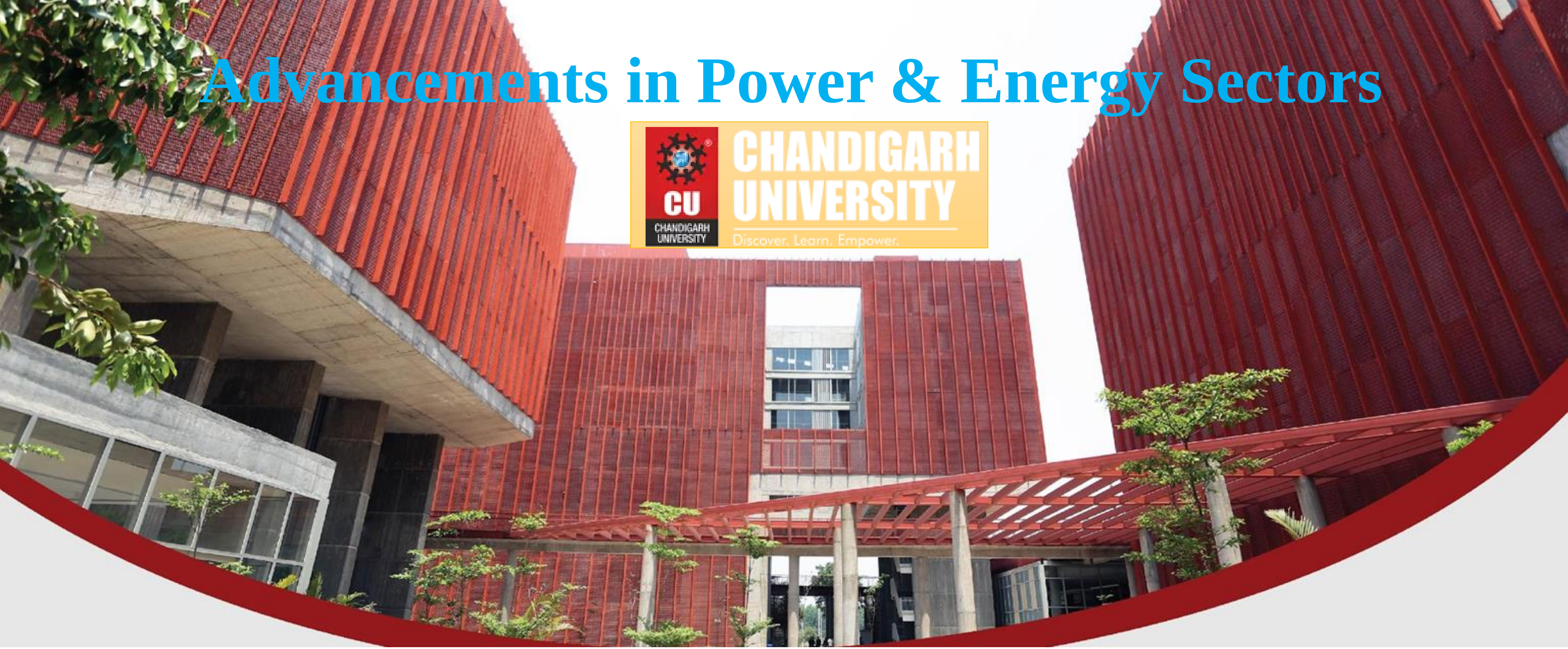
Advancements in Power & Energy Sectors



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IAS-PES SBC TIET, INDIA

IEEE Advancing Technology for Humanity

Presented By:

Dr. Rajesh M. Pindoriya

IEEE IAS Chapter Area Chair,
R10 East and South Asia,
rajeshpindoriya@ieee.org

IAS IEEE INDUSTRY APPLICATIONS SOCIETY Linking Research to Practice

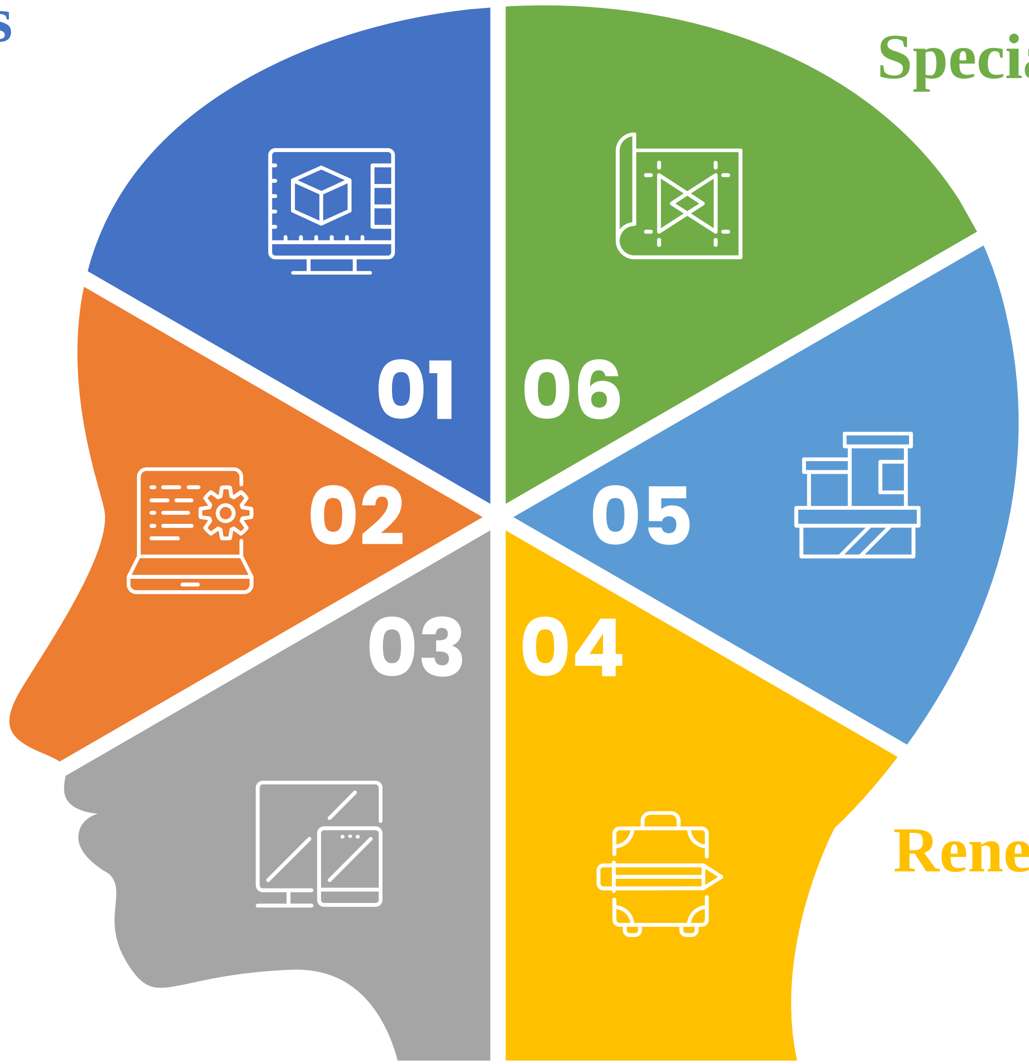
IEEE PES Power & Energy Society

Research Domain

Power Electronics
&
Electrical Drives

Electric Vehicles (EVs),
Hybrid EVs
&
Green Hydrogen EVs

Acoustic Noise
&
Vibration of
Electric Machines



Special Electrical Motors
PMSM, BLDC
SRM, SynRM

Condition Monitoring
&
Fault Diagnosis

Renewable Energy Resources
Solar and Wind

Speaker Biodata

Dr. Rajesh M. Pindoriya (GM’14 - M’20 – SM’22) received a B. Tech degree in Electrical and Electronics Engineering from Rajasthan Technical University Kota, Rajasthan, India in 2012 and M. E. in Power Electronics and Electrical Drives from Gujarat Technological University, Ahmedabad, Gujarat, India in 2014. He received a Ph.D. degree in Power Electronics and Electrical Drives from the Indian Institute of Technology Mandi (IIT Mandi), India, in 2020. He worked as a Project Engineer at IIT Mandi, India from Aug. 2020 to Jun. 2022. He is currently working as an Assistant Professor in the Department of Electrical and Instrumentation Engineering at Thapar Institute of Engineering & Technology (TIET), Patiala, Punjab, India.

His present interests and expertise are being inclined (but not limited) to, controlling special electrical motors such as Permanent Magnet Synchronous Motor (PMSM), Brushless Direct Current (BLDC) motor, Switched Reluctance Motor (SRM) and Synchronous Reluctance Motor (SynRM) drives for the application in Electric Vehicles (EVs) and Green Hydrogen Vehicles. He is also working on the design of novel power electronics modulation techniques for the reduction of acoustic noise and vibration of special electrical motors.

Dr. Pindoriya is a Chapter Area Chair of Region 10, East and South Asia. He is a founding chairperson and advisor of IEEE PELS, SIGHT Student Branch chapter IIT Mandi and IEEE IAS-PES Student Branch Chapter Thapar Institute of Engineering and Technology, Patiala, respectively. He is a currently mentor of the IEEE Student Branch IIT Mandi. He is a member and executive at large member of the PELS Student Subcommittee and PELS YP, respectively. Dr. Pindoriya is a Senior Member of IEEE, a Member of the Institution of Electronics and Telecommunication Engineers (IETE) (AM’17-M’21), and a Member of the Institution of Engineering (IE) (AM’17-M’21).

Outline

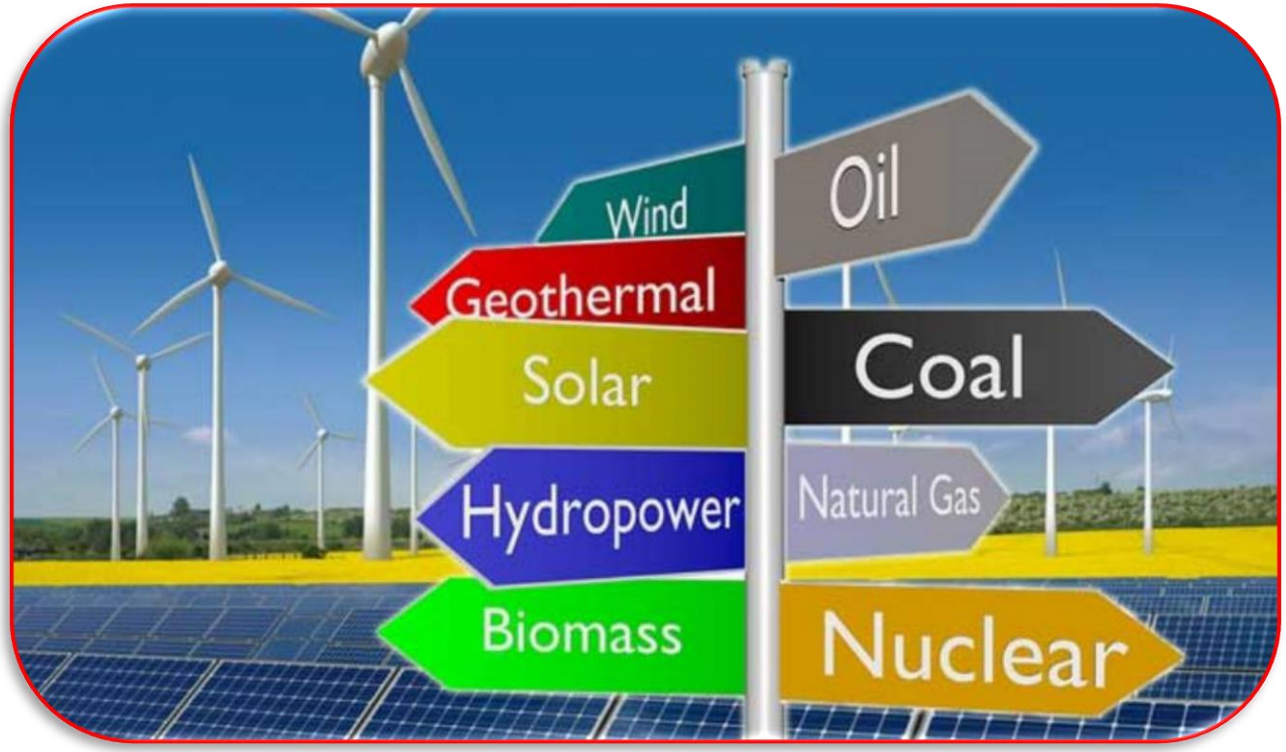
- Overview: Power and Energy Sectors
- Current Trends and Challenges in the Energy Sector
- Development in Power Electronics Technology
- Smart Grids and Energy Management
- Electric Vehicles and Sustainable Transportation
- Acoustic Noise and Vibration in EVs

Overview: Power and Energy Sector

- Power is the most critical component of infrastructure, crucial for nations' economic growth and welfare.

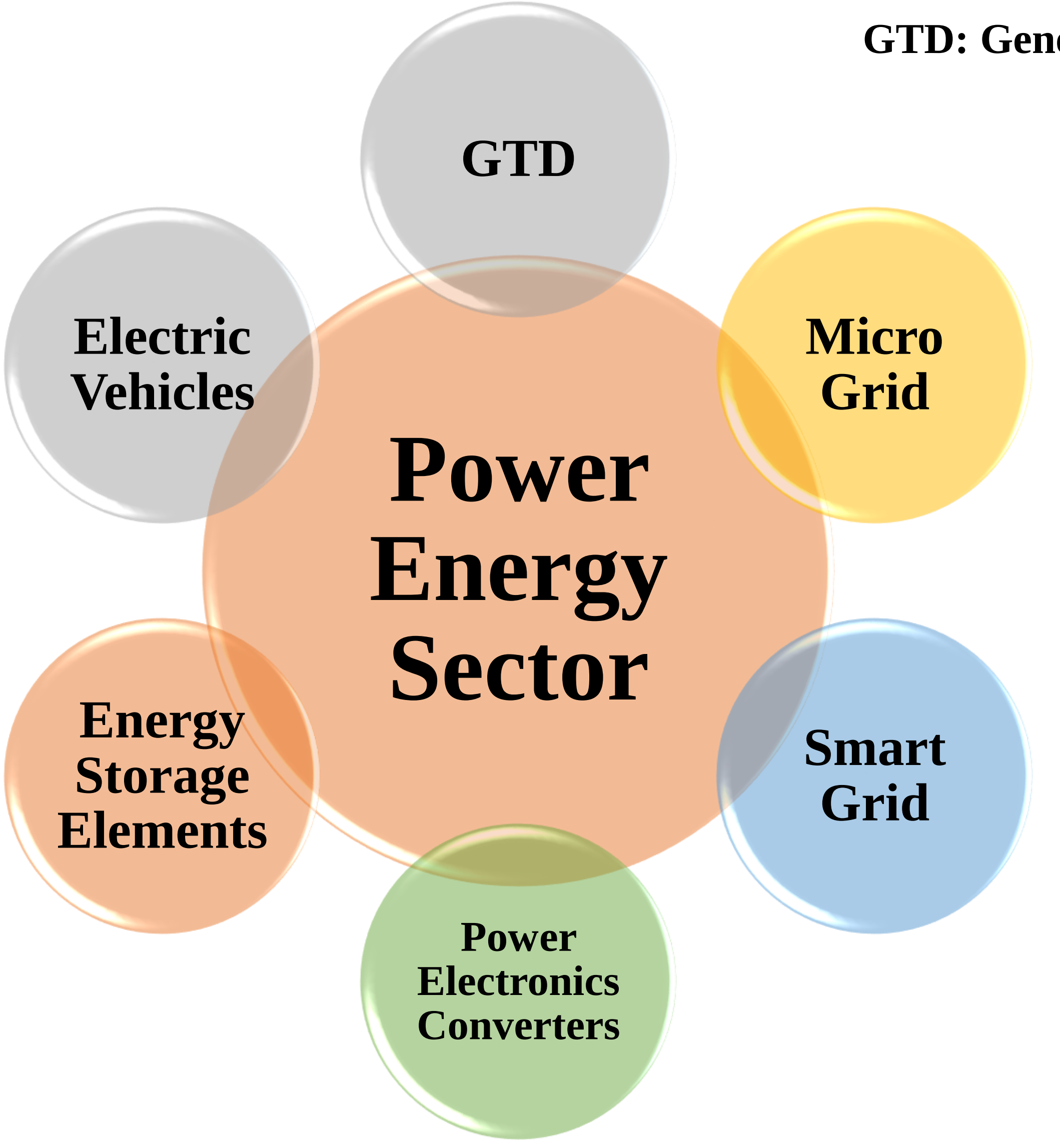
- India's power sector is one of the most diversified in the world. Sources of power generation range from conventional sources to viable non-conventional sources.

- Electricity demand in the country has increased rapidly and is expected to rise further in the future.

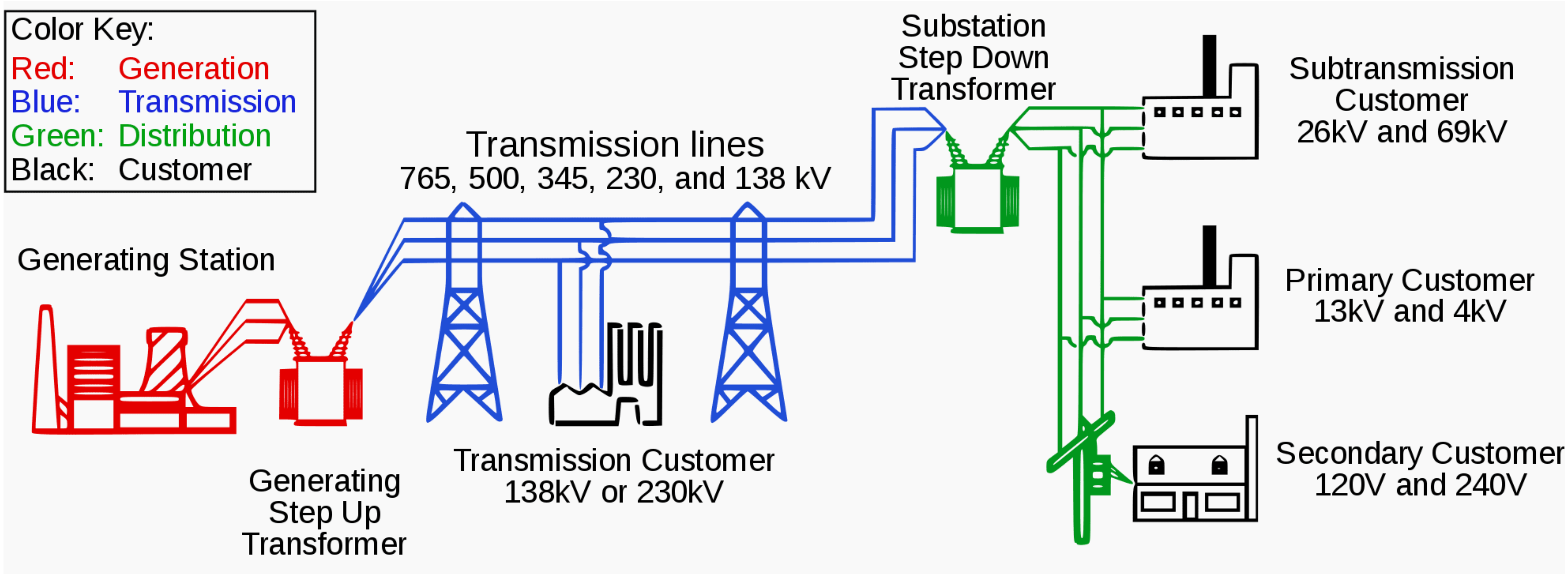


Overview: Power and Energy Sector

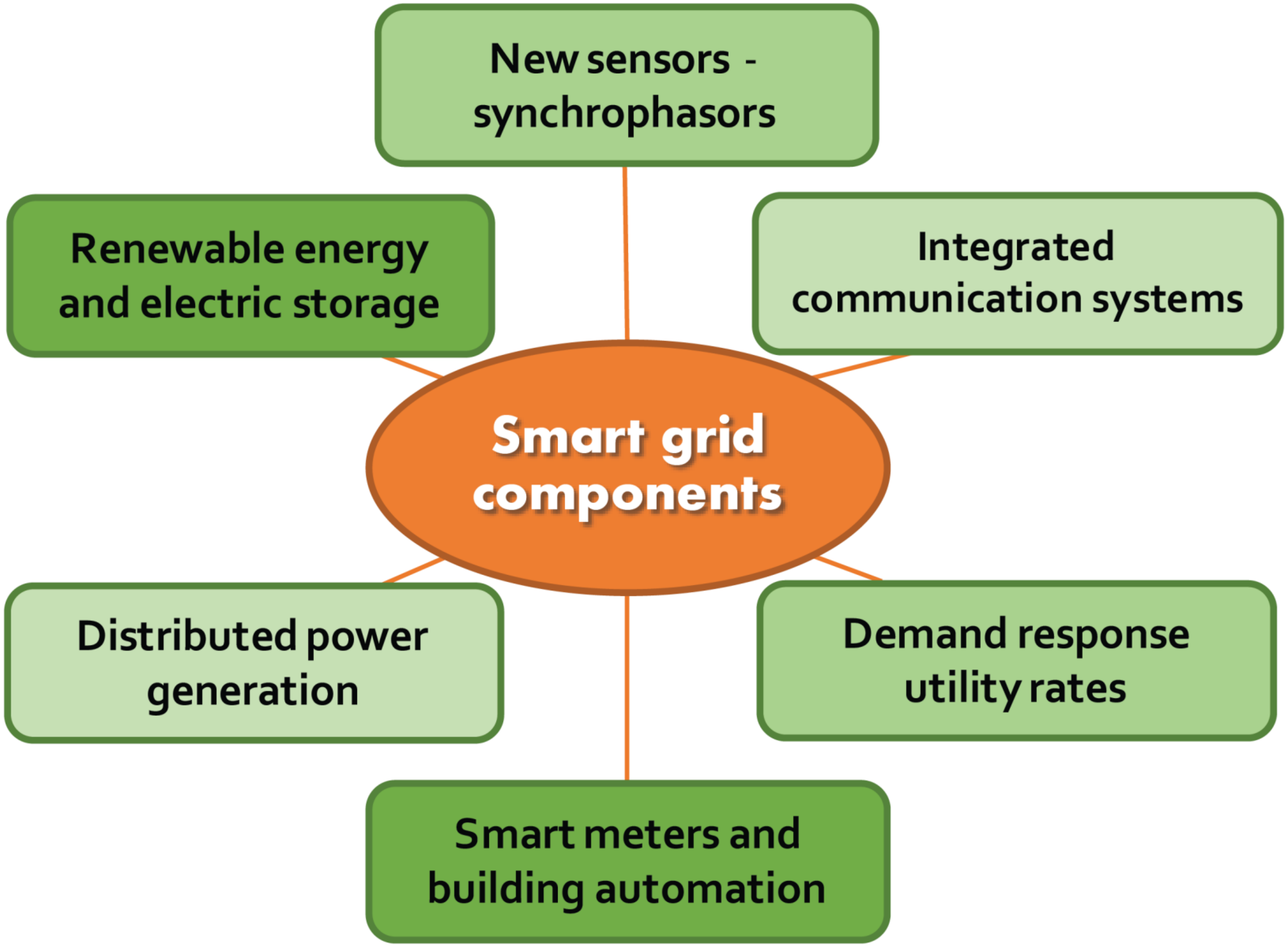
GTD: Generation, Transmission and Distribution



Power Generation, Transmission and Distribution System



Smart Grid Components

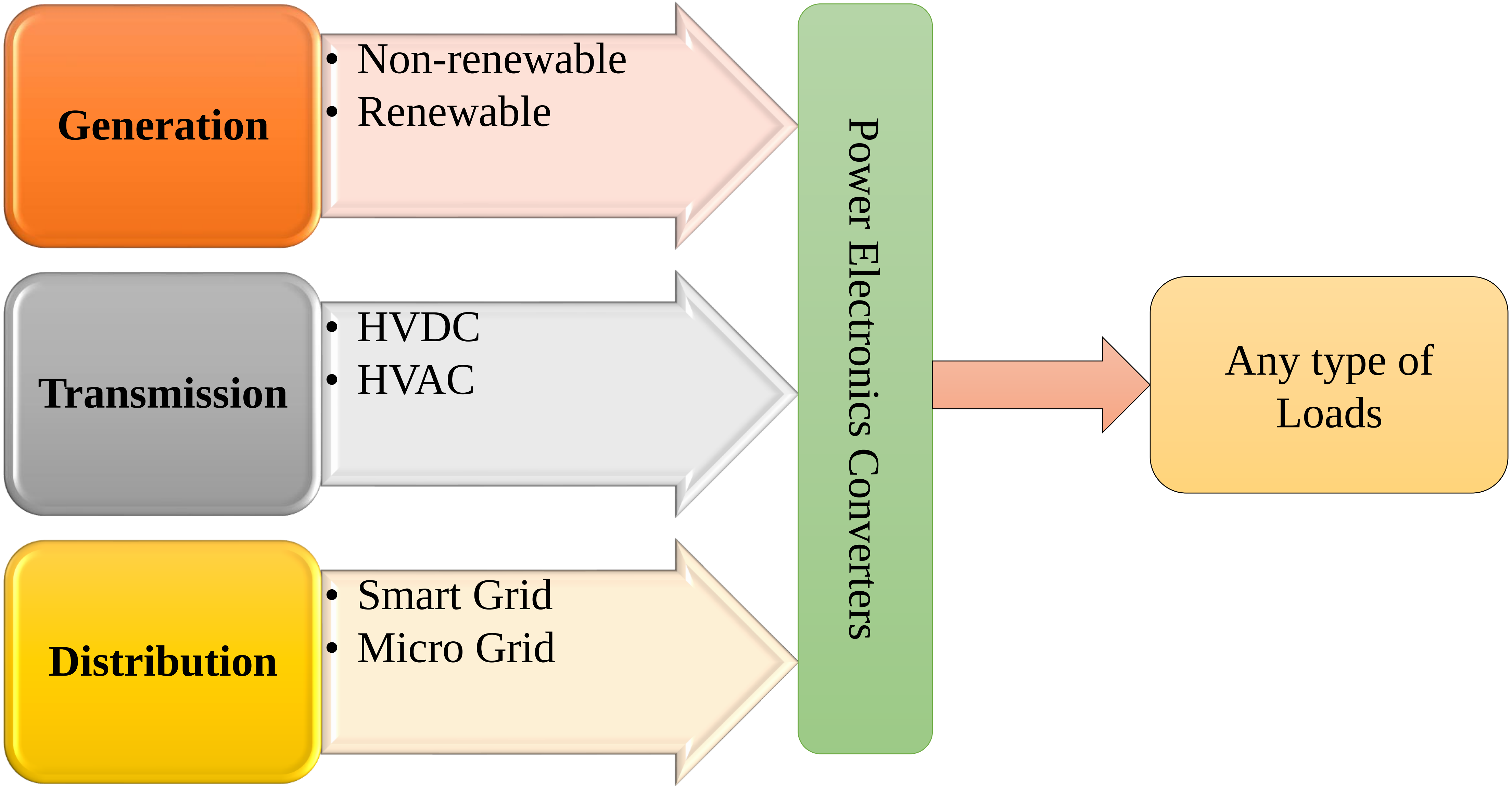


Net Zero Emissions

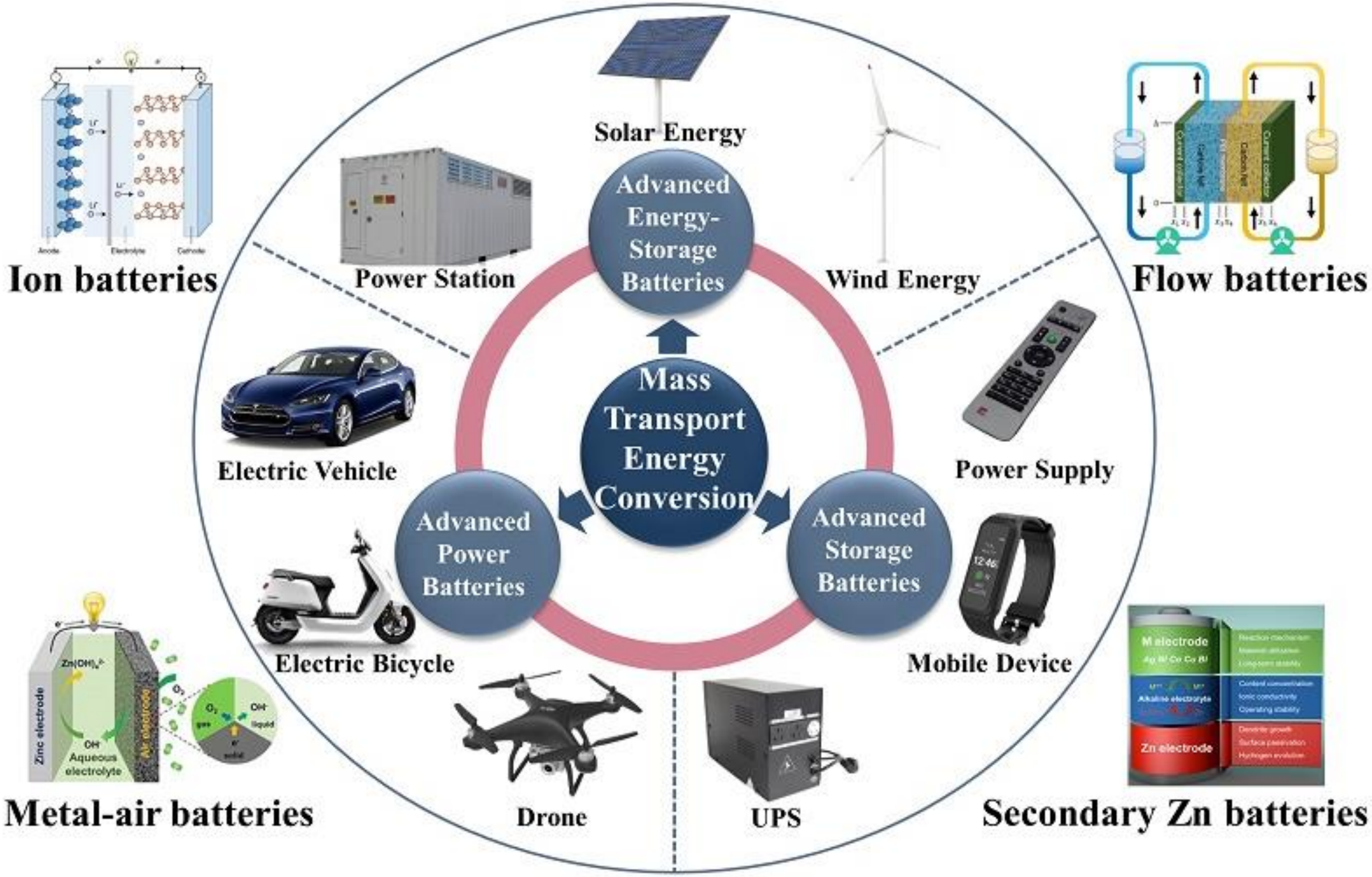
“Net zero emissions” refers to achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere.

Think of it like a set of scales: producing greenhouse gas emissions tips the scales, and we want to get those scales back into balance, which means no more greenhouse gas can be added to the atmosphere in any given year than is taken out.

Current Research Areas in the Power Sectors

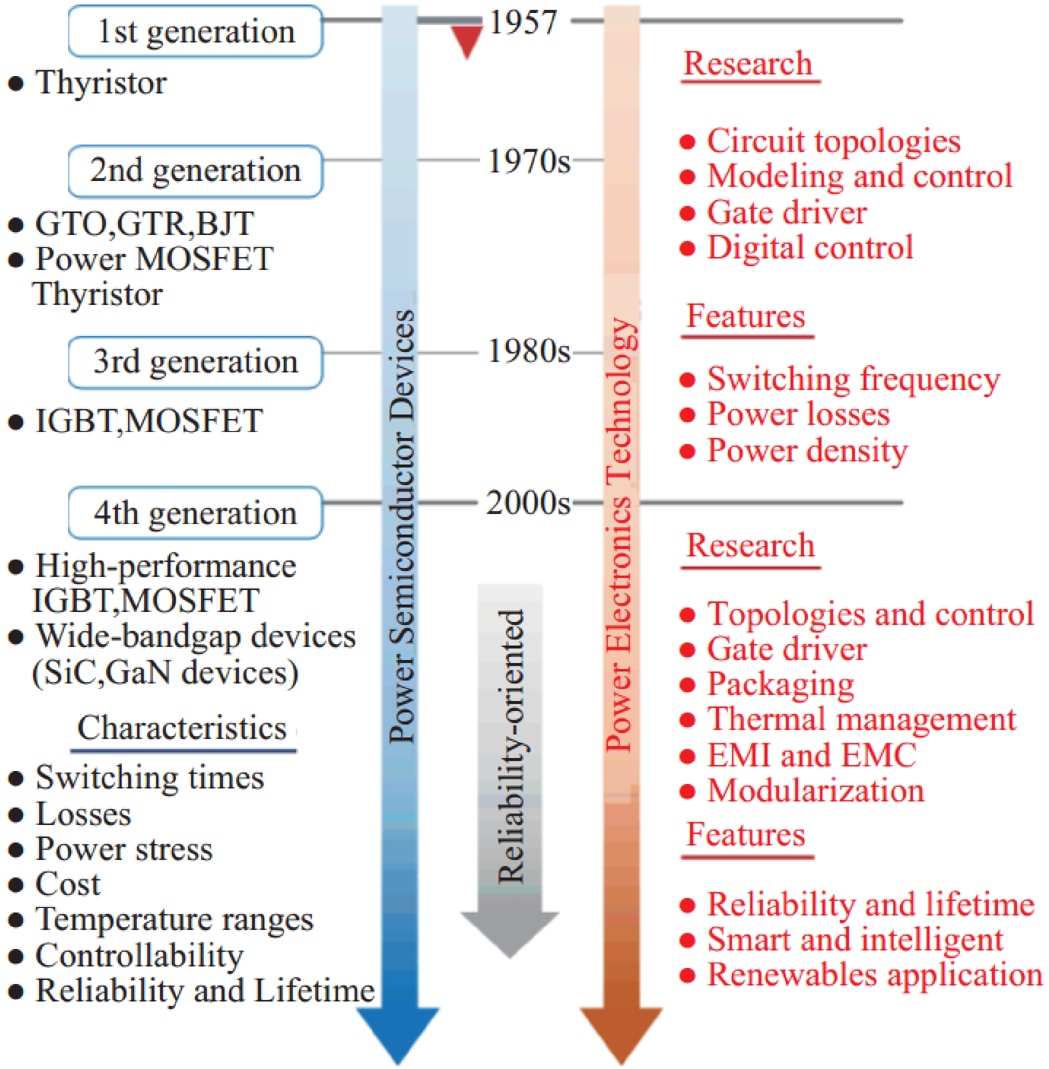


Mass Transport Energy Conversion



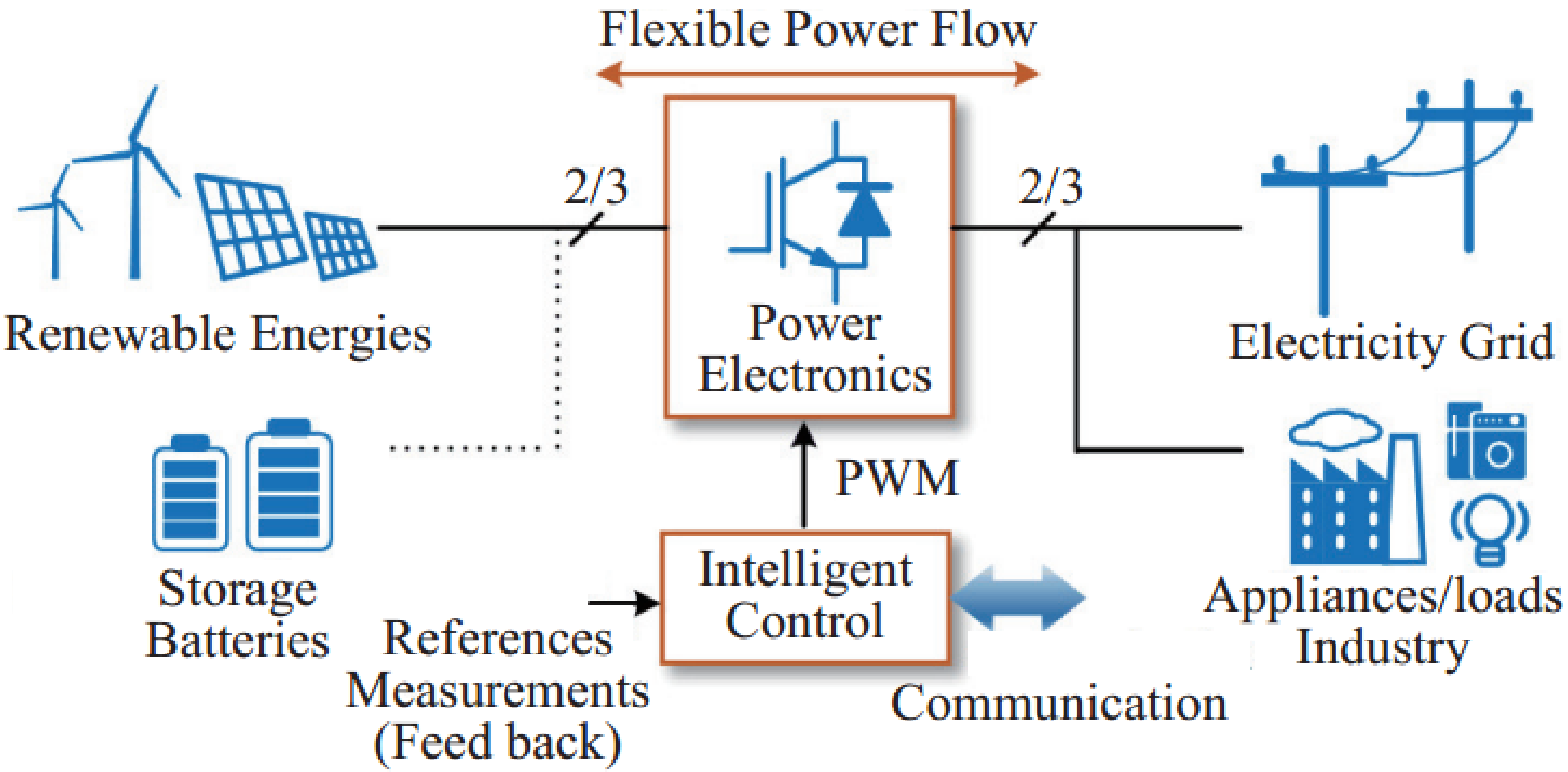
Development in Power Electronics Technology

Development in Power Electronics Technology



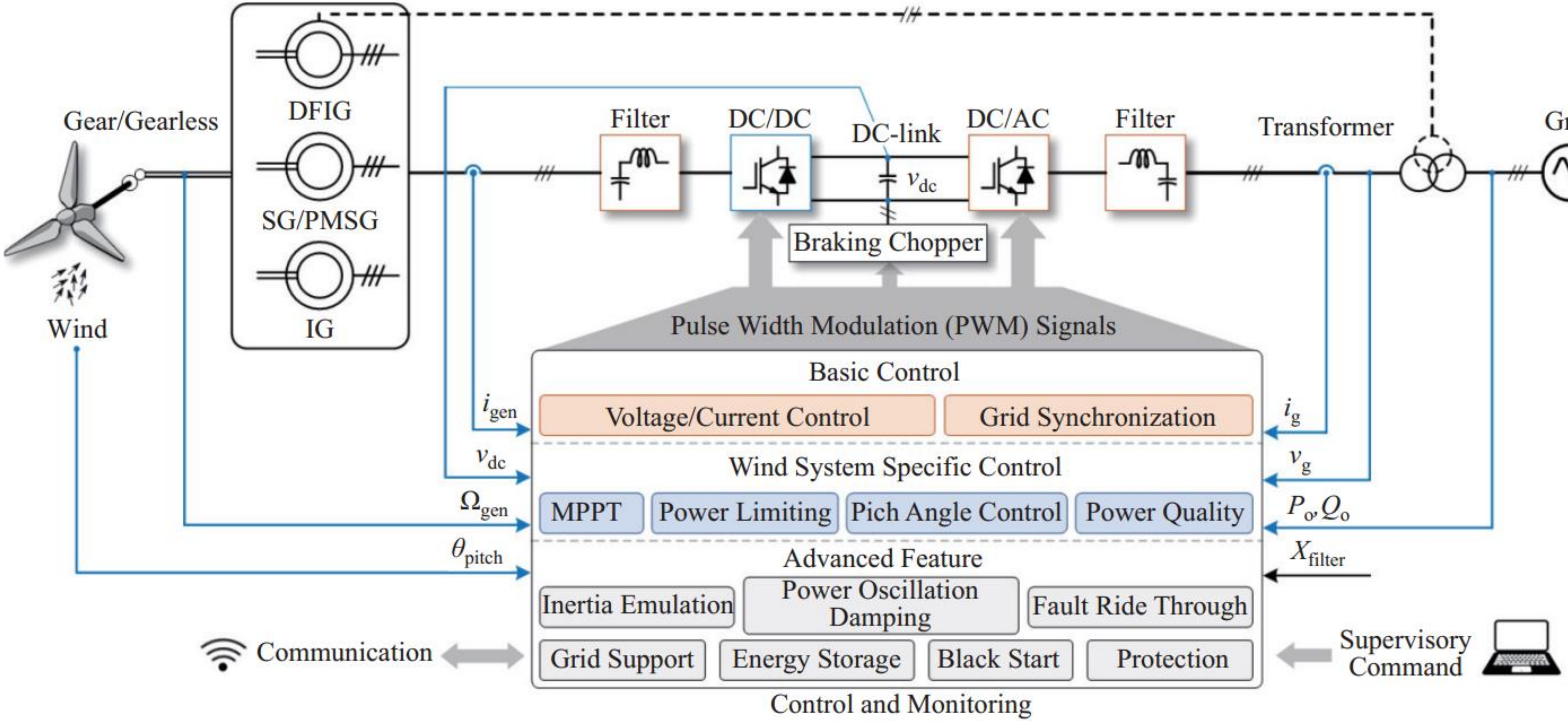
Z. Tang, Y. Yang and F. Blaabjerg, "Power electronics: The enabling technology for renewable energy integration," in CSEE Journal of Power and Energy Systems, vol. 8, no. 1, pp. 39-52, Jan. 2022

Configuration of a Typical Grid-Connected RES with Power Electronics Converters



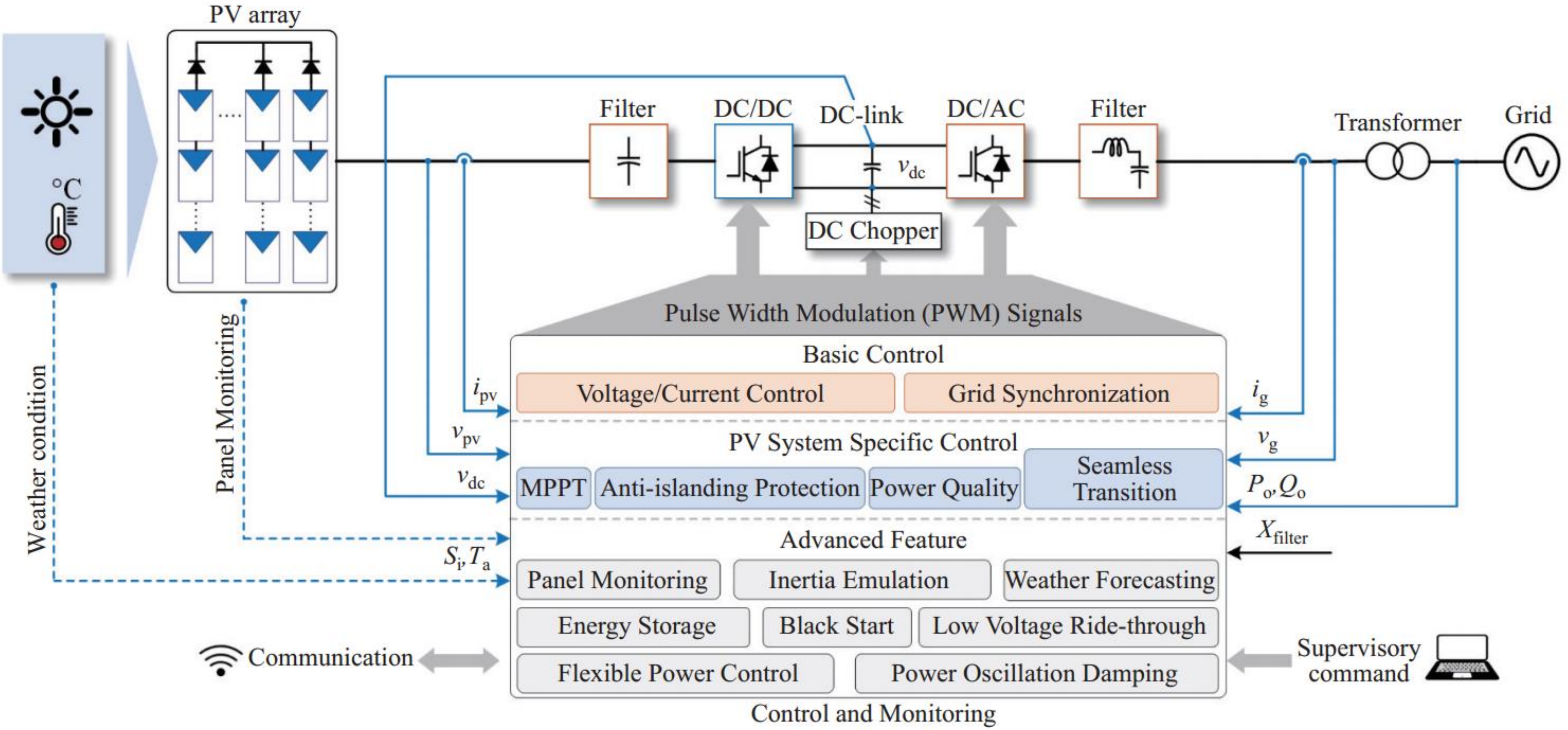
Z. Tang, Y. Yang and F. Blaabjerg, "Power electronics: The enabling technology for renewable energy integration," in CSEE Journal of Power and Energy Systems, vol. 8, no. 1, pp. 39-52, Jan. 2022

General Control Structure for Wind Power Systems



Z. Tang, Y. Yang and F. Blaabjerg, "Power electronics: The enabling technology for renewable energy integration," in CSEE Journal of Power and Energy Systems, vol. 8, no. 1, pp. 39-52, Jan. 2022

General Control Structure for Grid-Connected PV Systems



Z. Tang, Y. Yang and F. Blaabjerg, "Power electronics: The enabling technology for renewable energy integration," in CSEE Journal of Power and Energy Systems, vol. 8, no. 1, pp. 39-52, Jan. 2022

Electric Drives and Electric Vehicles

What is an Electric Drives

Definition of electric drive

- “Systems employed for motion control are called **drives**”
- “Drives employing electric motors are known as **electrical drives**”

Why its required

- To control the speed and torque of the electric motors

Applications of electric drives

Electric Vehicles

Celling fan

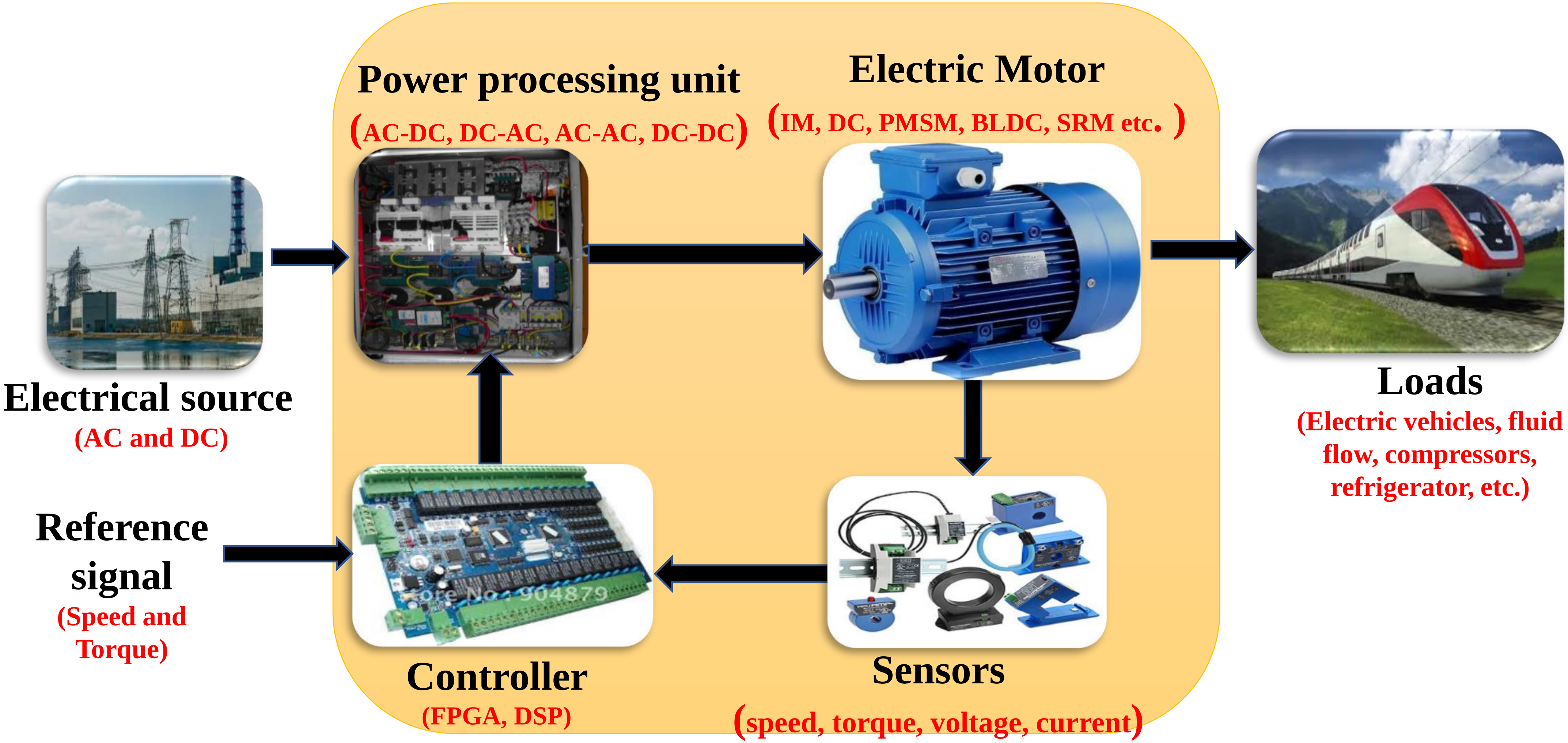
Refrigerator

Lift

Vacuumed cleaner

Ship

Introduction: Electric Drives



Introduction: Electric Vehicles

- Transport is a fundamental requirement of modern life, but **traditional Internal combustion (IC) engines are quickly becoming outdated.**

- Petrol or diesel vehicles are highly polluting and are being quickly replaced by fully Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) (see Fig. 1).

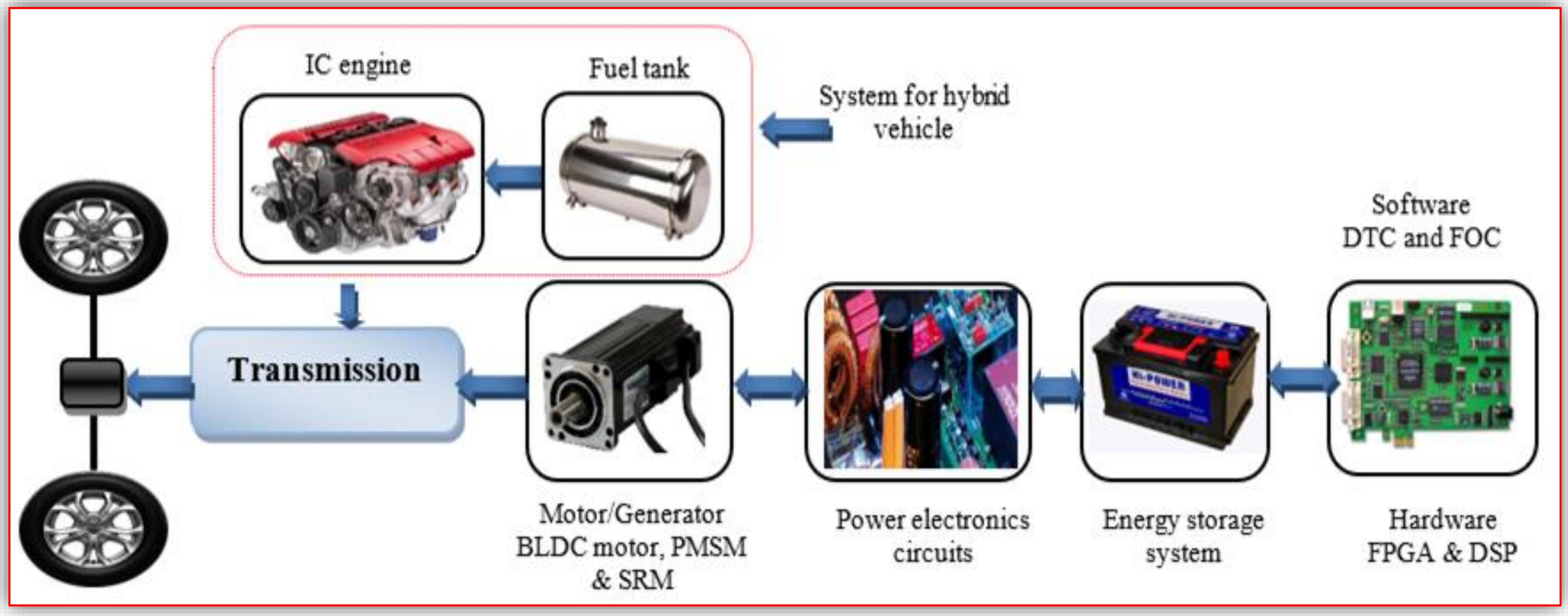
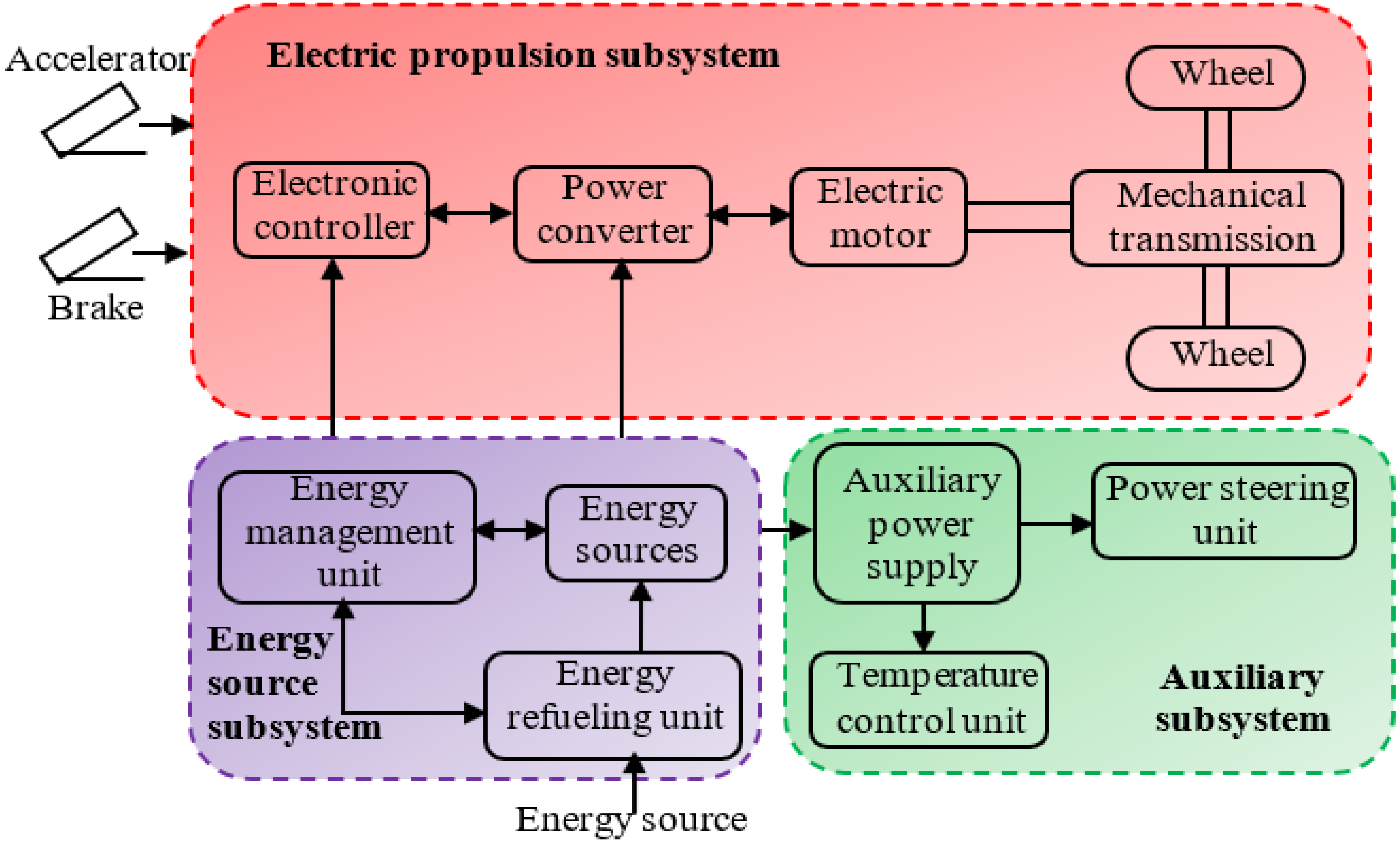


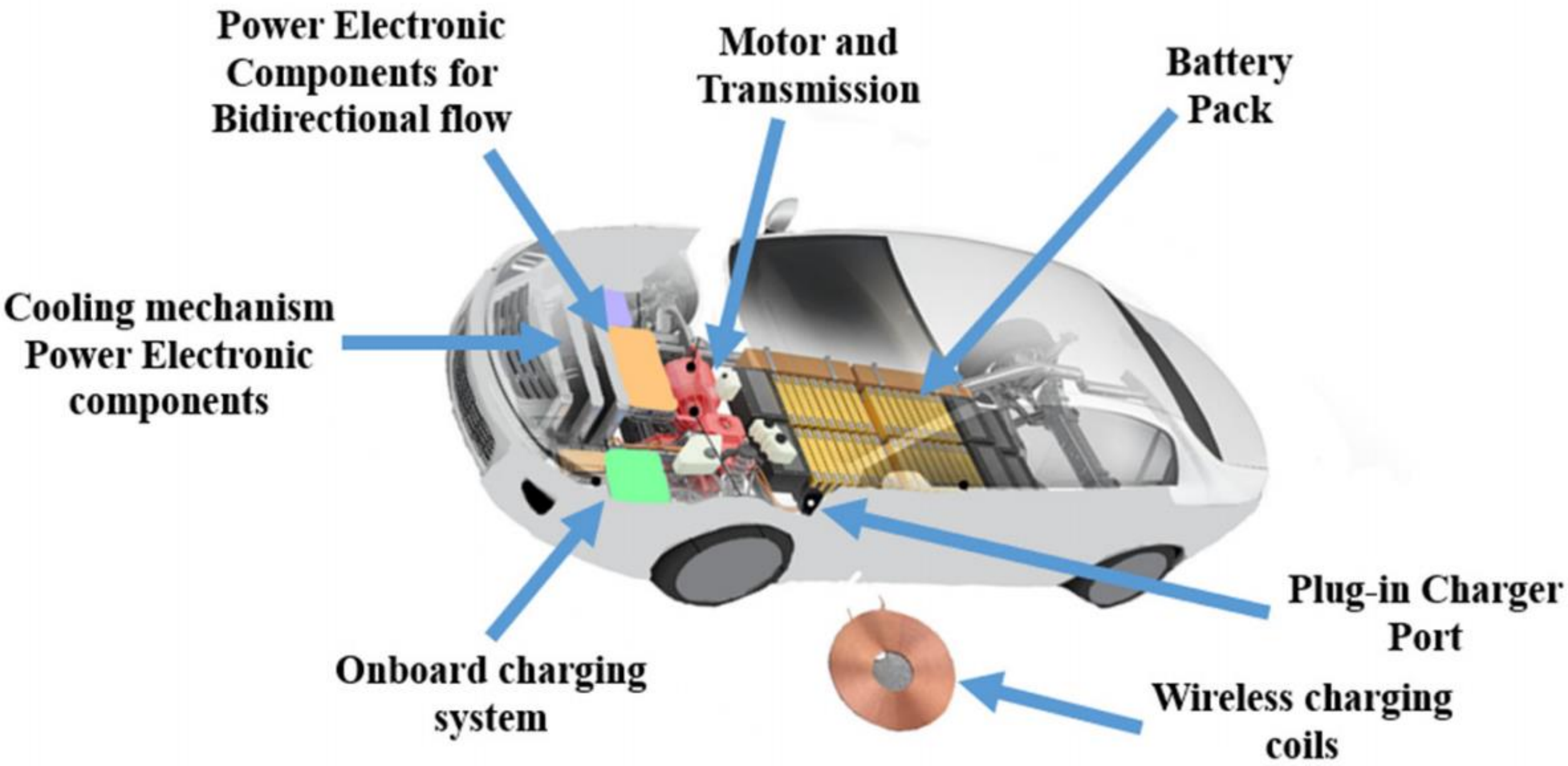
Fig. 1. A schematic layout of EVs and HEVs.

Components of Electric Vehicles



1. C. C. Chan, “The State of the Art of Electric and Hybrid Vehicles.” Proc. IEEE 2002, 90, 247–275, 2002.

Conceptual EV structure and components



Benefits of Electric Vehicles

Lower running costs

Low maintenance cost

Petrol and diesel use is destroying our planet

Tax and financial benefits

No noise pollution

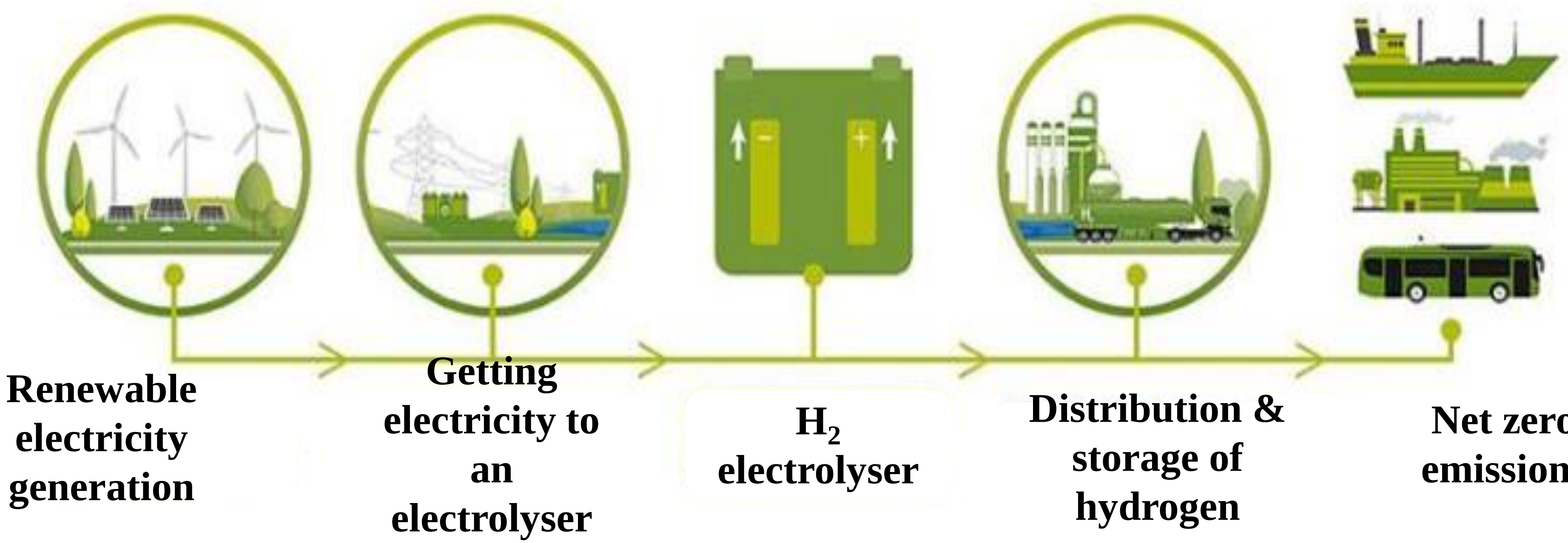
Issues with Battery Operated Vehicles

1. Size of the Battery
2. Charging Time of the Battery
3. Not Possible to Long Drive

Introduction: Green Hydrogen Technology

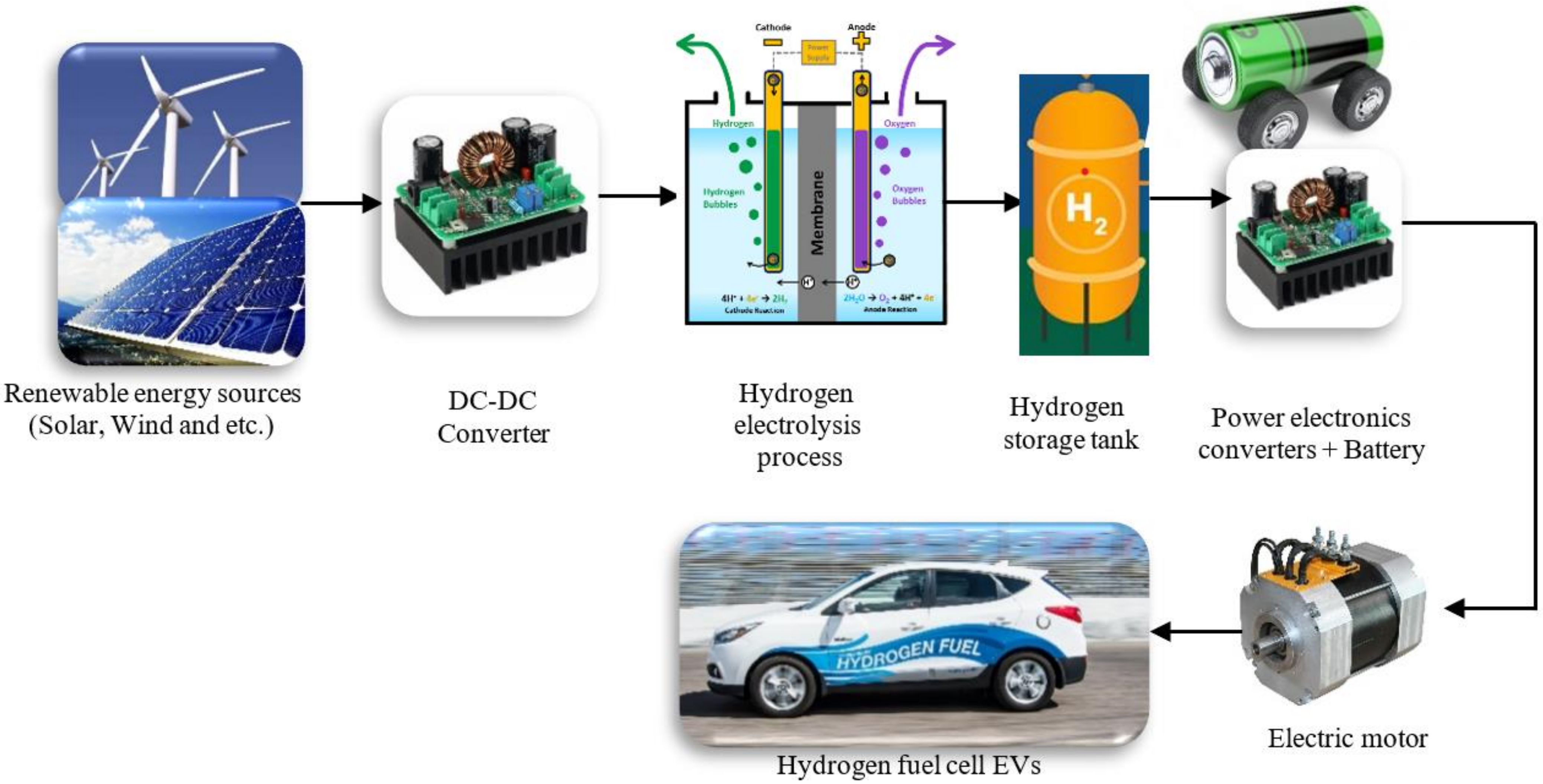
- Green hydrogen is **hydrogen that is generated by renewable energy or from low-carbon power**.

- Green hydrogen has significantly lower carbon emissions than grey hydrogen, which is produced by steam reforming of natural gas, which makes up the bulk of the hydrogen market.



Source: https://www.sciencedirect.com/science/article/pii/S036031991732791X

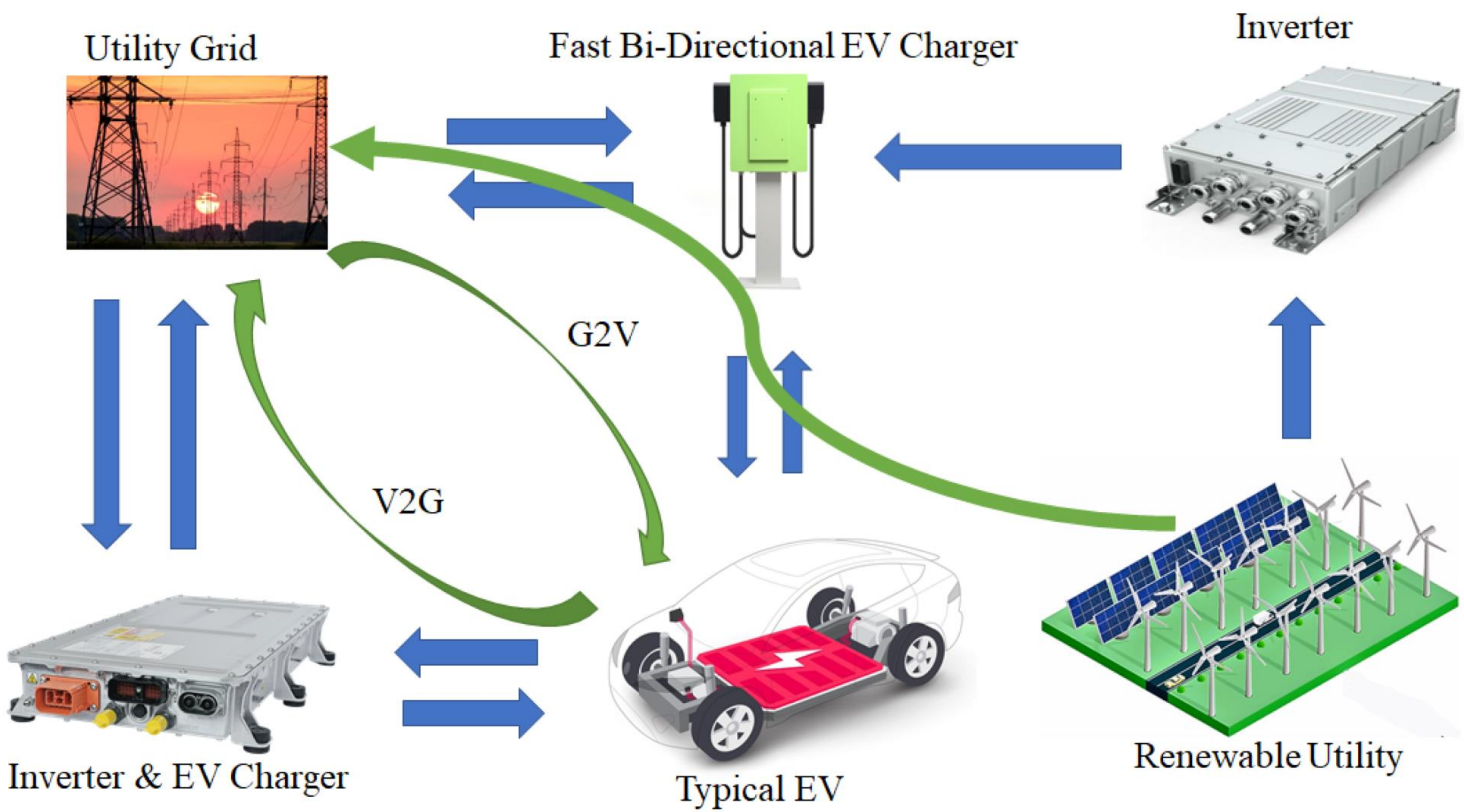
Schematic Layout of Powered by Hydrogen FCEVs



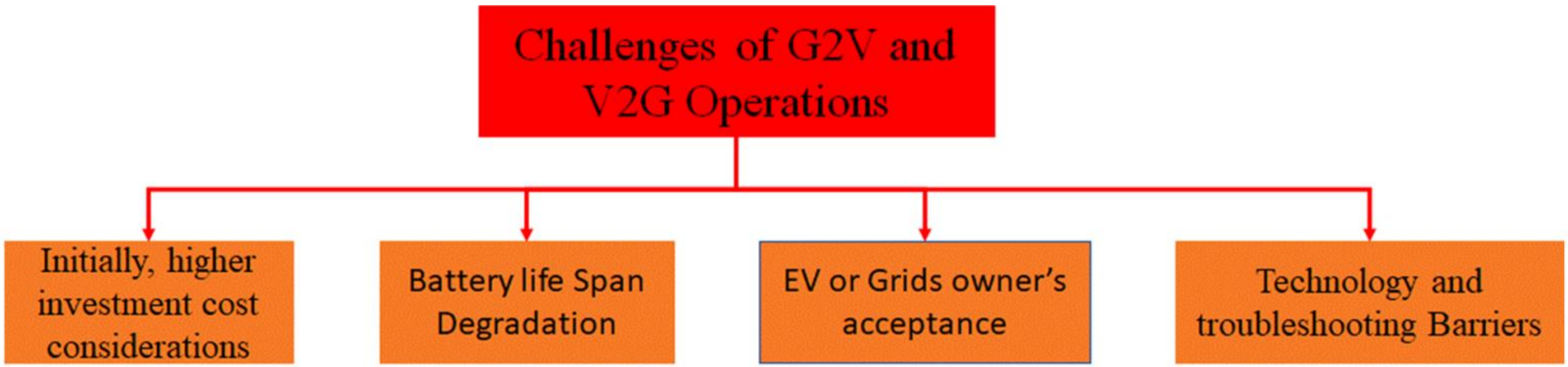
Major Trends and Future Developments

- Vehicles to Grid (V2G)
- Batter Charging Technologies
- Batter Battery Technologies
- Wireless Power Transfer
- Green Hydrogen Fuel

G2V and V2G Power Flows Block Diagram

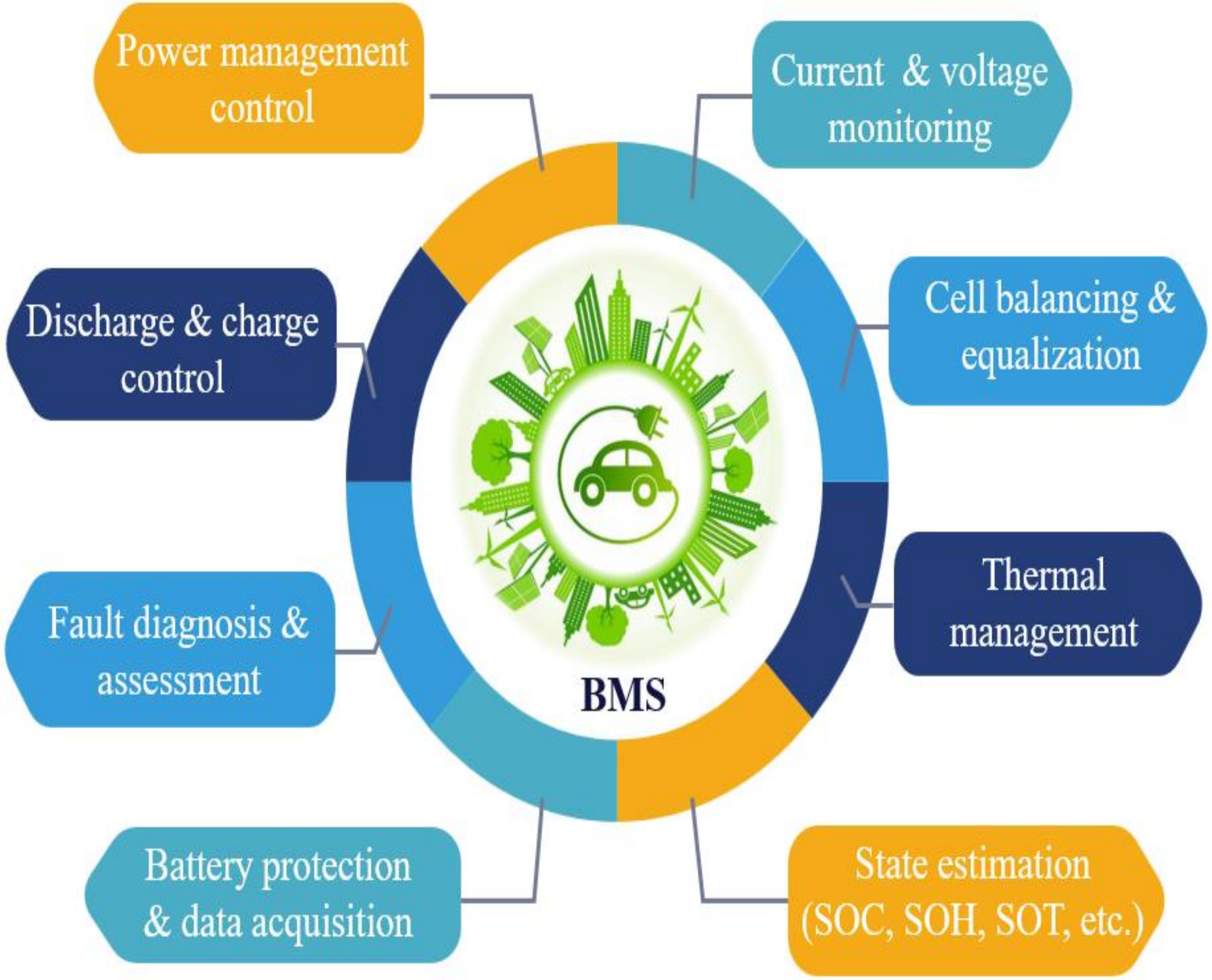


Challenged of G2V and V2G Operation

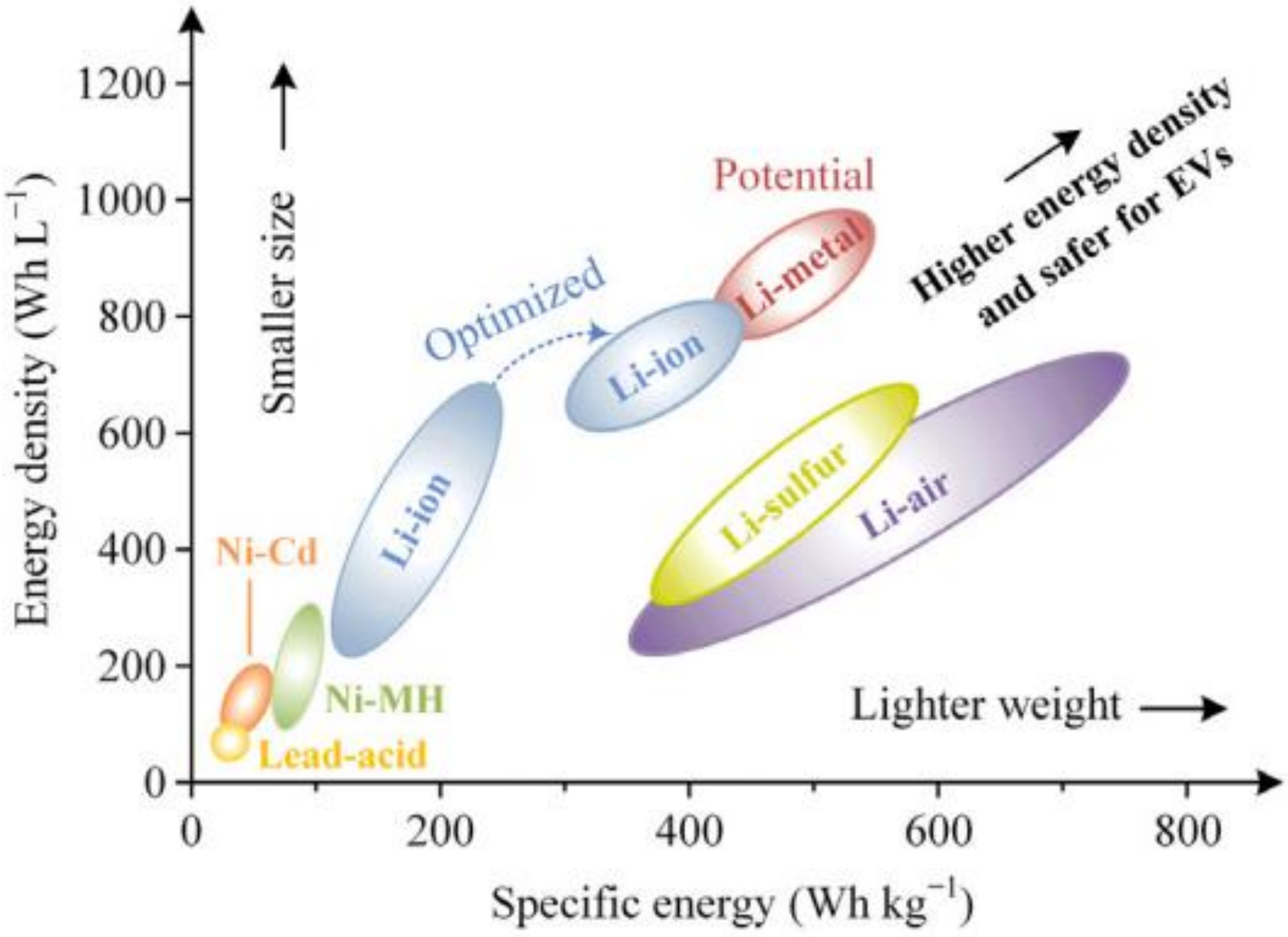


Battery Management System (BMS)

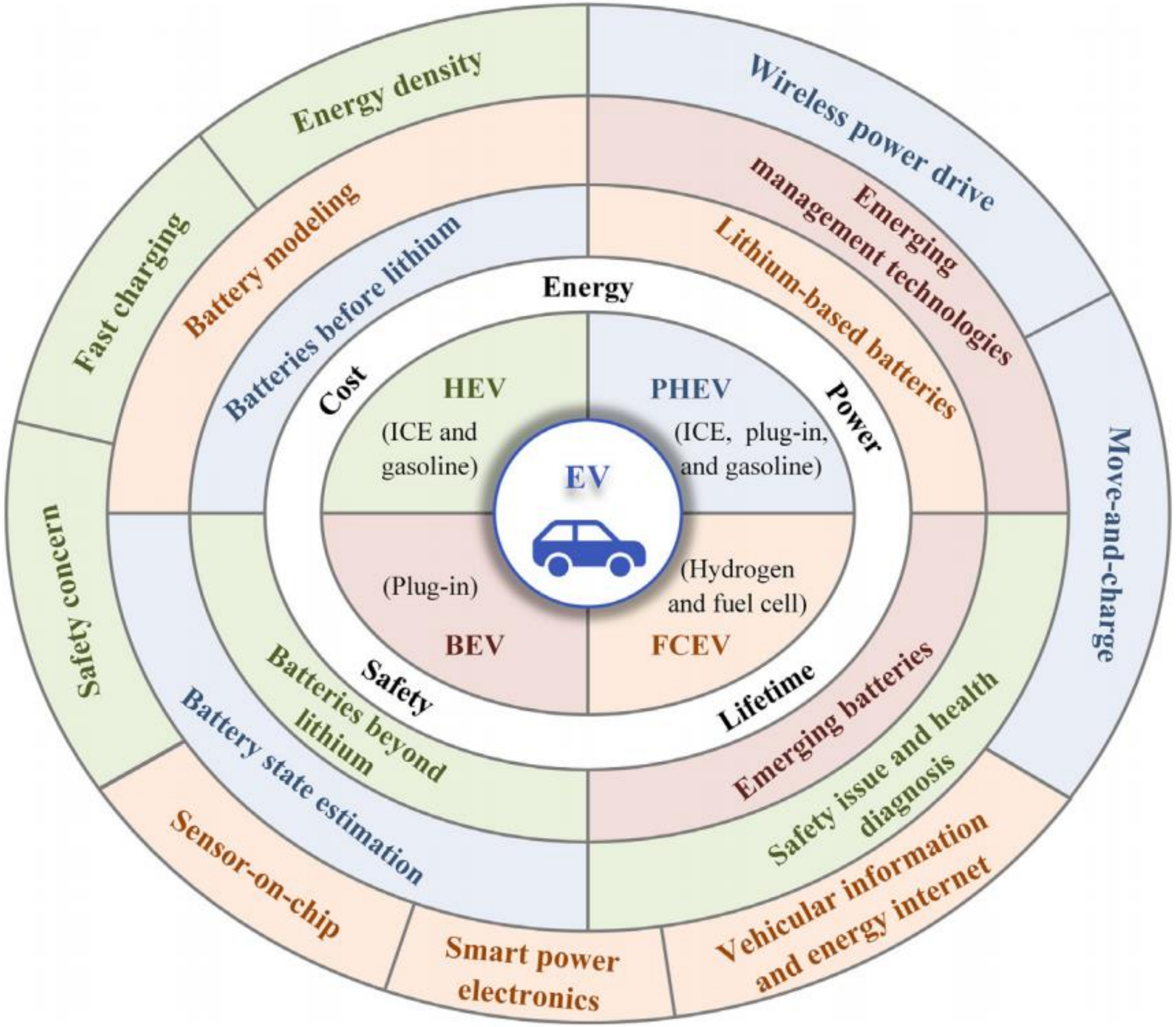
Battery Management System (BMS)



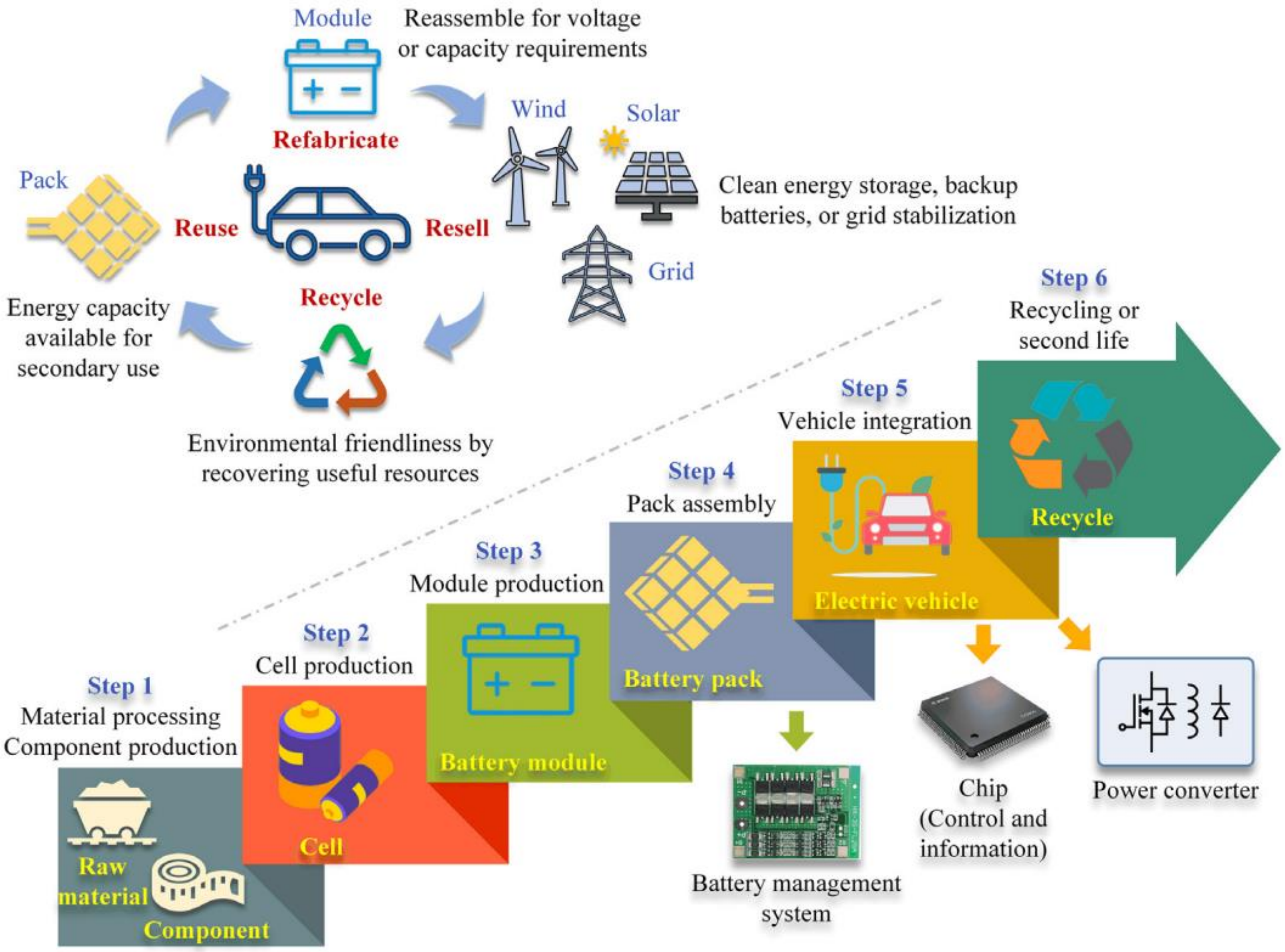
Comparison of Battery



Research Trends in EVs



Industrial value chain and circulation of rechargeable batteries for electric vehicle mobility



Acoustic Noise and Vibration in Electric Drives

Introduction: Acoustic Noise and Vibration in PMSM Drive

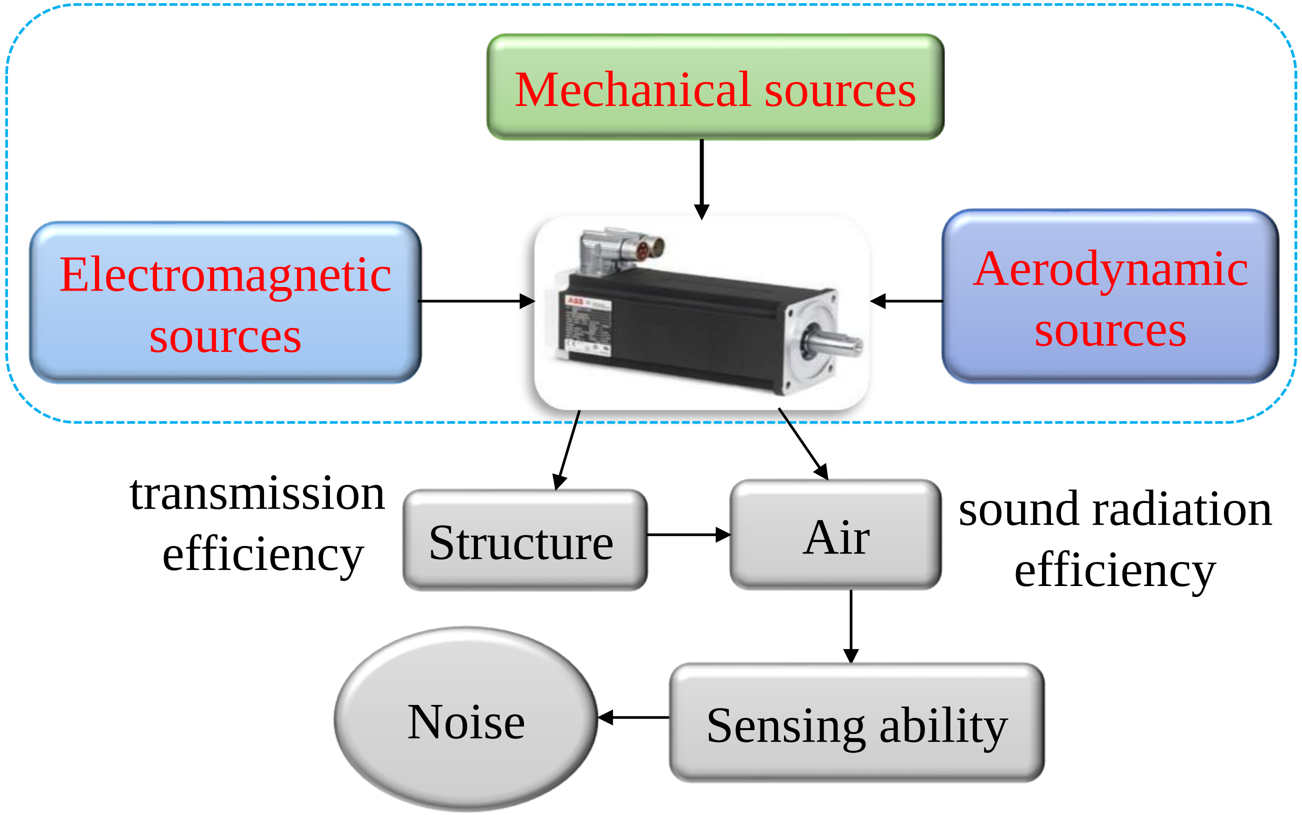


Fig. 1. Noise generation and propagation in electrical machines.

- Acoustic noise is an **audible sound which is undesirable.**
- Vibrations may be perceived **directly where they are transmitted to the body through.**

Source: J. F. Gieras, C. Wang and J. C.S. Lai, “Noise of Polyphase Electrical Motors”, *Taylor & Francis Group*, 2006.

A SPWM-based Vector Control Technique for PMSM Drive

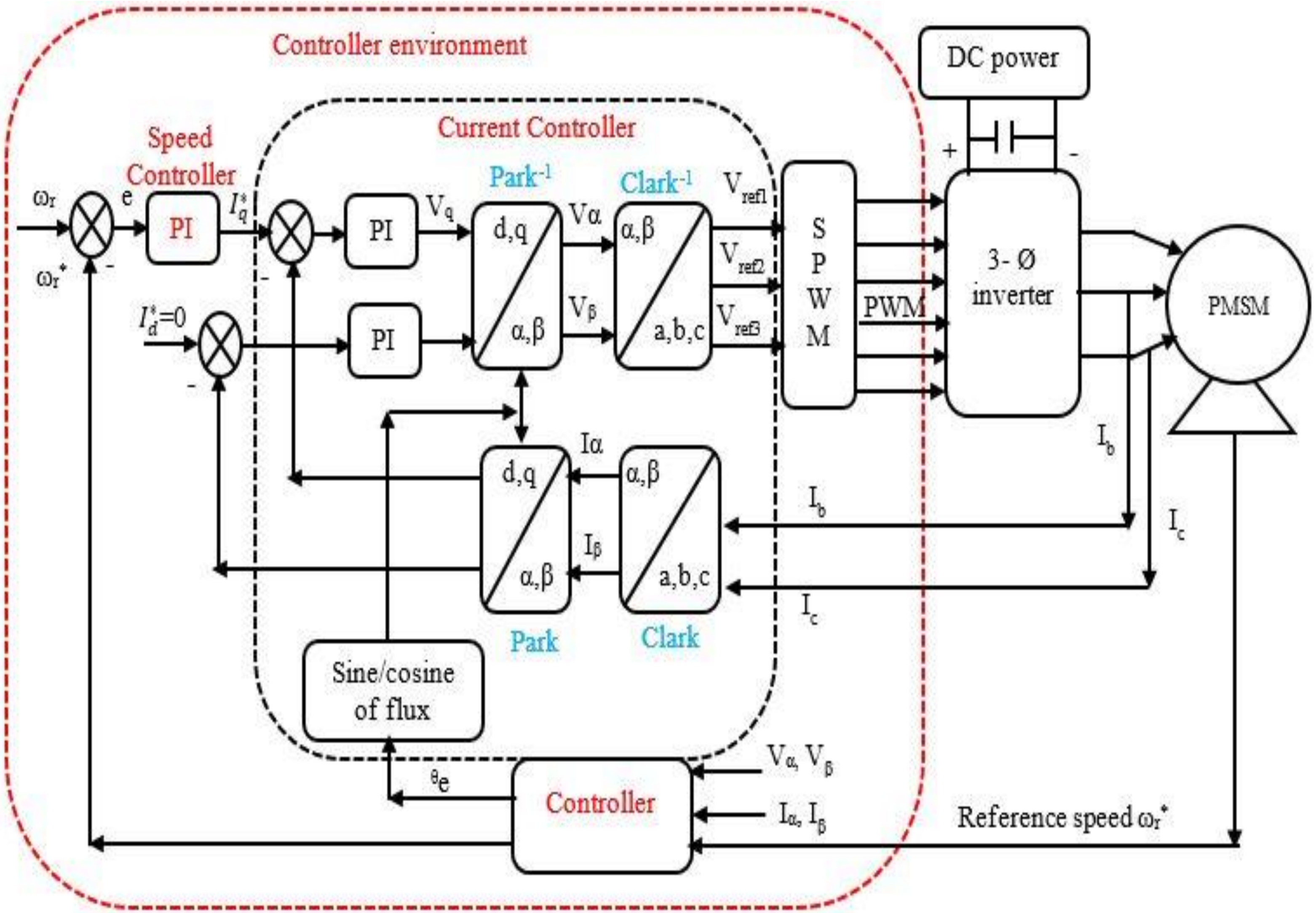


Fig. 2. A SPWM-based vector control design and control system for a PMSM drive.

An Experimental Setup of PMSM Drive

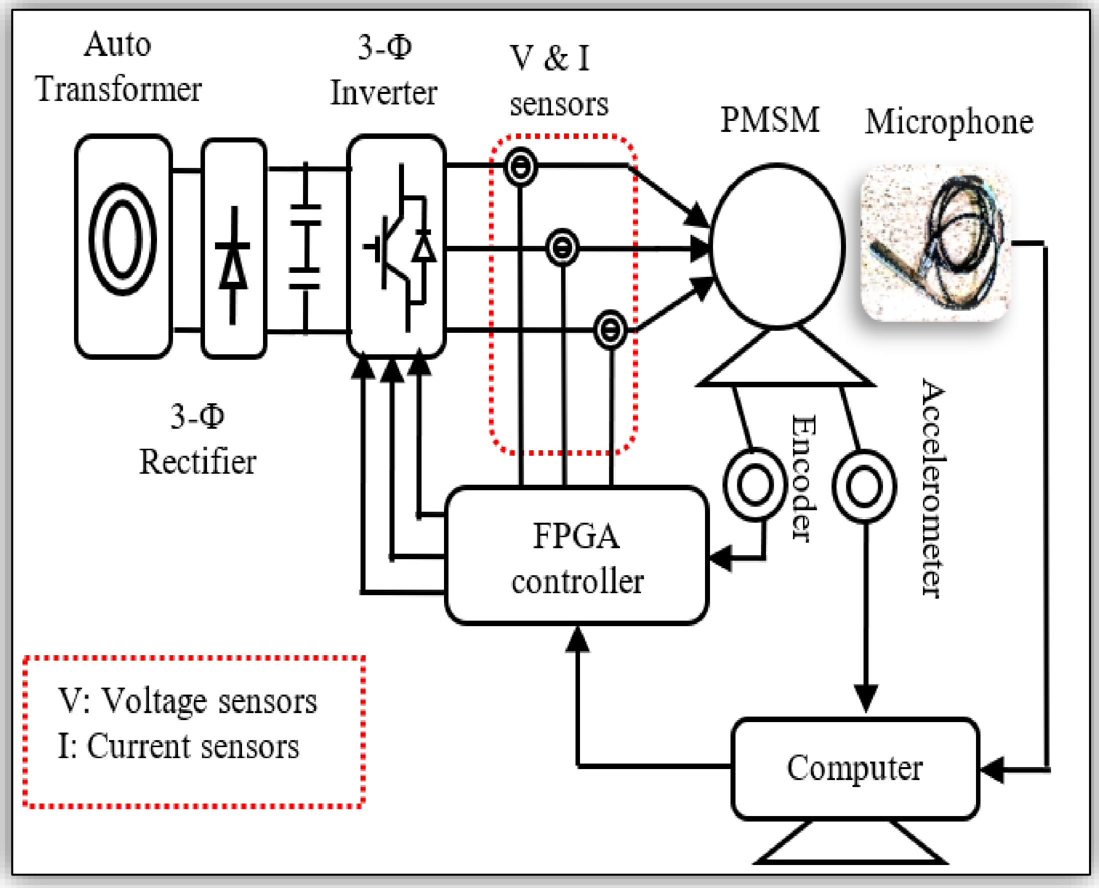


Fig. 3. Schematic diagram of experimental set-up.

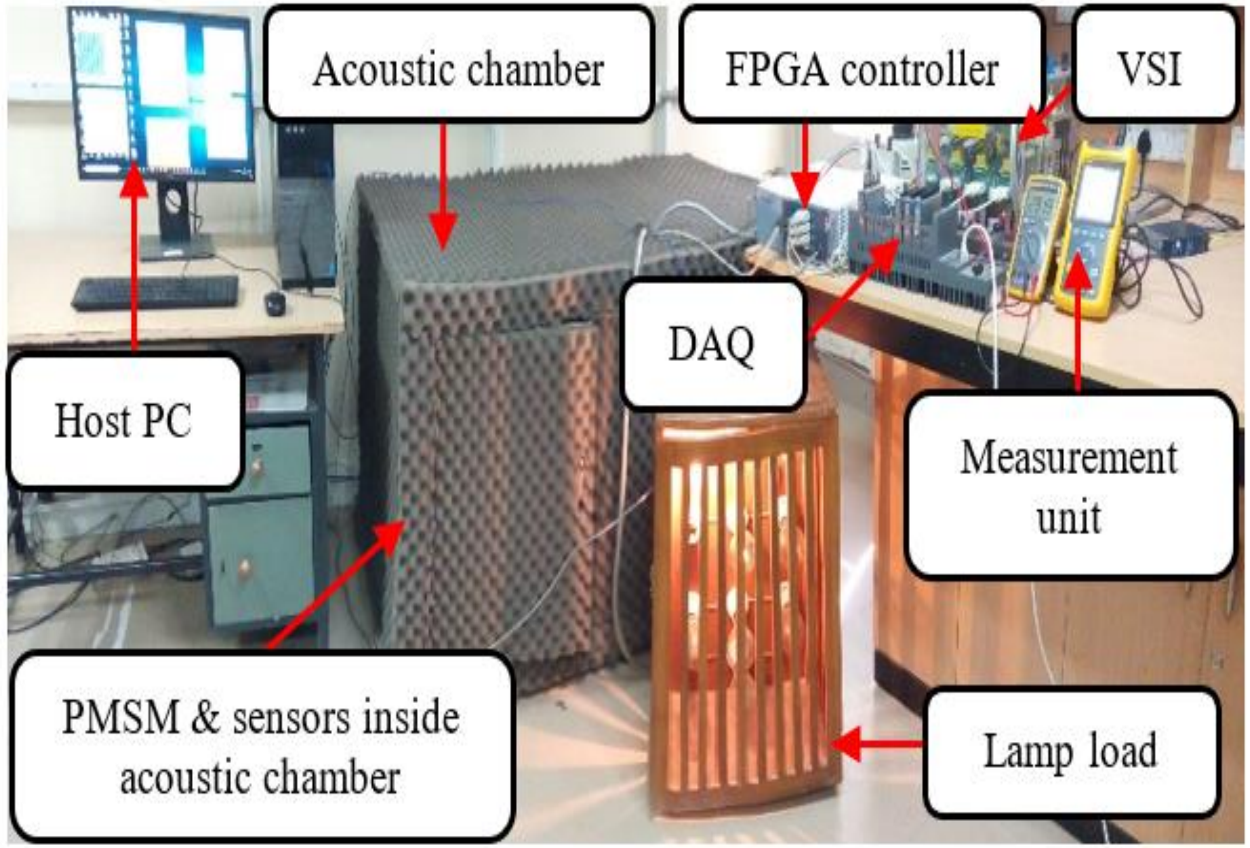
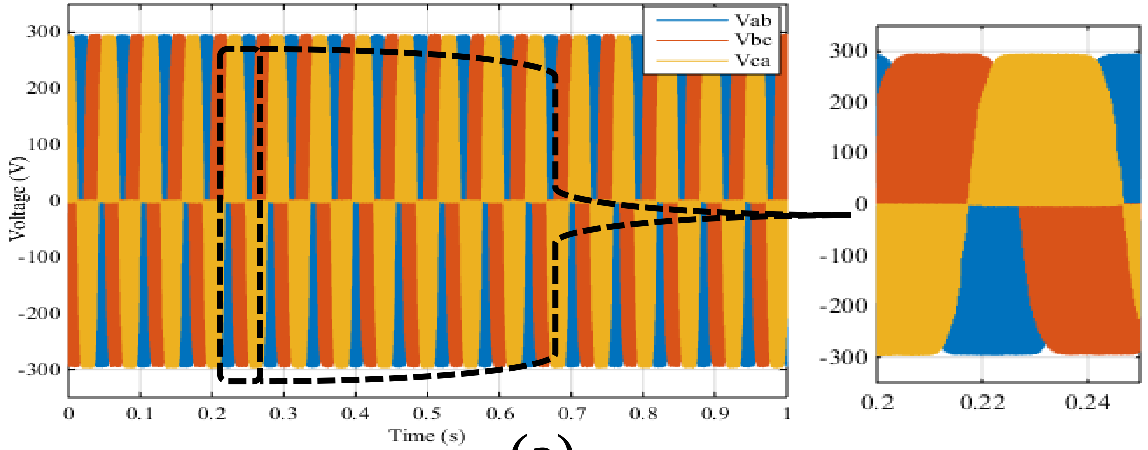
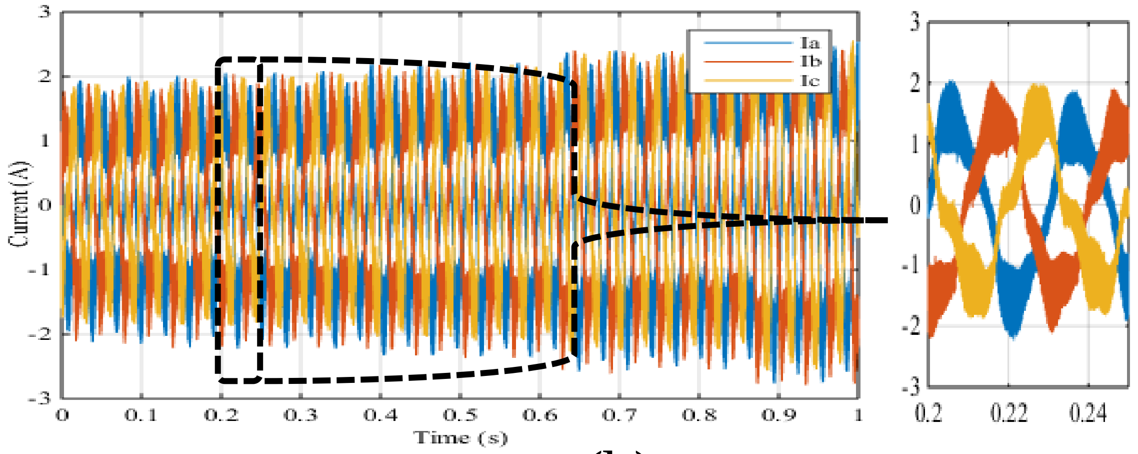


Fig. 4. An experimental set-up for an analysis of acoustic noise and vibration of PMSM drive.

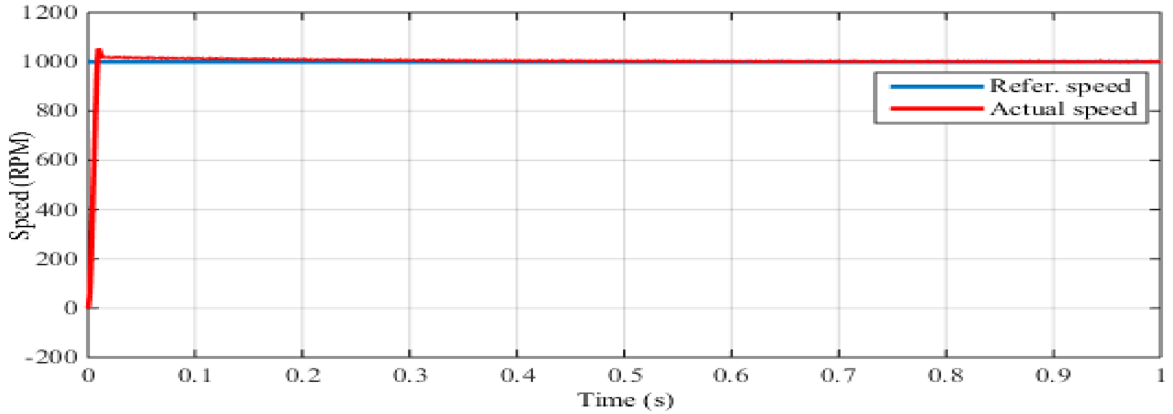
An Experimental: Results and Discussion



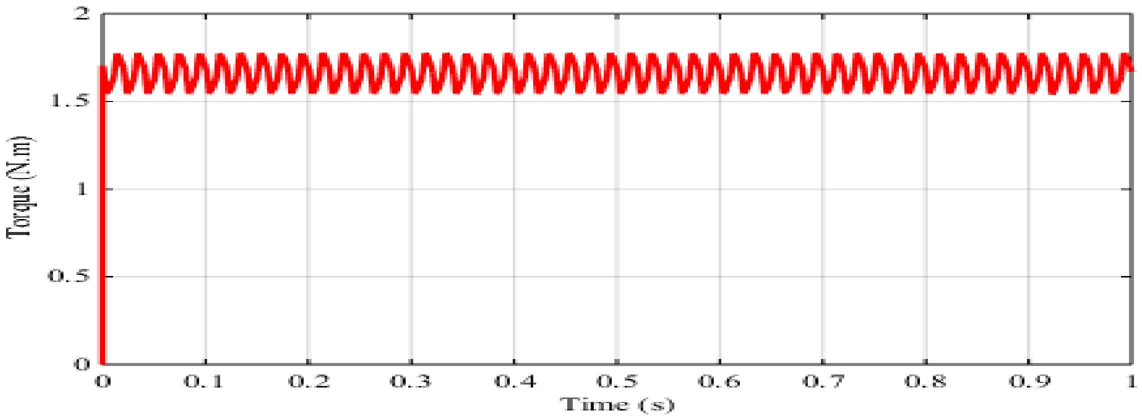
(a)



(b)



(c)



(d)

Fig. 5. Experimental results of sensored-based PMSM drive: (a) three-phase stator voltage and (b) three-phase stator current, (c) steady-state speed response and (d) steady-state torque response.

Introduction: Acoustic Chamber [1-2]

Why Acoustic chamber???

- Nowadays consumers demand more **smooth and silent devices**, whether it is a computer, power electronics gadget and etc.
- Therefore **testing of all devices one free-field enclosure** is required.
- It provides a **free-field environment**, which is nearly close to free from background noise and humming noise.

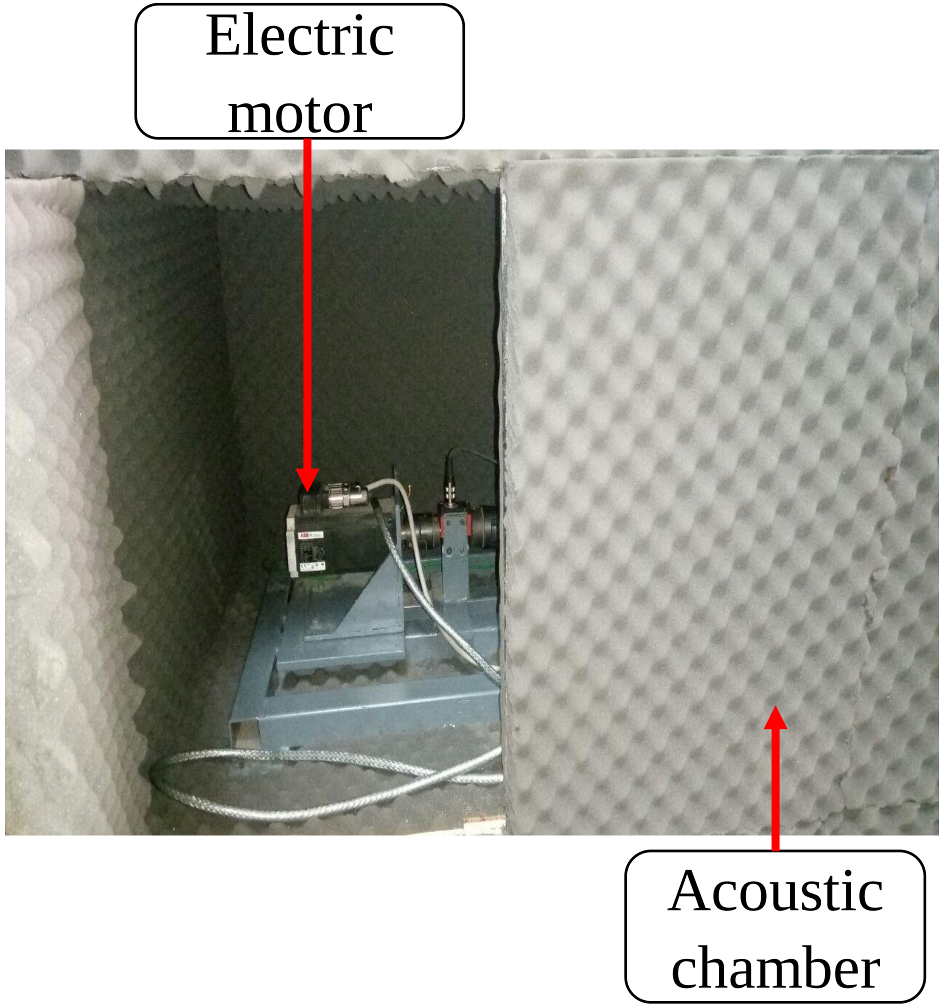
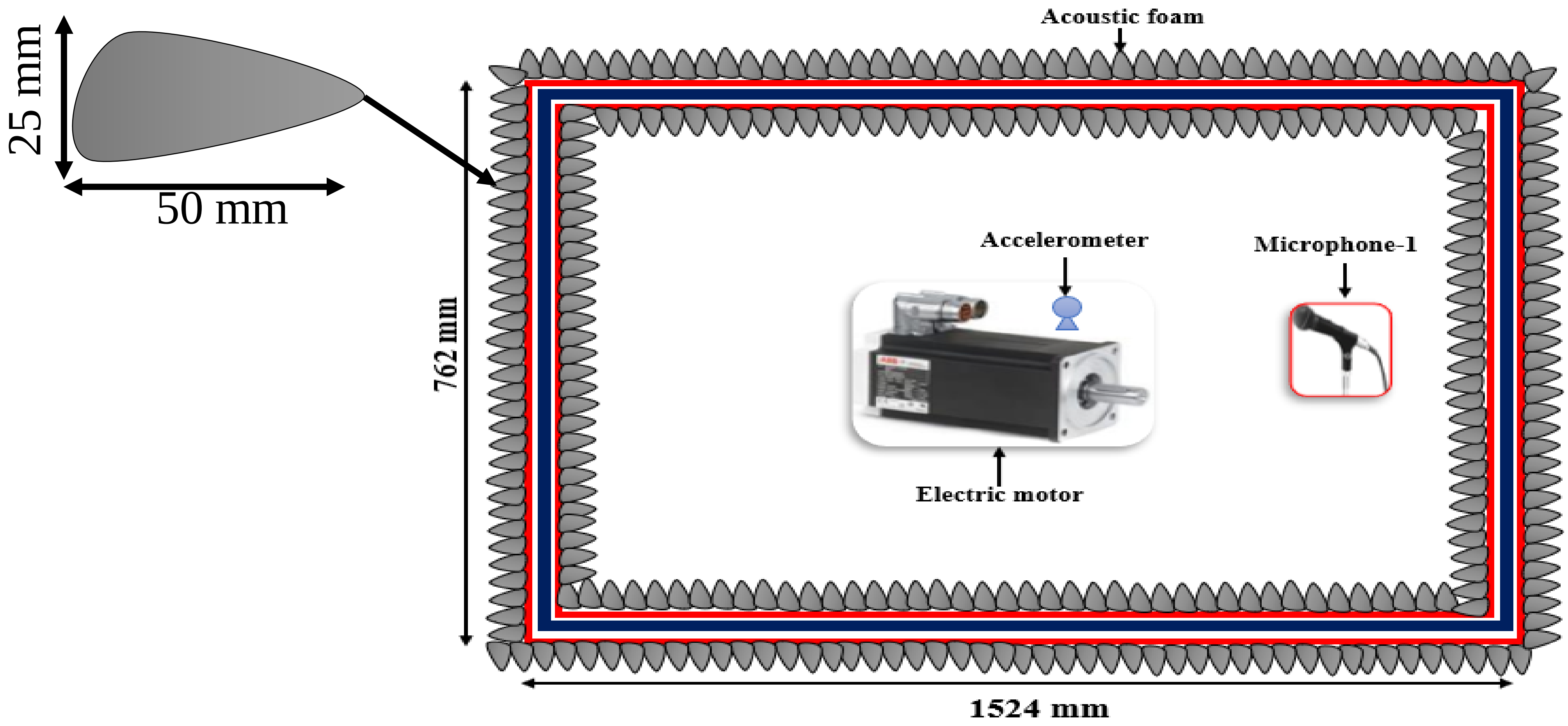


Fig. 6. Pictorial view of acoustic chamber.

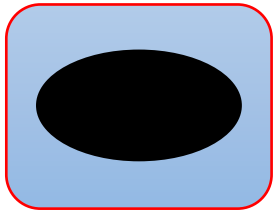
[1] Determination of Sound Power Levels of Noise Sources: Precision Methods for Anechoic and Semi Anechoic Rooms, *ISO 3745:1977, ISO Standards Handbook*, Switzerland, 1990.

[2] R. Rusz, "Design of a Fully Anechoic Chamber", *Master's Degree Project Thesis*, 2015.

Schematic Layout of Low-Cost Acoustic Chamber



Microphone-2



Amplifier as a noise source

Sound barrier sheet (thickness of 3 mm)

Wooden ply (thickness of 12 mm)

Experimental Setup Specification

TABLE. 1. EXPERIMENTAL SET-UP SPECIFICATION

Specification Item	Value	Unit
Power	1.07	kW
Rated speed	3000	RPM
No. of poles	04	
Torque	3.6	N-m
Current cont. stall	6.29	A
Rated bus voltage	300	V
Spartan 3AN FPGA kit	20	MHz Clock frequency
Peak current	16	A
IGBT based inverter stack	600 30	V A
Accelerometer sensitivity (PCB Piezotronics 352C03)	10	mV/g
Microphone (1/2" free-field) (National Instrument USB 4432)	20	kHz

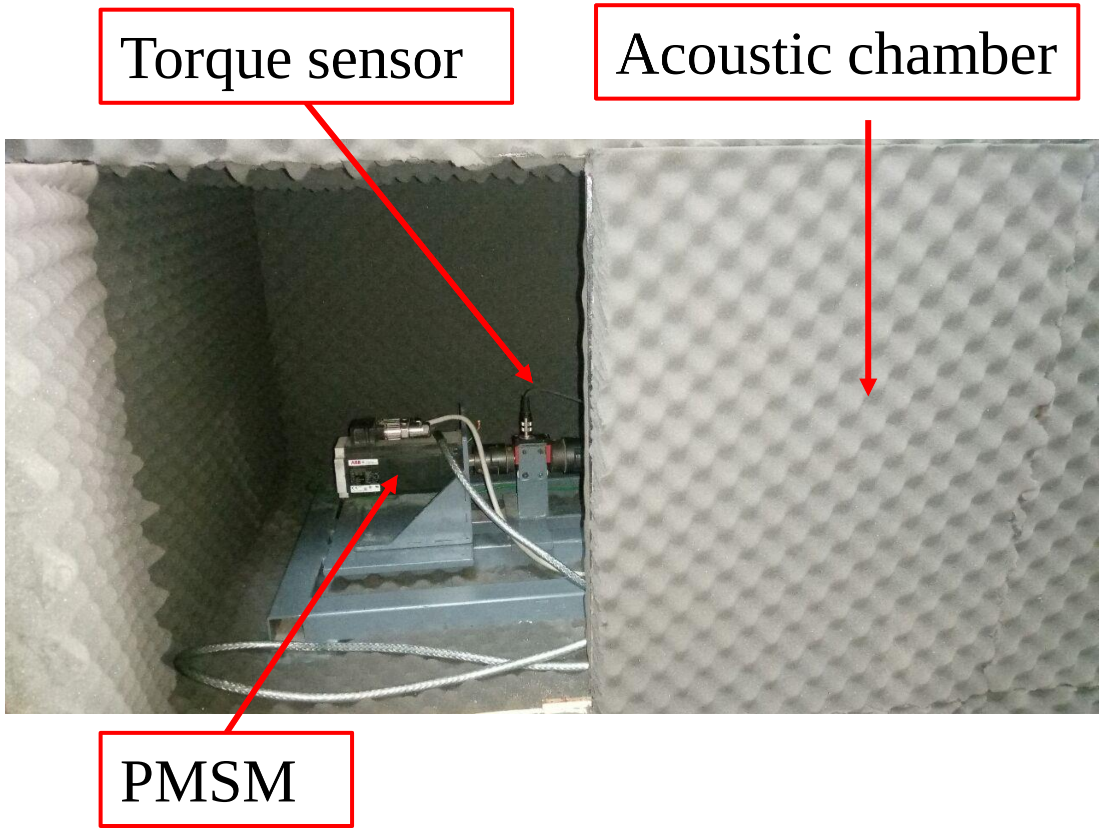


Fig. 7. Acoustic chamber with sensors and PMSM drive.

Experimental Results and Discussion

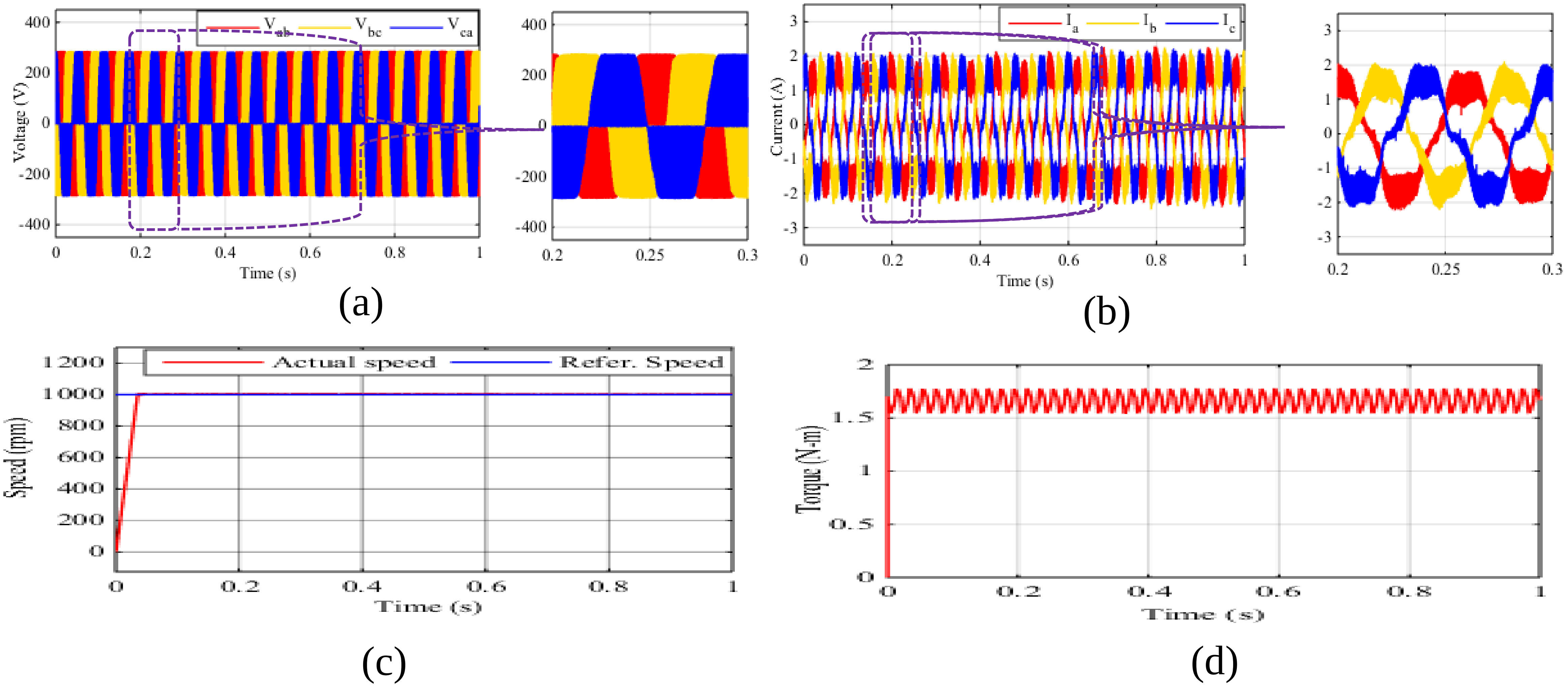


Fig. 8. Experimental results of PMSM drive: (a) Three-phase stator voltage response, (b) Three-phase stator current response, (c) Steady-state speed response, and (d) Steady-state torque response.

Experimental Results and Discussion

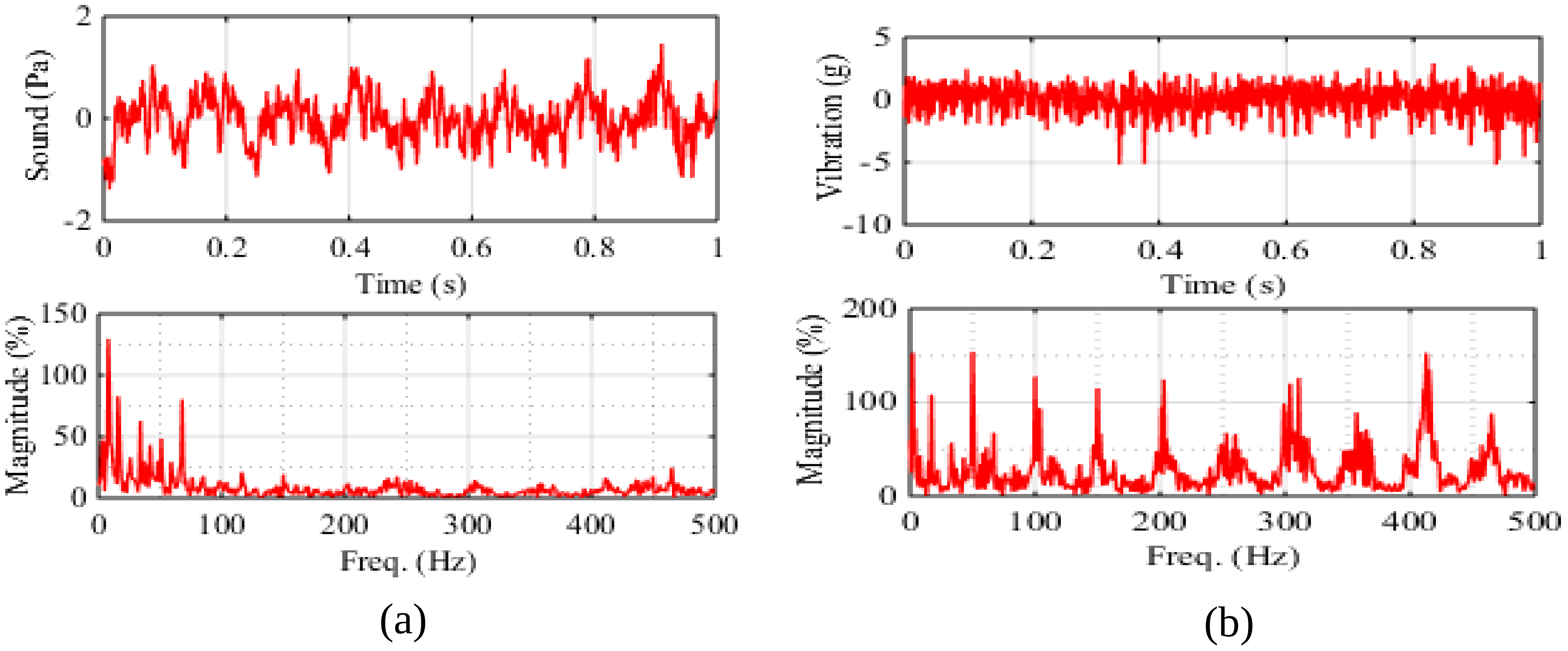


Fig. 9. Experimental results of PMSM drive: (a) time and frequency domain response of acoustic noise and (b) time and frequency domain response of vibration.

Mitigation Technique of Acoustic Noise and Vibration [3]

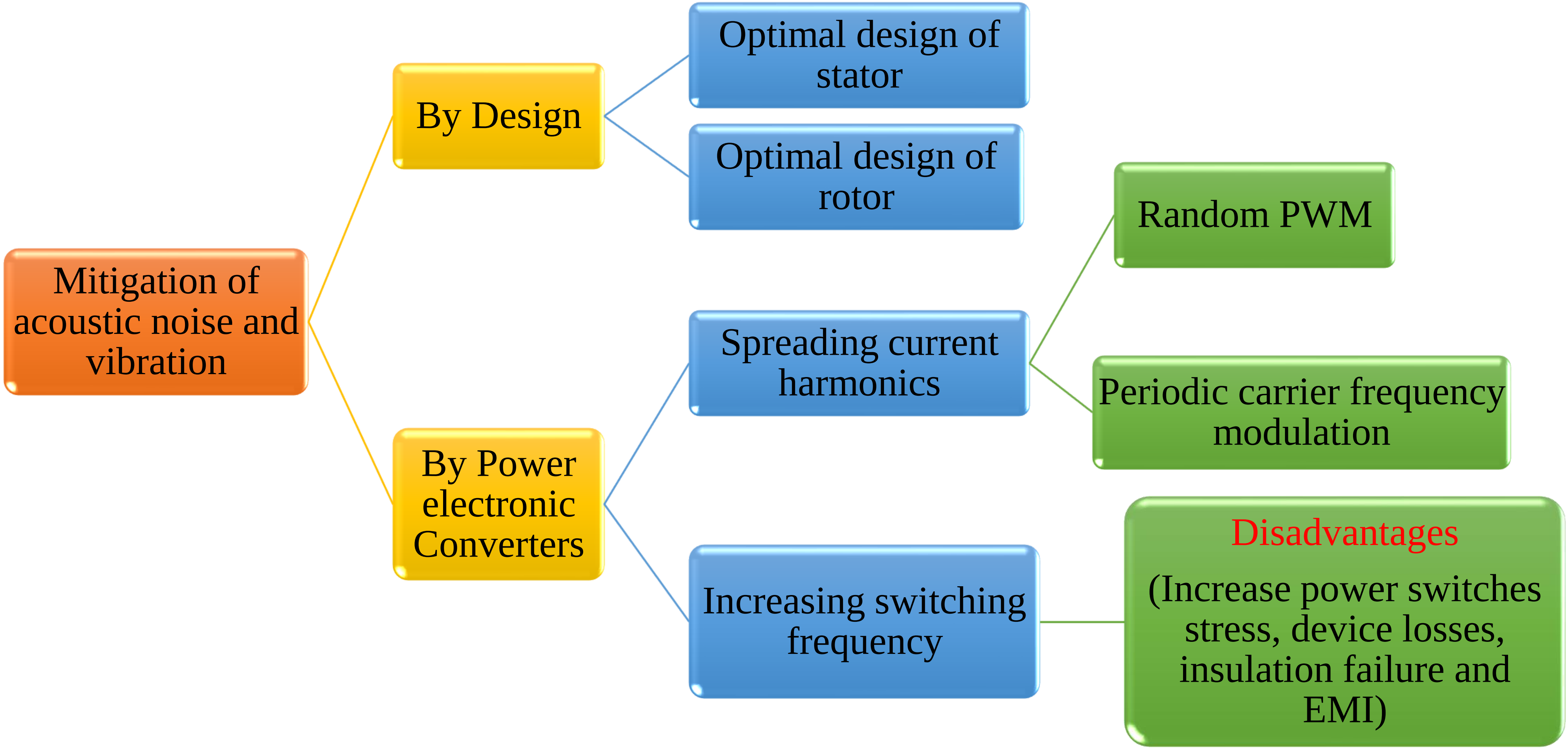


Fig. 10. Mitigation techniques of acoustic noise and vibration of PMSM drive.

[3] A. M. Trzynadlowski, F. Blaabjerg, R. L. Kirlin and S. Legowski, "Random pulse width modulation techniques for converter-fed drive systems-a review," in *IEEE Transactions on Industry Applications*, vol. 30, no. 5, pp. 1166-1175, Sept.-Oct. 1994.

Random Pulses Width Modulation (RPWM) Techniques [3]

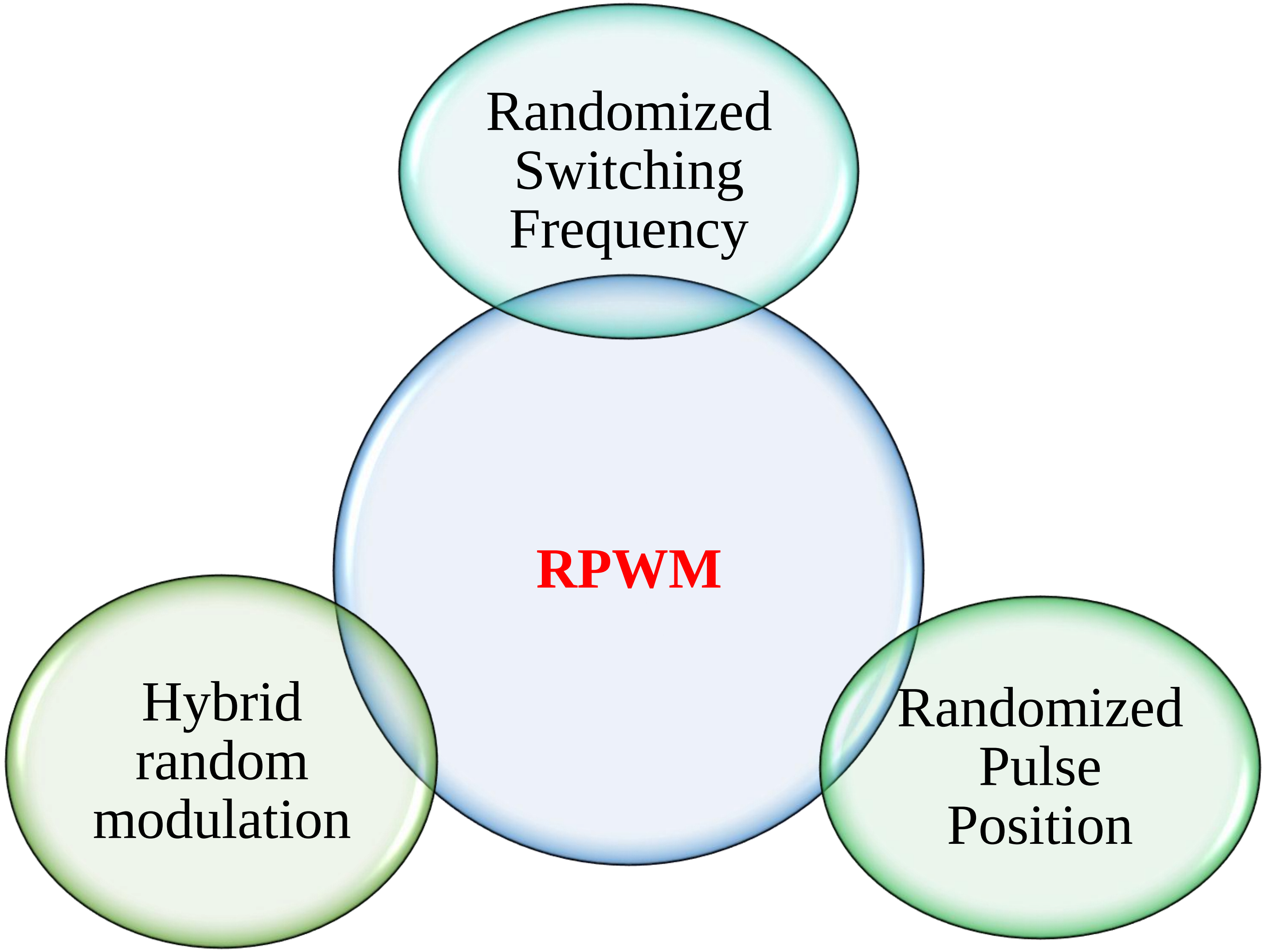


Fig. 11. Classification of random PWM technique.

Pseudorandom Carrier Modulation Technique [3]

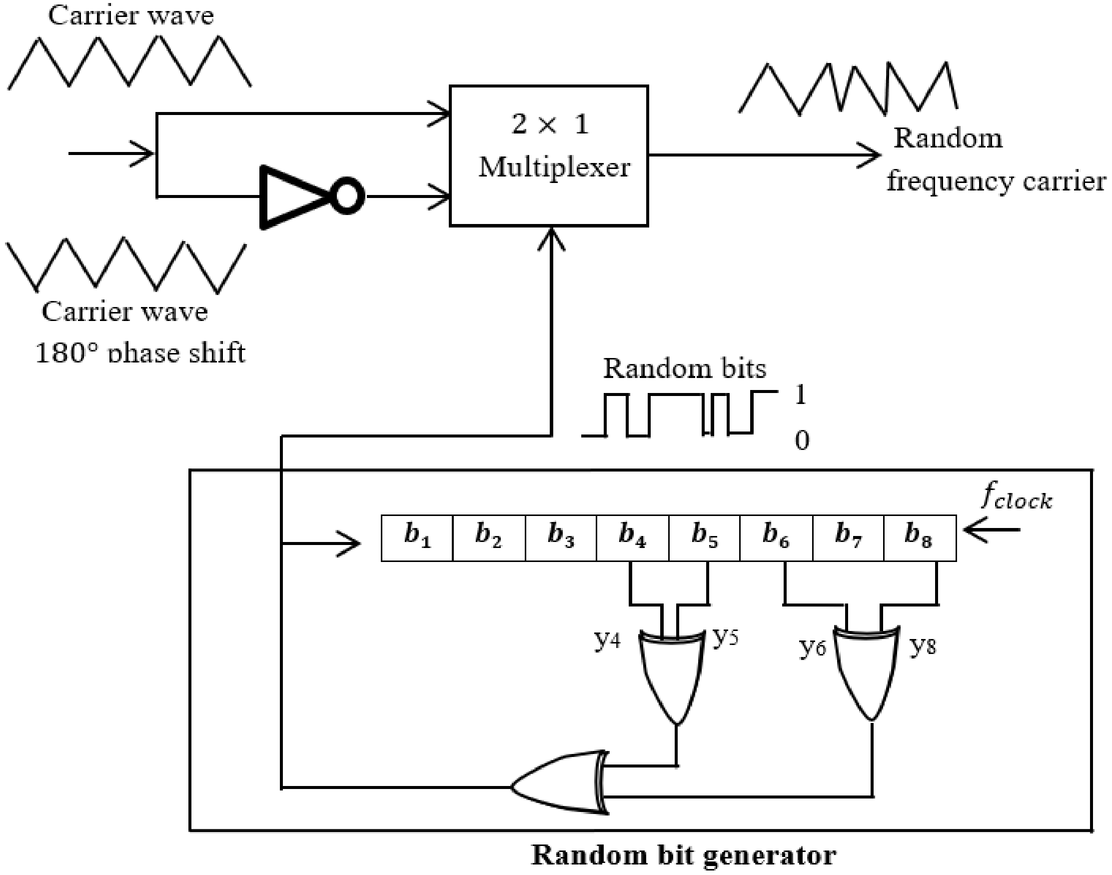


Fig. 12. Block diagram of pseudorandom carrier modulation technique.

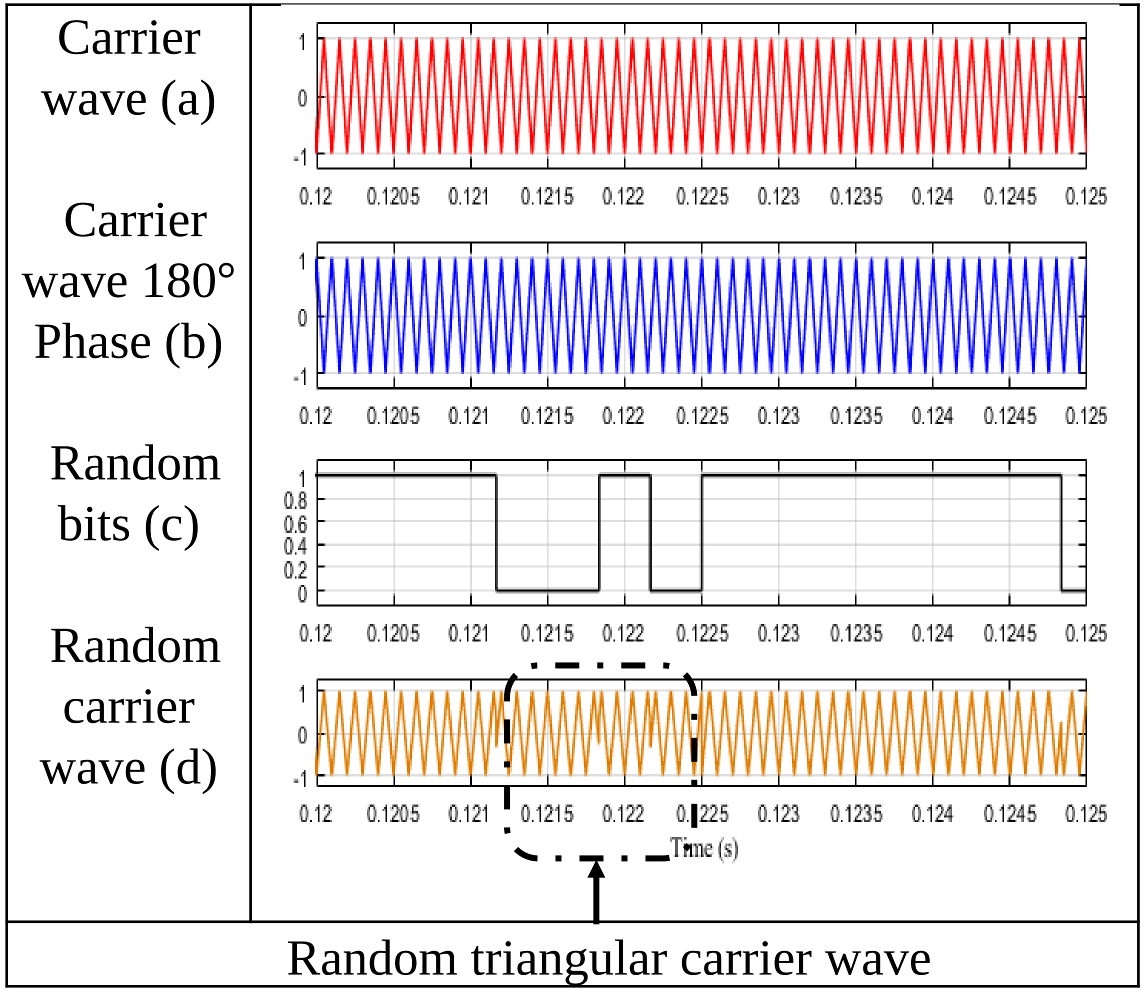
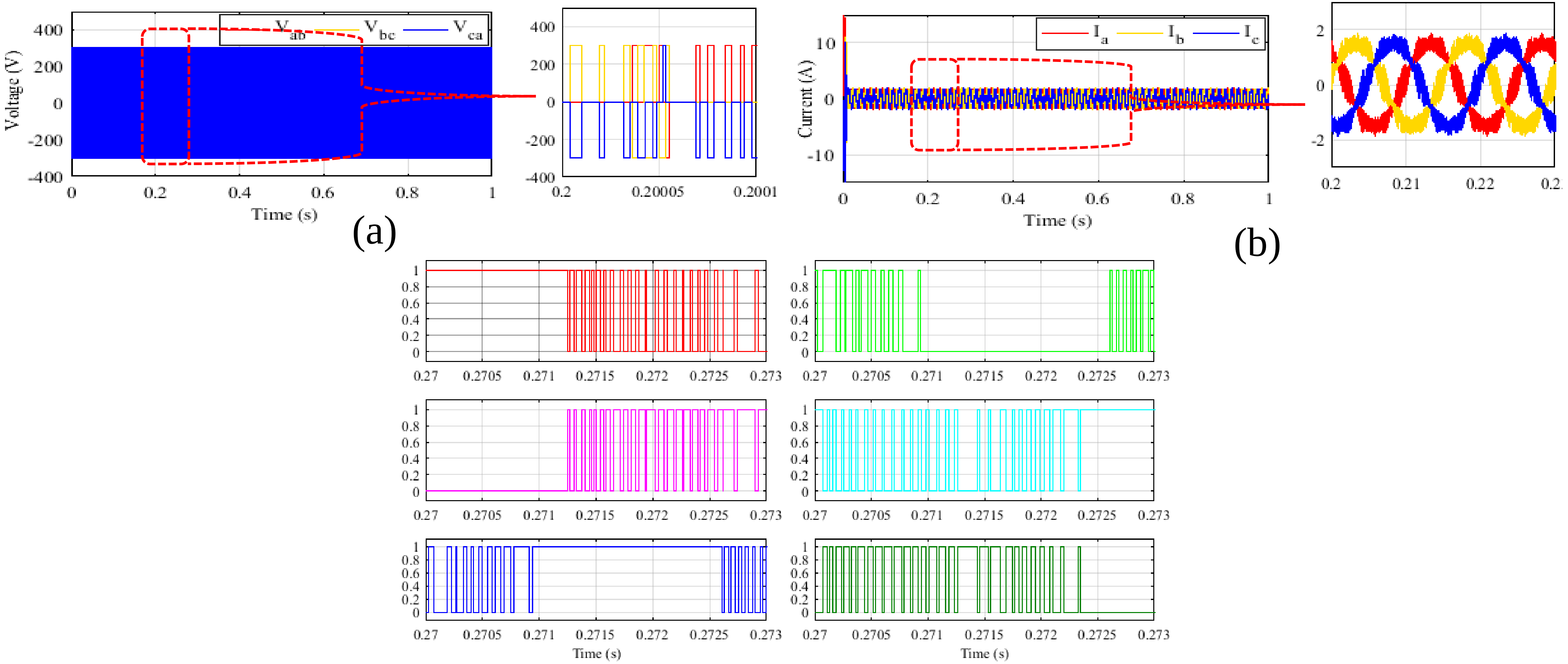


Fig. 13. Intermediate waveforms for pseudorandom carrier modulation technique.

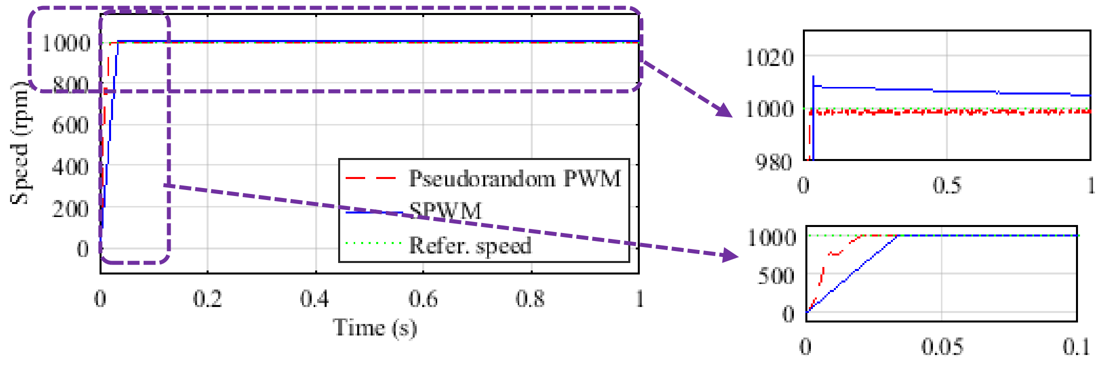
Simulation Results and Discussion



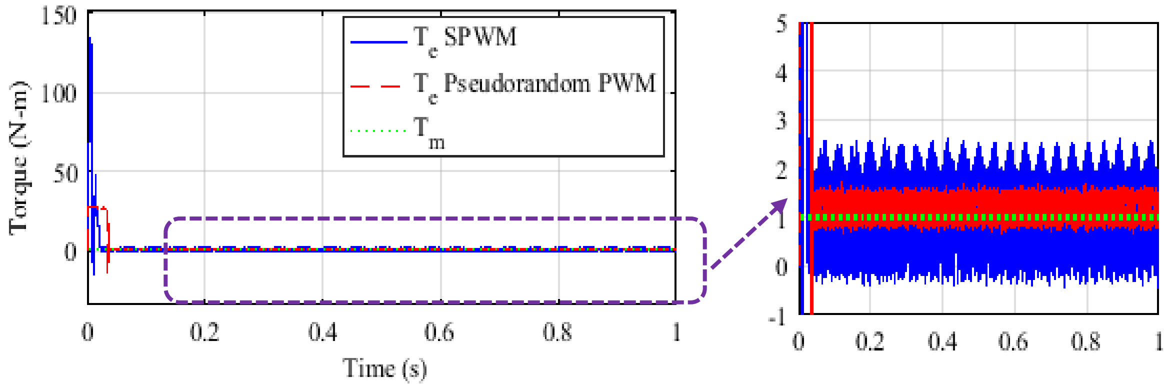
(c)

Fig. 14. Simulation results of three-phase PMSM drive: (a). stator voltage response, (b) stator current response, and (c) pseudorandom PWM switching signal for three-phase inverter

Simulation Results and Discussion



(a)



(b)

Fig. 15. Simulation results of PMSM drive: (a) steady-state speed response, and (b) steady-state torque response.

Experimental Results and Discussion

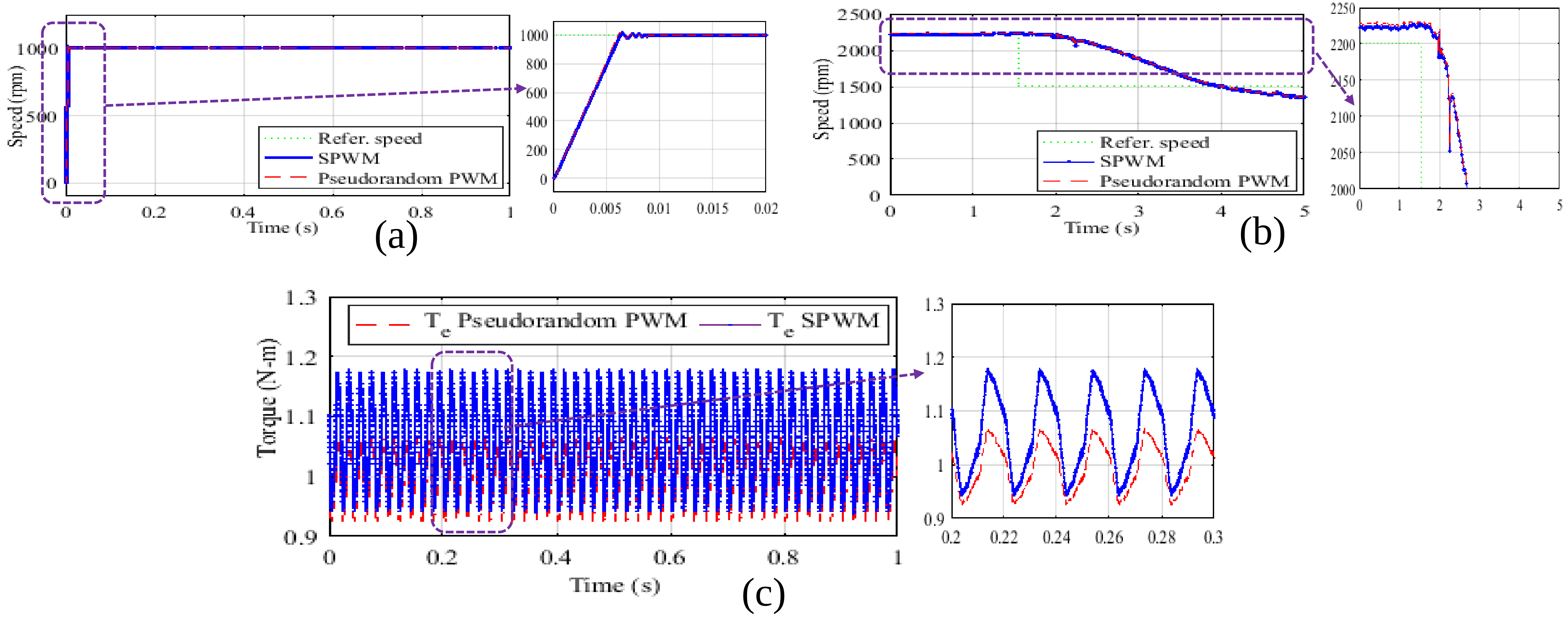


Fig. 16. Experimental results of PMSM drive: (a) Steady-state speed response, (b) Dynamic speed response and (c) Steady-state torque response.

Experimental Results and Discussion

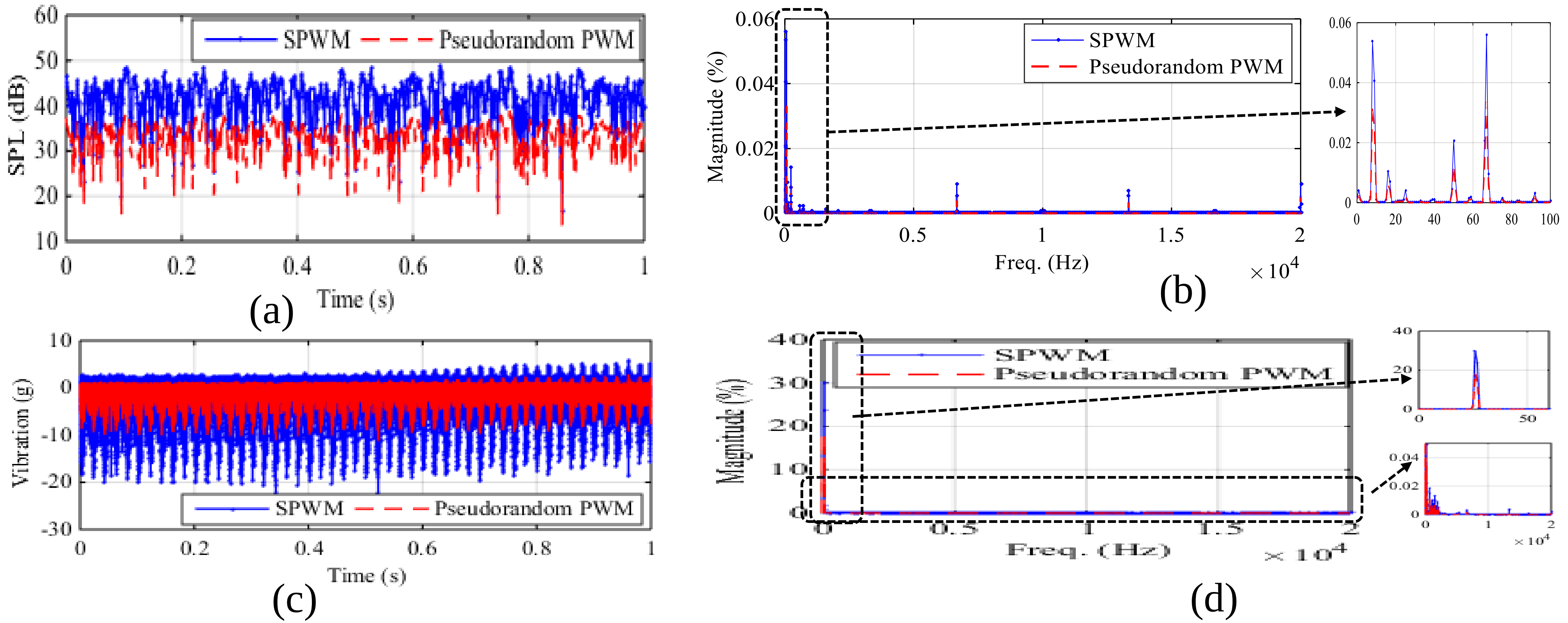


Fig. 17. Experimental results of acoustic noise and vibration during steady-state speed response of PMSM drive: (a) Time domain spectrum of sound, (b) Frequency domain spectrum of sound, (c) Time domain spectrum of vibration and (d) Frequency domain spectrum of vibration.

Experimental Results and Discussion

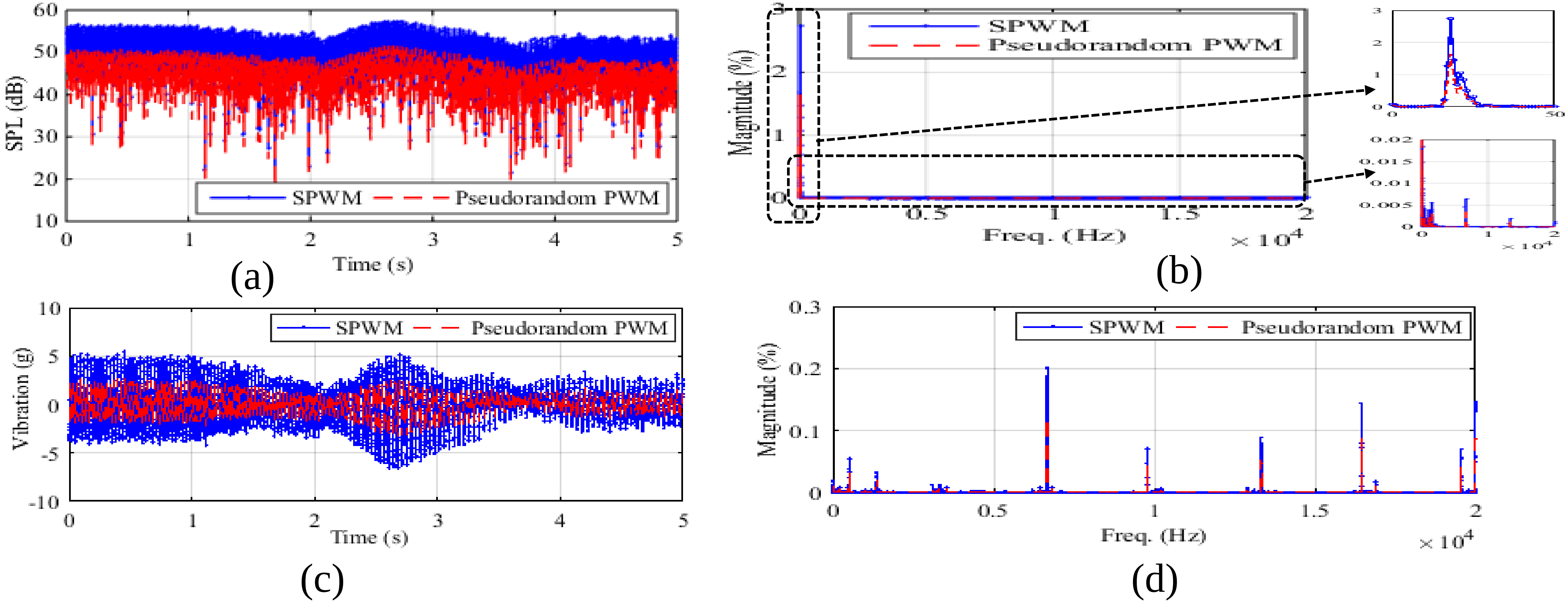


Fig. 18. Experimental results for sound and vibration during dynamic speed operation of PMSM drive: (a) Time domain spectrum of sound, (b) Frequency domain spectrum of sound, (c) Time domain spectrum of vibration and (d) Frequency domain spectrum of vibration.

Comparison of SPWM and PTPWM Technique

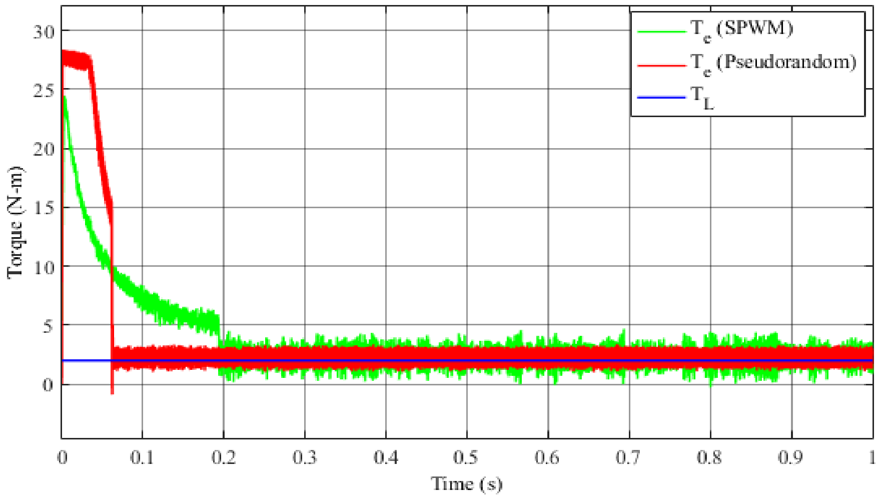


Fig. 19. Comparison of torque ripple of PMSM drive.

TABLE. 2. COMPARISON OF ACOUSTIC NOISE OF PMSM DRIVE

S. No	T_m (N-m)	SPL (dB)		% of reduction of acoustic noise
		SPWM technique	PTPWM technique	
1	1	48	37	22.92
2	1.5	52	42.23	18.79
3	2	59.5	48.45	18.57

TABLE. 3. COMPARISON OF VIBRATION OF PMSM

S. No	T_m (N-m)	Vibration (g)		% of reduction of vibration
		SPWM technique	PTPWM technique	
1	1	1.8	0.9	40.12
2	1.5	2.8	1.2	53.4
3	2	3.2	1.7	46.2

Key References

1. J. F. Gieras, C. Wang and J. C.S. Lai, “Noise of Polyphase Electrical Motors”, *Taylor & Francis Group*, 2006.

2. A. M. Trzynadlowski, F. Blaabjerg, J. K. Pedersen, R. L. Kirlin and S. Legowski, "Random pulse width modulation techniques for converter-fed drive systems-a review," in *IEEE Transactions on Industry Applications*, vol. 30, no. 5, pp. 1166-1175, Sept.-Oct. 1994.

3. Y. C. Lin, Y. G. Jung, and J. Kim, “A Pseudorandom Carrier Modulation Scheme”, in *IEEE Transactions on Industry Applications*, vol. 25, no. 4, April 2010

4. W. Liu, T. Placke, and K.T. Chau, “Overview of Batteries and Battery Management for Electric Vehicles,” in *Science Direct*, *Energy Report*, vol. 8, pp. 4058-4084, 2022.

5. Z. Tang, Y. Yang and F. Blaabjerg, "Power electronics: The enabling technology for renewable energy integration," in CSEE Journal of Power and Energy Systems, vol. 8, no. 1, pp. 39-52, Jan. 2022

Thank you for your attention

Queries

The future really is in our hands!

Thank you so much for your attentions

Q & A