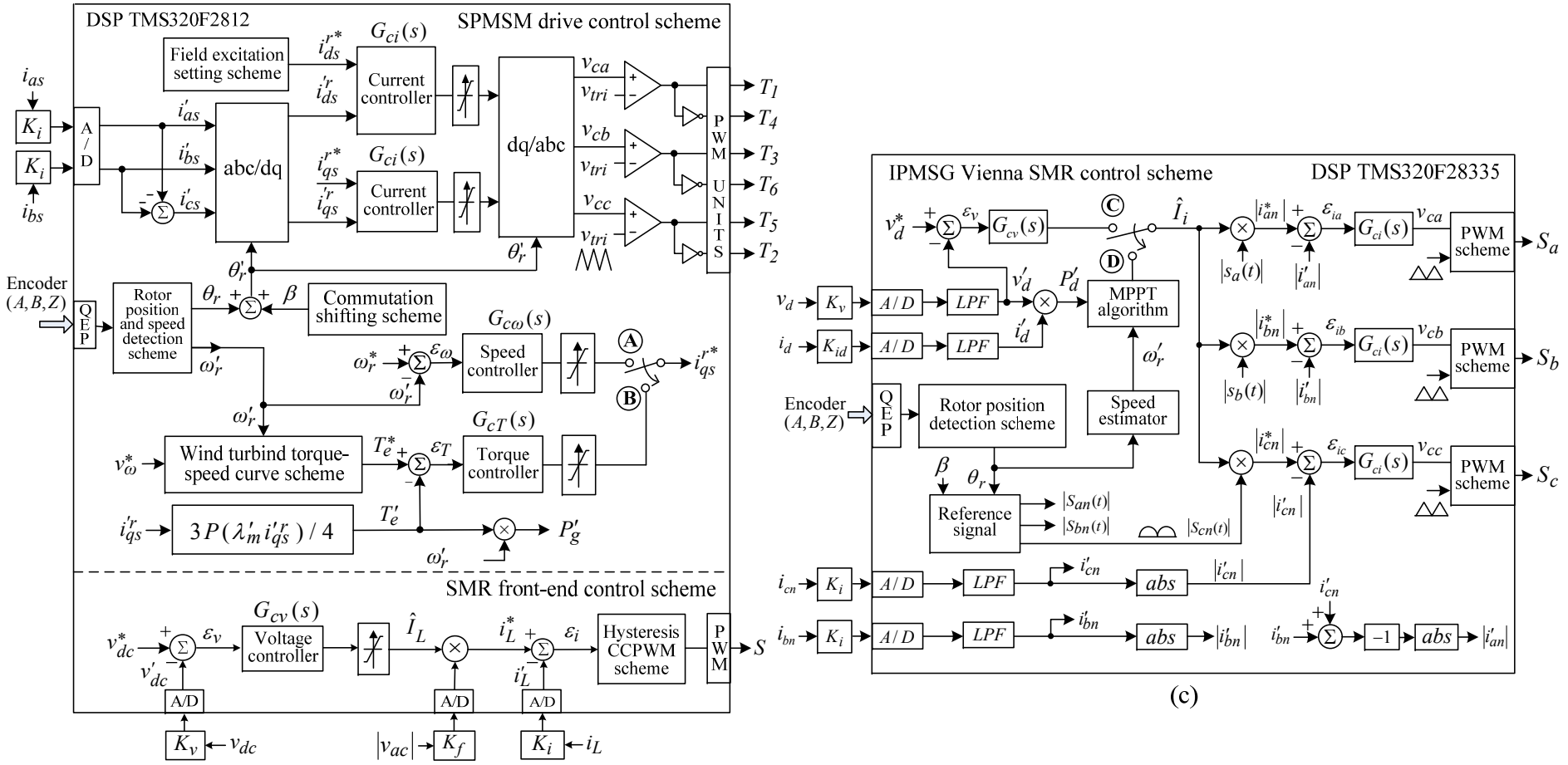


(b)

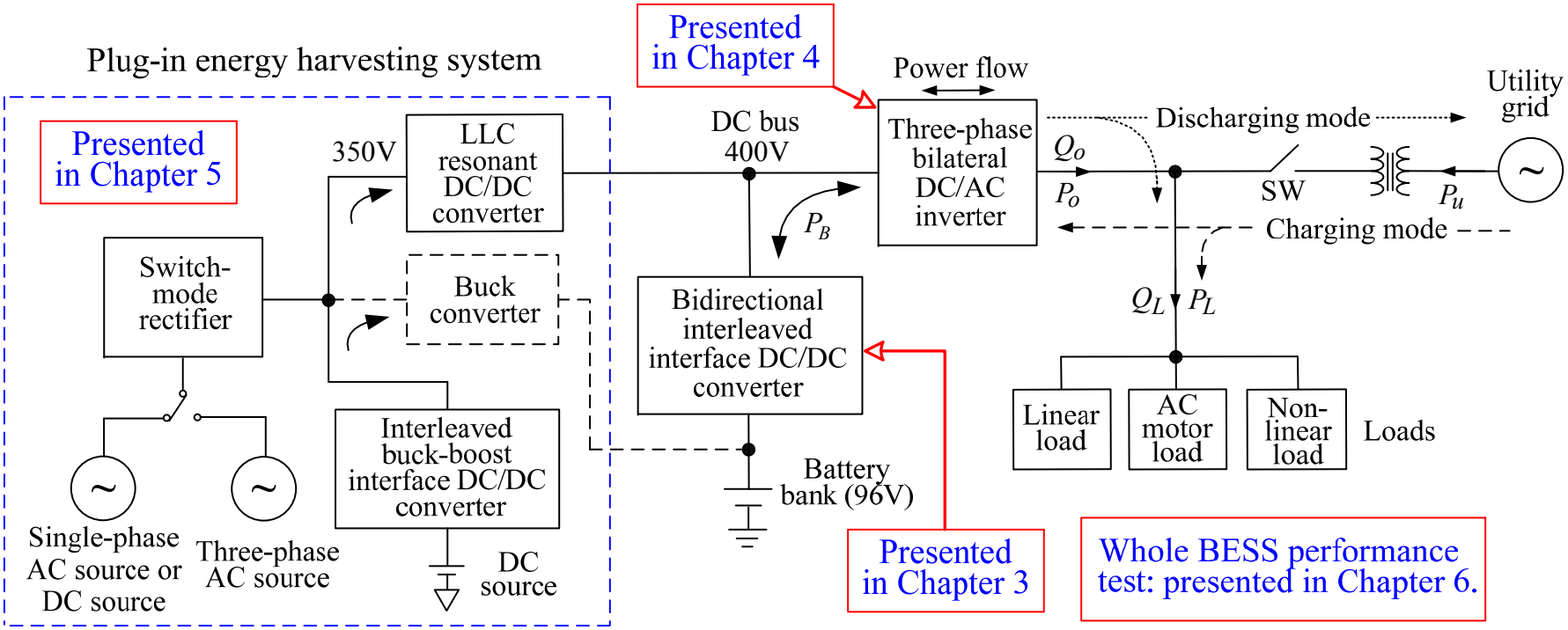
A permanent-magnet synchronous motor driven prime mover emulator



Control schemes of the permanent-magnet synchronous motor driven prime mover emulator



A battery energy storage system with plug-in energy harvesting



Grid-connected operation:

Discharging mode:

1. $P_o = P_L - P_u (P_o > P_L), P_u = \text{Preset value}, \quad Q_o = Q_L$
2. $P_o = P_L + P_u (P_o < P_L), \quad Q_o = Q_L$

Floating mode: $P_o = 0 \quad (P_L = P_u), \quad Q_o = Q_L$

Charging mode: $P_u = P_L - P_o (P_o = \text{Charging Power}), \quad Q_o = Q_L$

Autonomous operation:

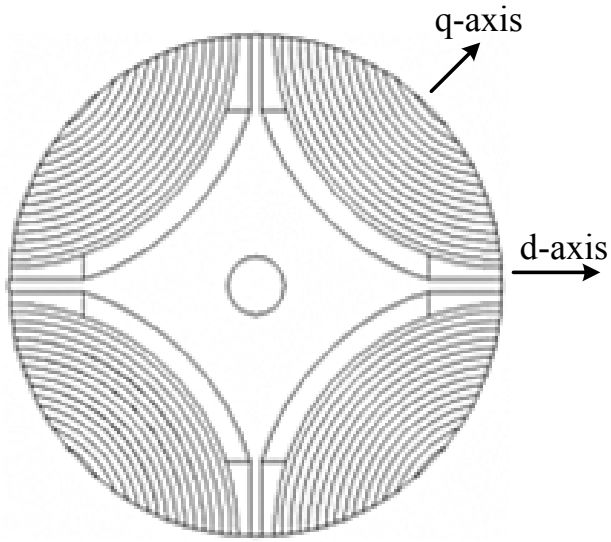
SW is opened, the inverter supplies uninterruptible power to the load, the waveform and magnitude of load terminal voltage are properly controlled.

Plug-in energy harvesting system:

1. The harvested energy is directly charge the battery bank in the BESS.
2. BESS charging mode: the harvested energy is used to make the auxiliary charging.
3. BESS discharging and inverter modes: the harvested energy is used to for powering the loads and/or the utility.

- Synchronous reluctance motors (SynRM): three-phase distributed armature windings are excited by an inverter with sinusoidal currents.
- The commutation must be properly made.

www.motorsummit.ch/data/files/MS.../ms12_tammi.pdf



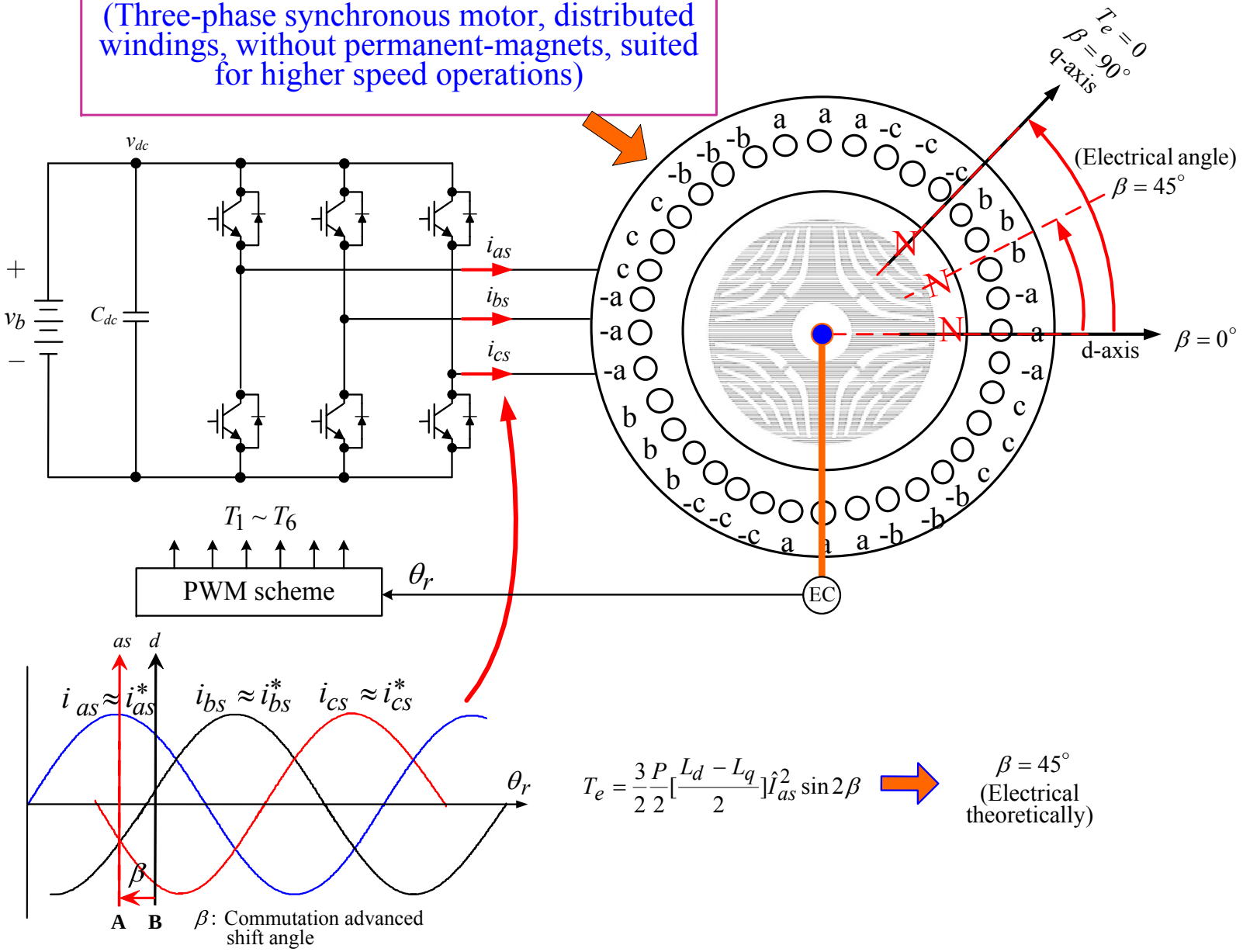
$$T_e = \frac{3}{2}\frac{P}{2}\left[\frac{L_d - L_q}{2}\right]\hat{I}_{as}^2 \sin 2\beta$$

$$\beta = 45^\circ$$

(Commutation instant advanced shift angle)

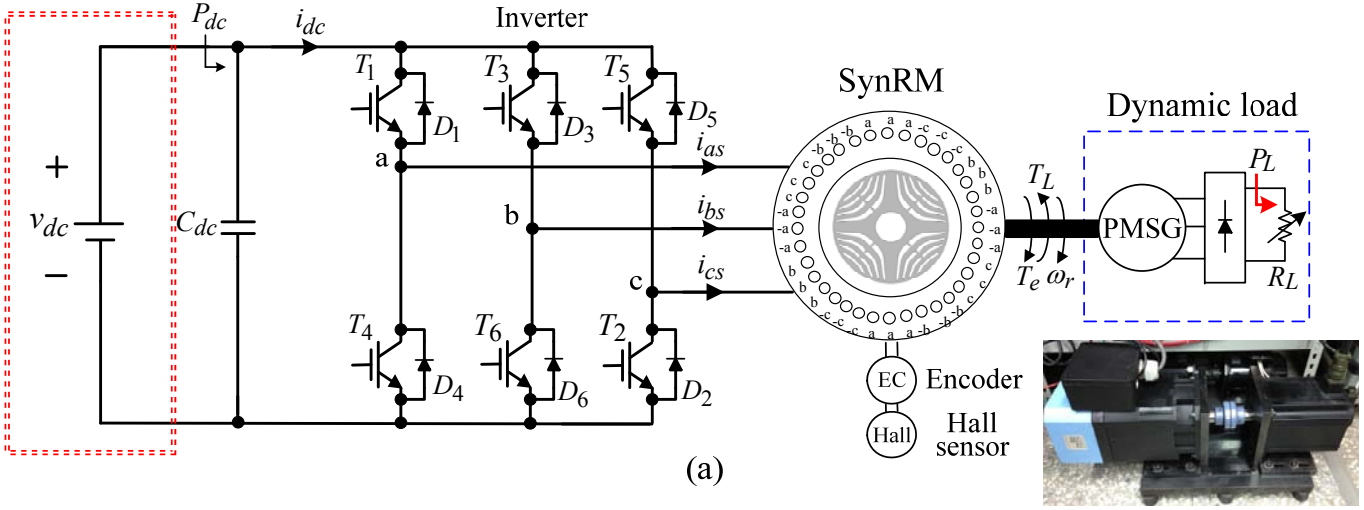
Synchronous reluctance motor (SynRM)

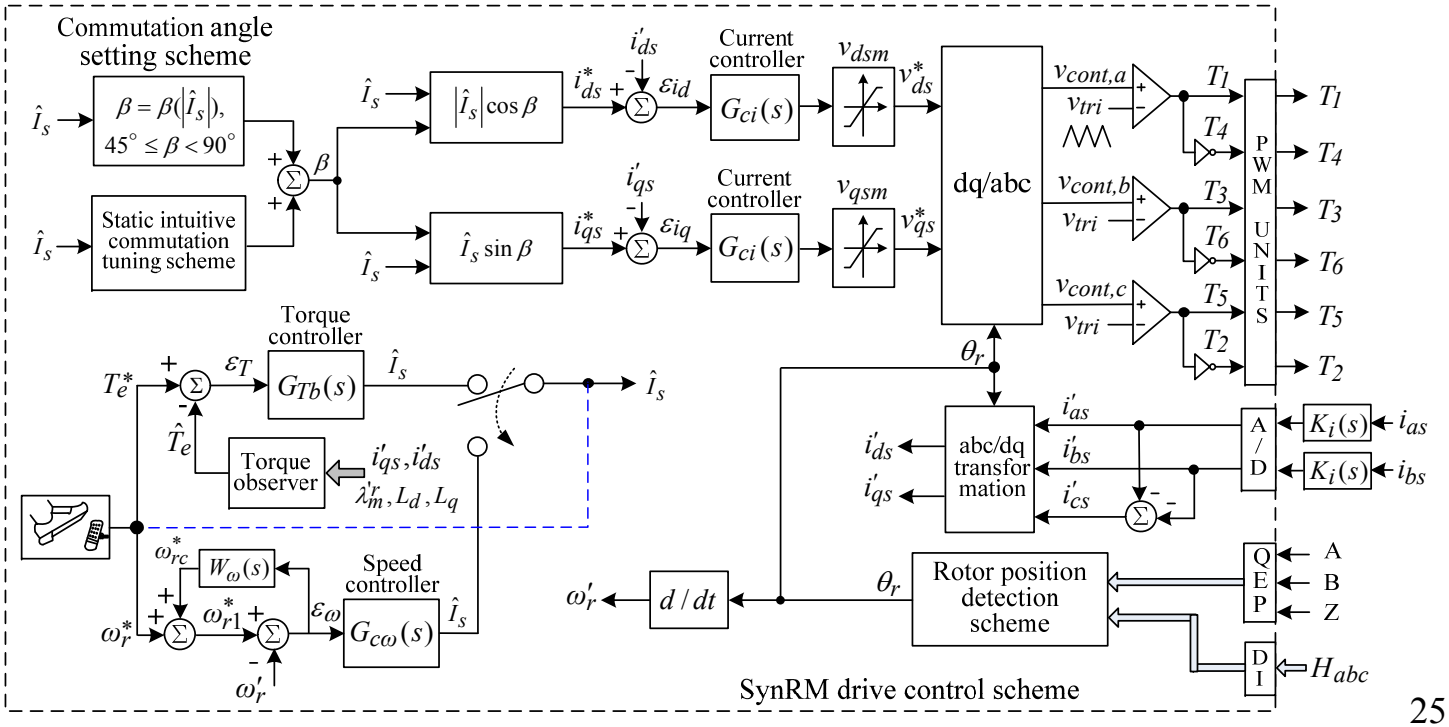
(Three-phase synchronous motor, distributed windings, without permanent-magnets, suited for higher speed operations)



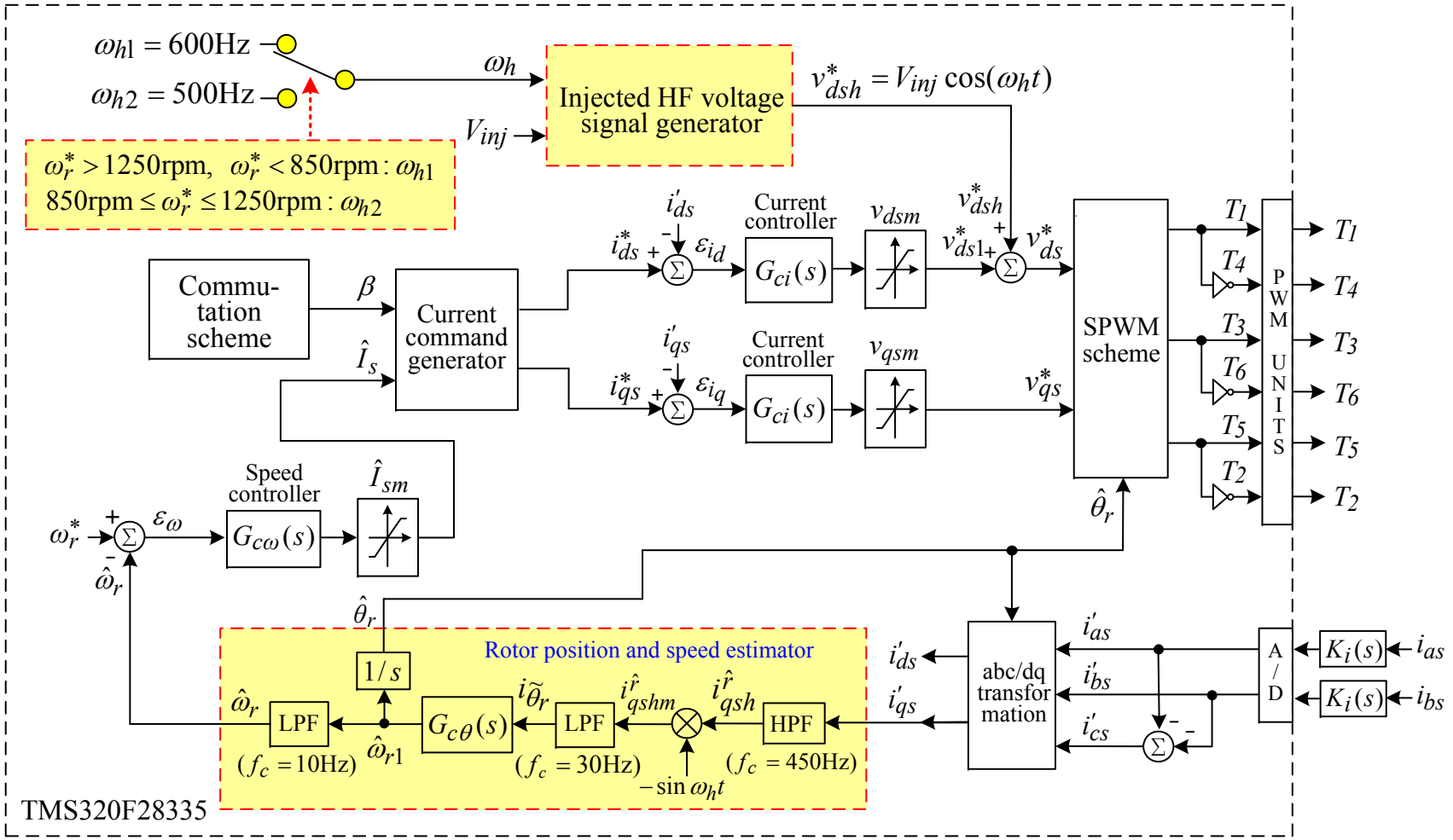
The developed SynRM drive

To be replaced by a three-phase four-quadrant SMR for conducting regenerative braking





Sinusoidal Wave HFI Position Sensorless SynRM Drive with changed injection frequencies

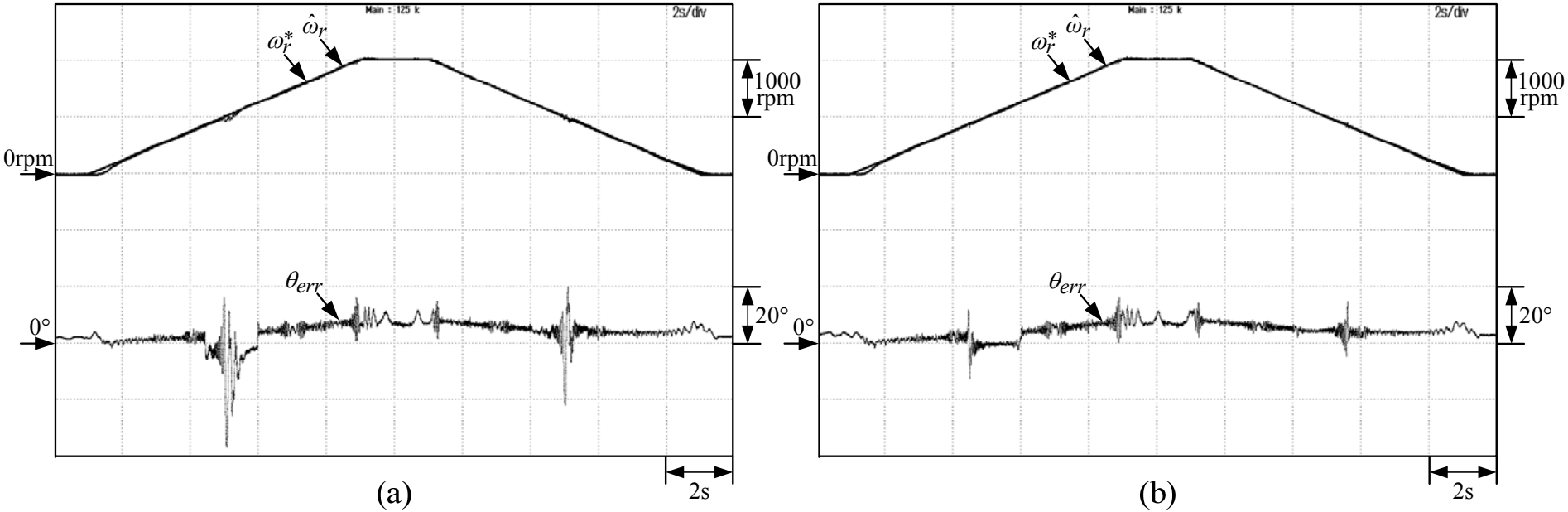


- **Effectiveness:**

A speed command change $\omega_r^* = 0 \rightarrow 2000\text{rpm} \rightarrow 0$ with rising and falling rates being 250rpm/s at $(V_{dc} = 550\text{V}, R_L = 51.8\Omega)$.

Fixed-frequency $f_h = 600\text{Hz}$

Varied-frequency injection



The smoother operation and better driving performance using the proposed signal injection approach can be observed.