



Motor Control Technology and its Application to Electric Motorbikes

Seminar on Technology for Electric Motorbikes

December 12, 2018

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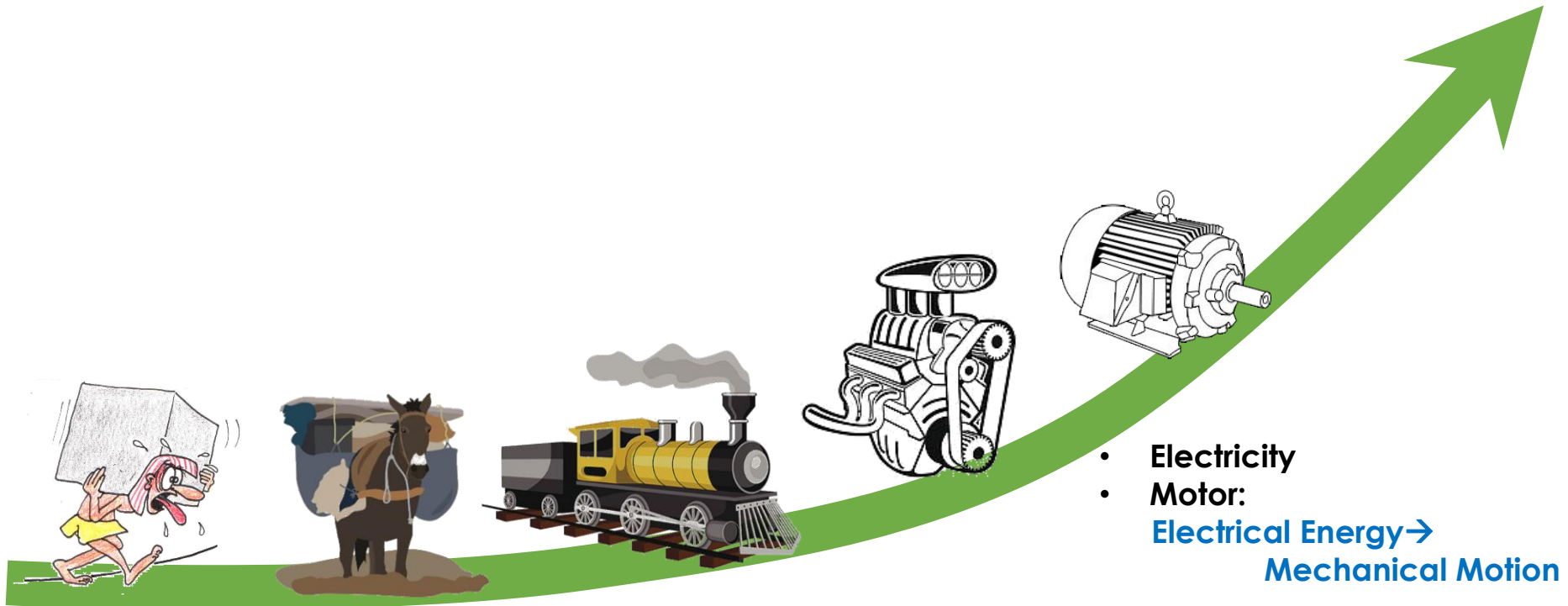
Hanoi University of Science and Technology

Outline

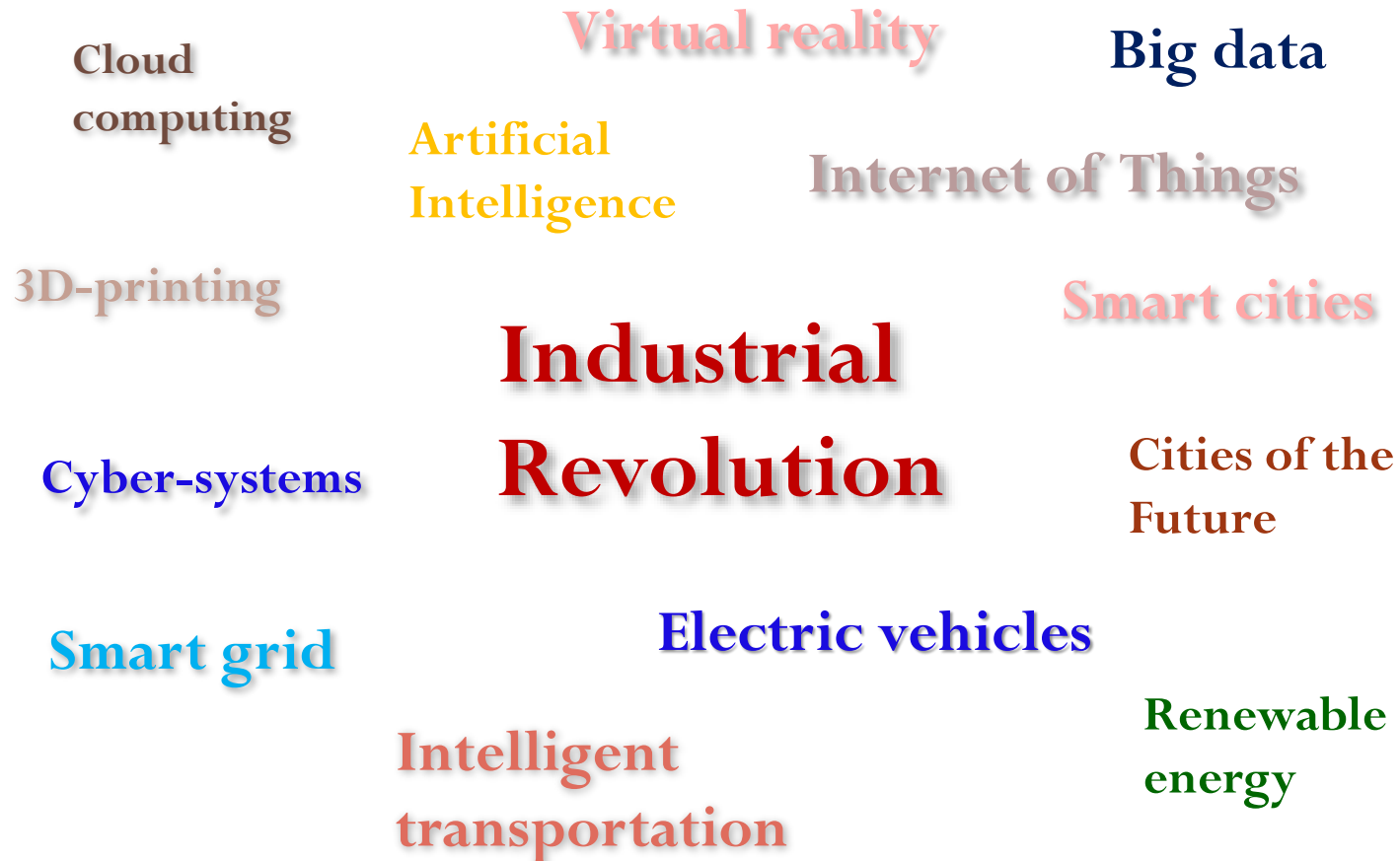
1. Introduction
2. Components
3. Motors and Motor Control
4. Storage system, Charging Technology & Power Management
5. Conclusion

Introduction (background)

“If you want to find the secrets of the Universe, think in terms of energy, frequency, and vibration” – Nikola Tesla (1856-1943)



Context: New era of development



Electrified Vehicles: Classification

- **Road Electric Vehicles**
 - **Passenger cars (4-wheels)**



- **Motor cycles**

- **Electric transporters (in golf-field, hospitals, air-ports, ...)**
- **Electric buses (e-Buses)**



- **Electric Trains**
- **Electric ships, boats**
- **Electric air-plane**

Electric Vehicles

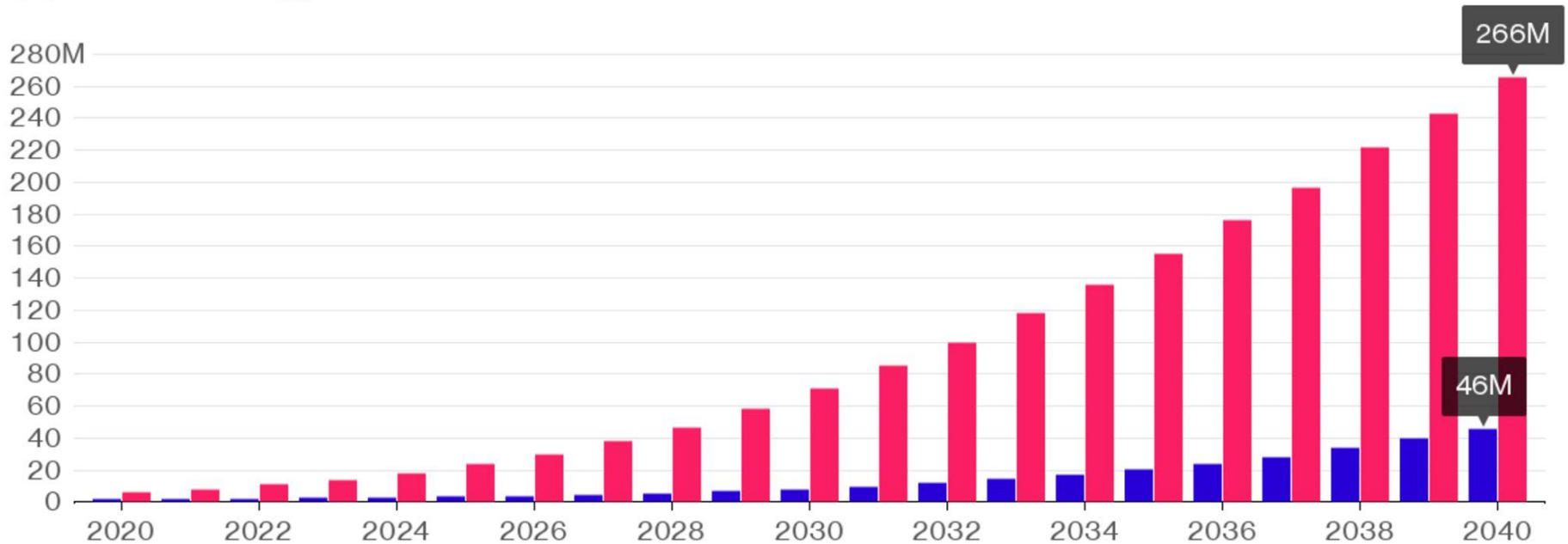
- “Old” history (1834), but New challenges for:
 - Global warming
 - Fossil fuel exhaustion
- **State-of-the-art technology**
 - High performance
 - Comfortable
 - Safe
- **Problems:**
 - Energy storage systems
- **Recent technologies:**
 - Quick charging stations
 - Wireless Power Transfer (WPT)

EV growing forecast

Growing Expectations

OPEC's electric vehicle forecast grew by almost 500% last year

■ 2015 Forecast ■ 2016 Forecast

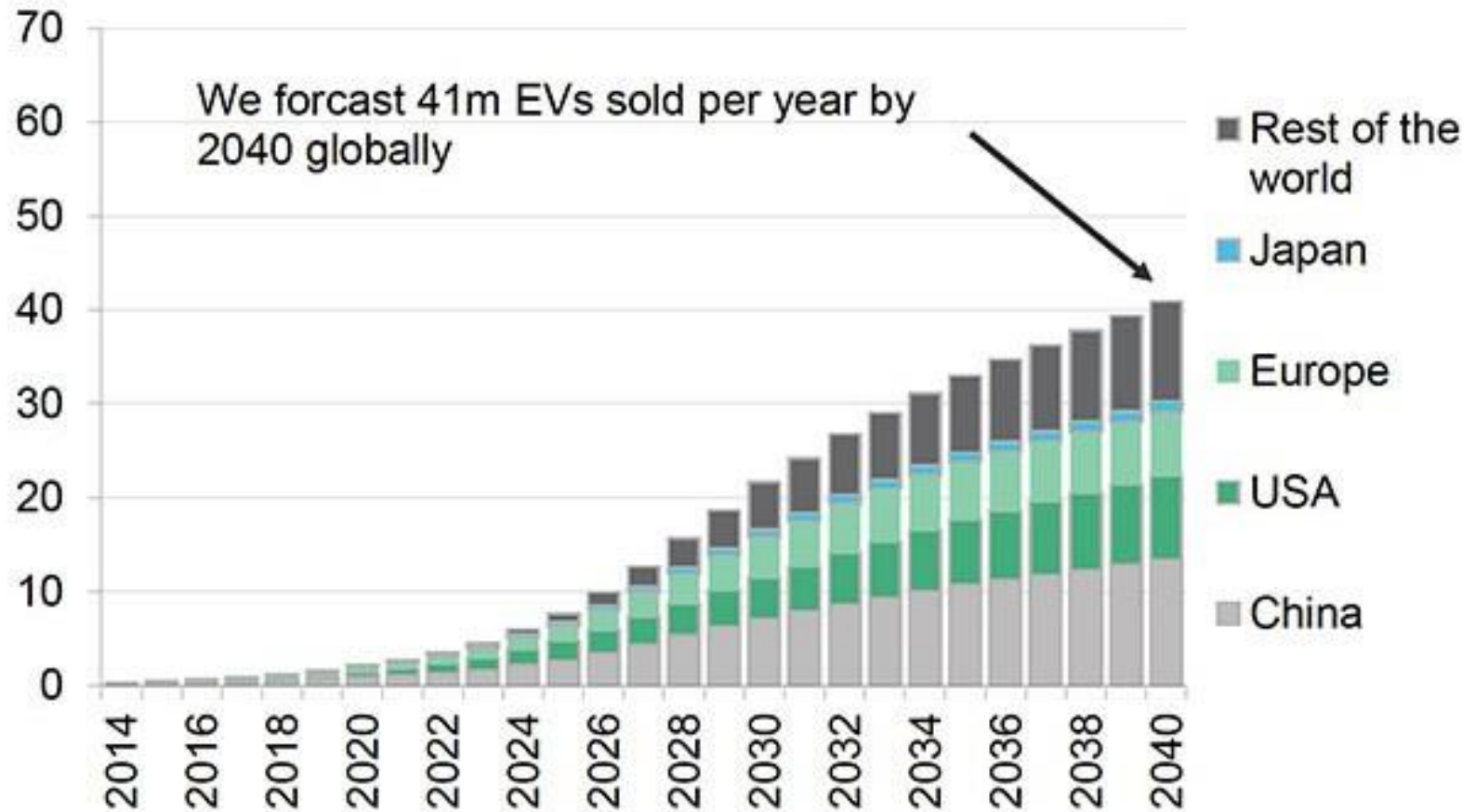


Source: Bloomberg New Energy Finance

Bloomberg 

Global EV sales forecast

2015–2040 (m vehicles per year)



Source: Bloomberg New Energy Finance, Marklines

Situation in Vietnam

- **Traffic jams**
- **Pollution in large cities**
- **Motor-cycles depending society**

What is the best solution for Vietnam large cities ?

A combination of:

- **Public transport (Buses, Urban trains, Subways)**
- **Electric Vehicles (Passenger cars: 4 and 3 wheels)**
- **Electric Motor cycles**

2. Components of e-motorcycles

- Motor
- Battery

(No Model.)

H. W. LIBBEY.
ELECTRIC BIOCYCLE.

No. 596,272.

Patented Dec. 28, 1897.

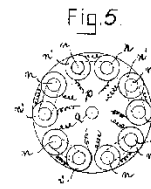
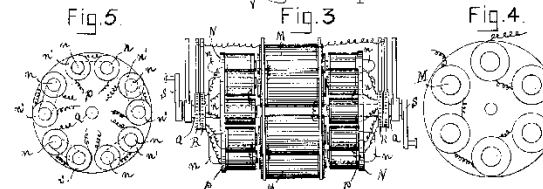
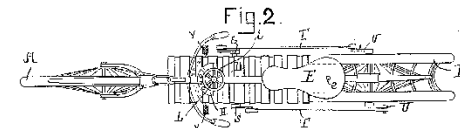
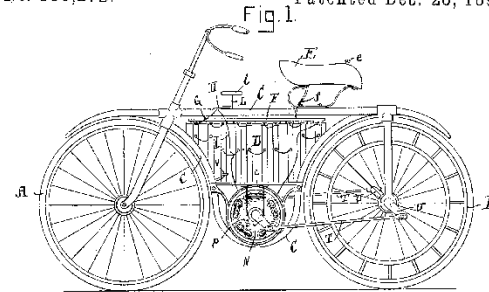
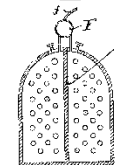


Fig. 6.



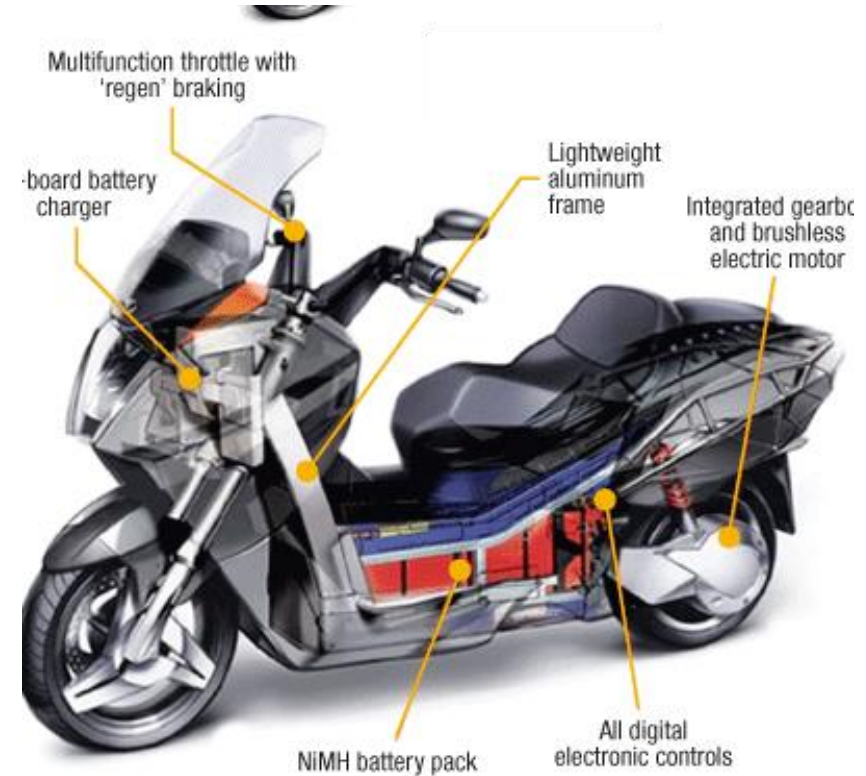
Witnesses
Paul E. Wilson
Laura E. Hayward

Inventor
H. W. Libbey
by Edwin Blount
Attorney

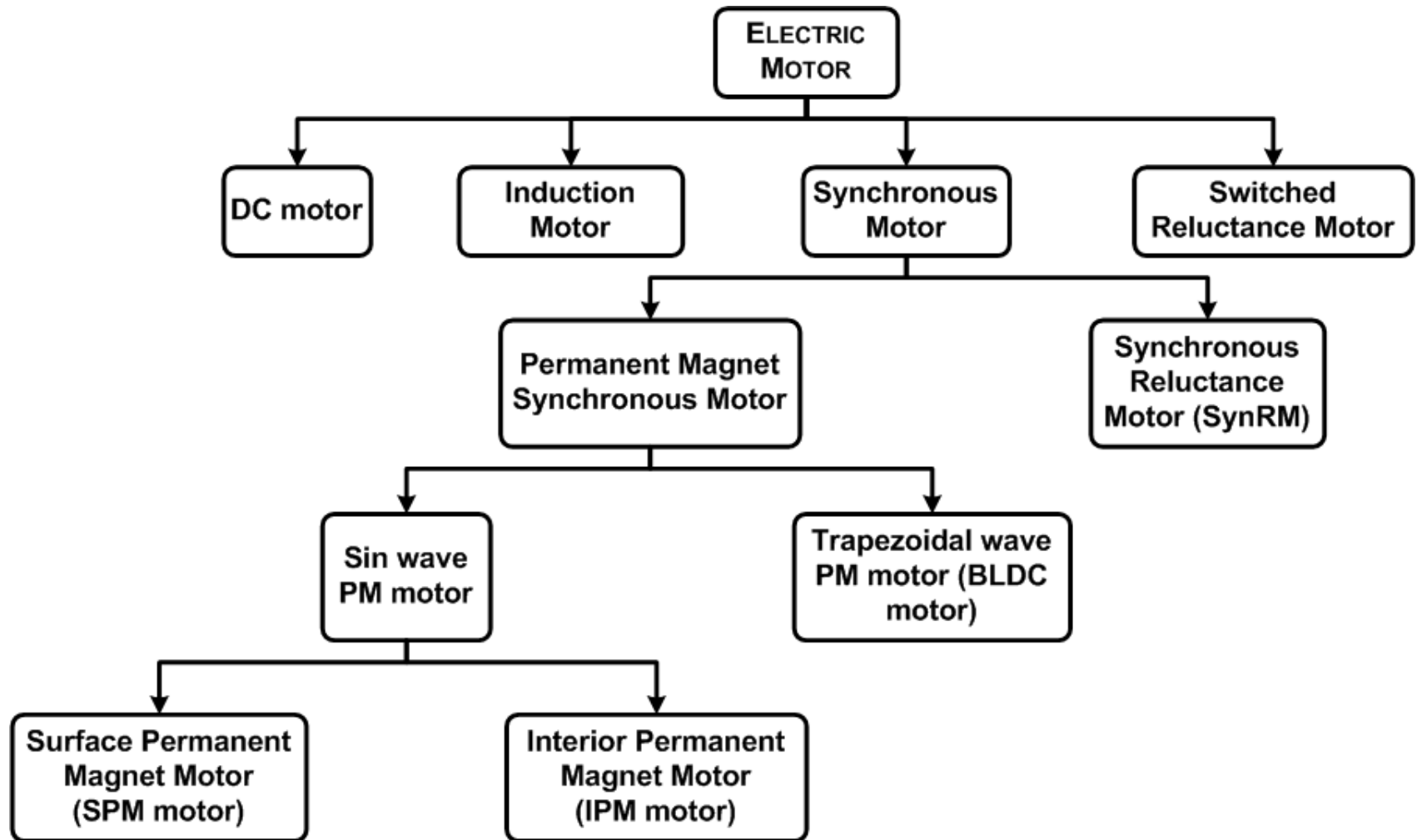
THE NEWBERRY PRESS CO. PRINTED AT CHICAGO, ILL.

2. Components of e-motorcycles

- **Motor**
 - **Converters**
 - **Battery**
 - **Control Units**
-
- **Charging infrastructure**
 - home chargers
 - charging stations



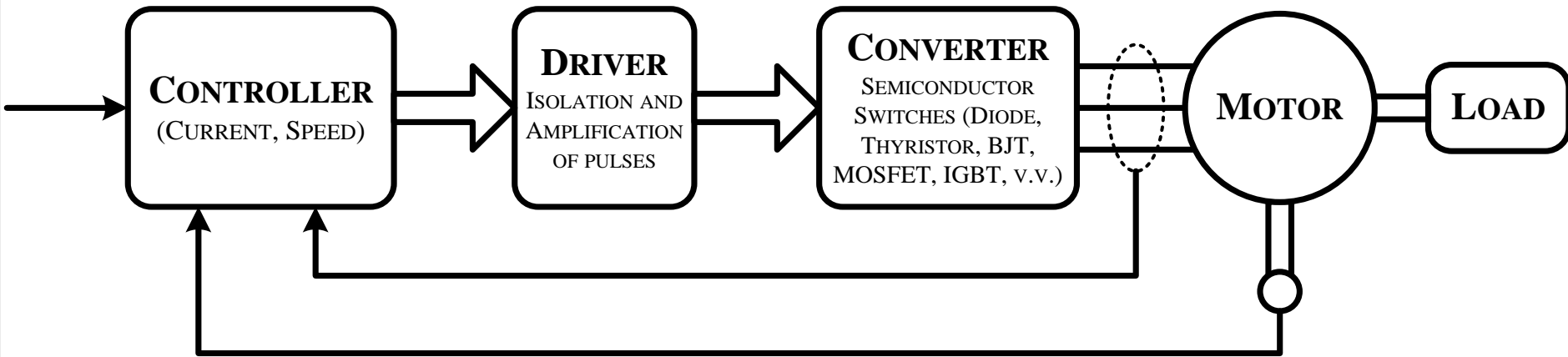
3. Motors and Motor Control



Motor & Motor Control

- What is the “**Best Motor**” for Motor cycles ?
- Advanced Control Techniques
 - To improve the performance
 - To improve the efficiency (energy saving)

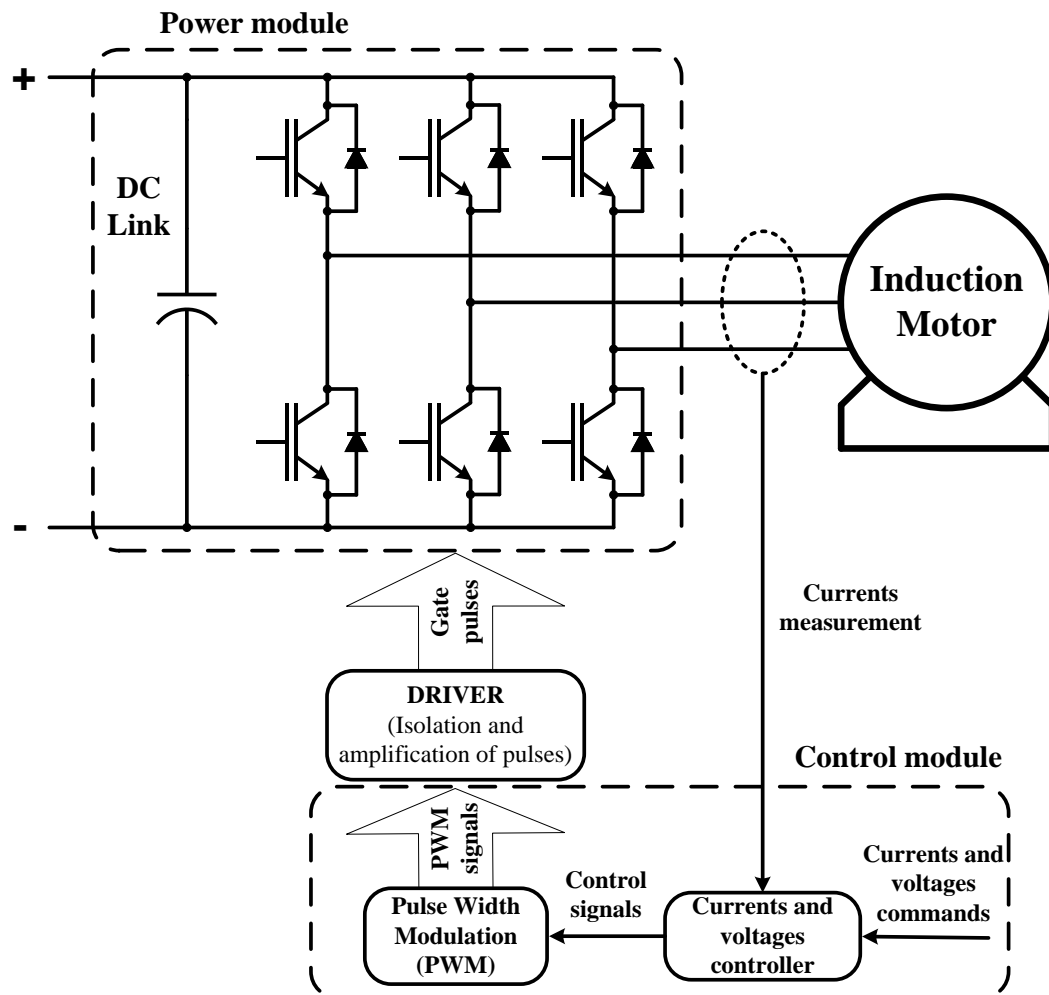
General Configuration



$$T = f(\phi, I)$$

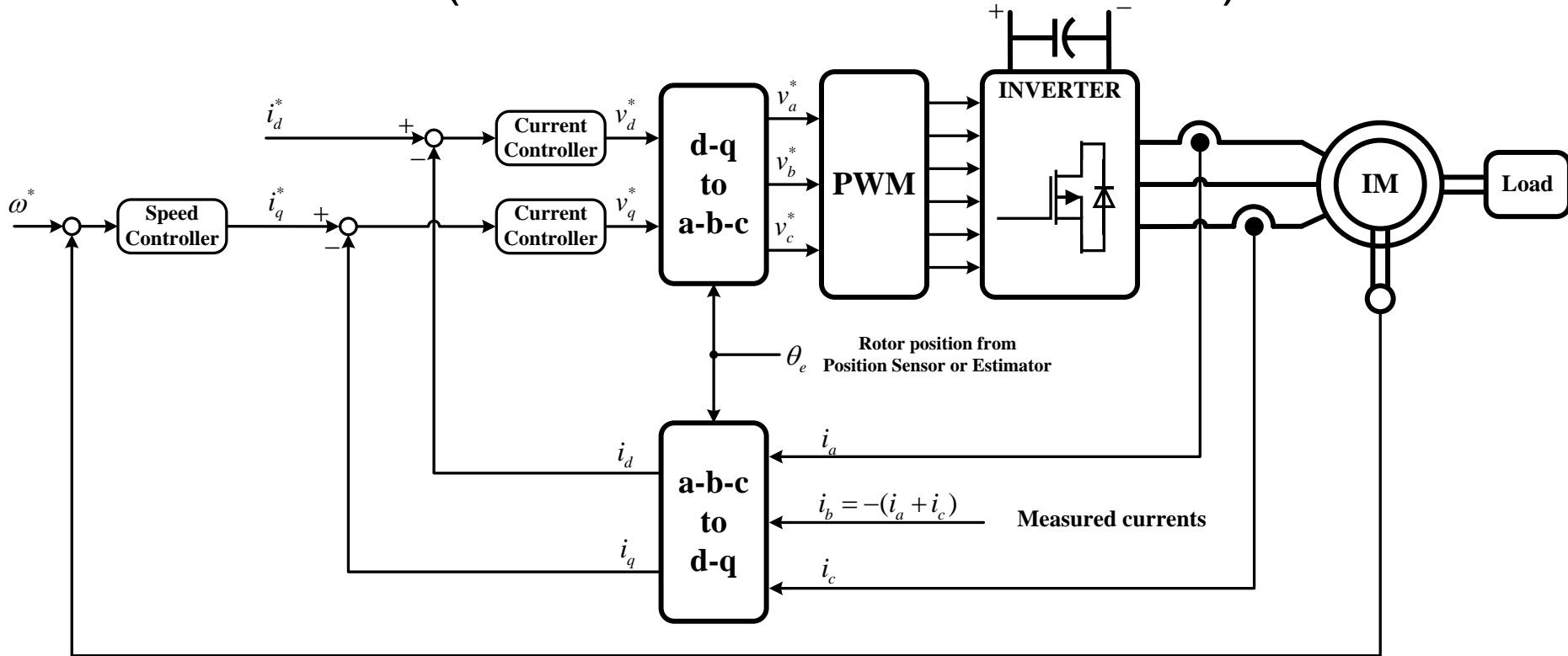
3.1. Induction Motor or Asynchronous Motor Control

Voltage/Frequency control: using **inverter**

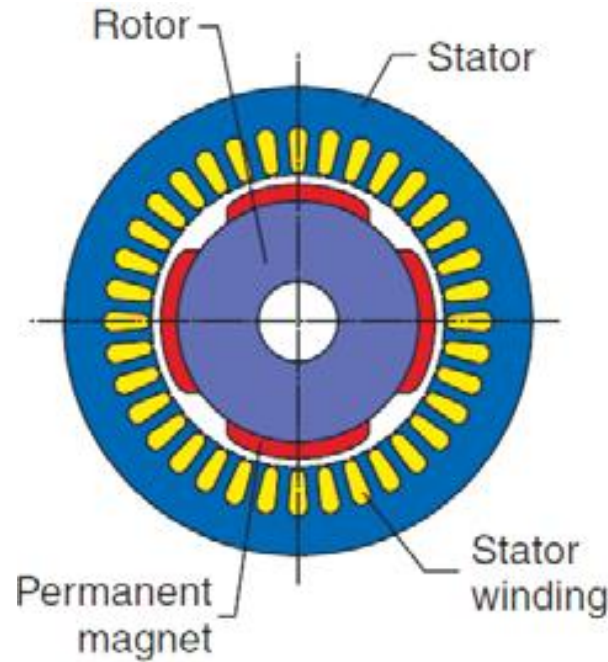


IM Control

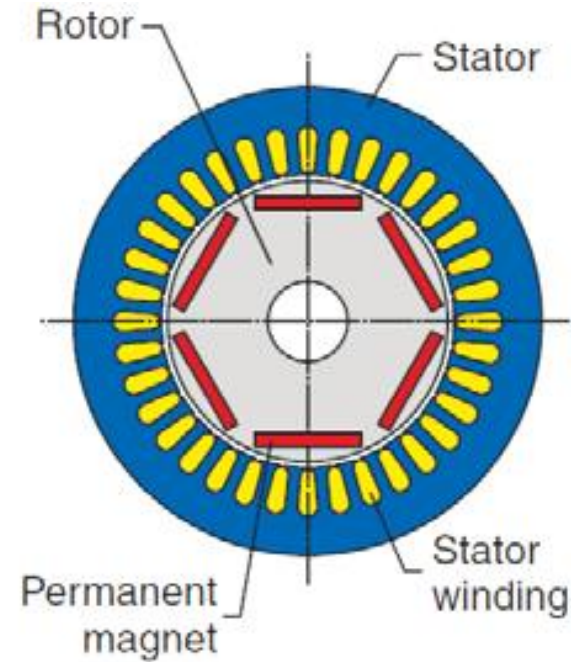
- Vector control (Field Oriented Control – FOC)



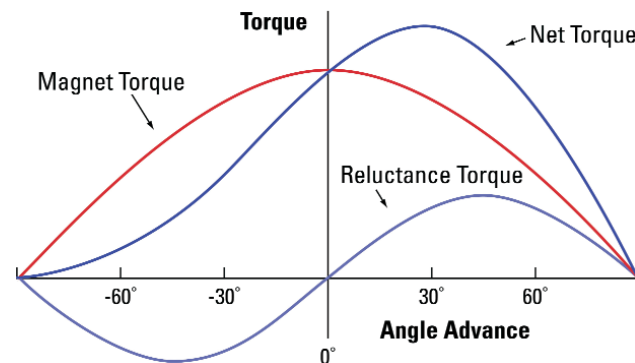
3.2. IPM Control



Surface mounted permanent magnet motor (SPM).



Interior permanent magnet motor (IPM).

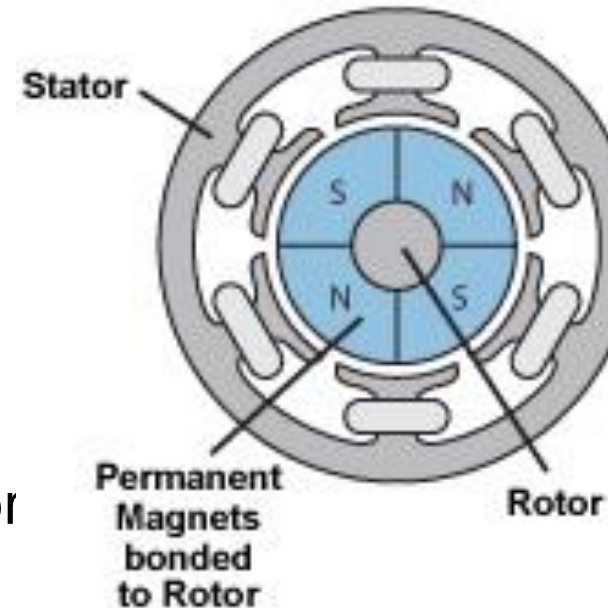


• IPM vs SPM

3.3. BLDC Motor Control

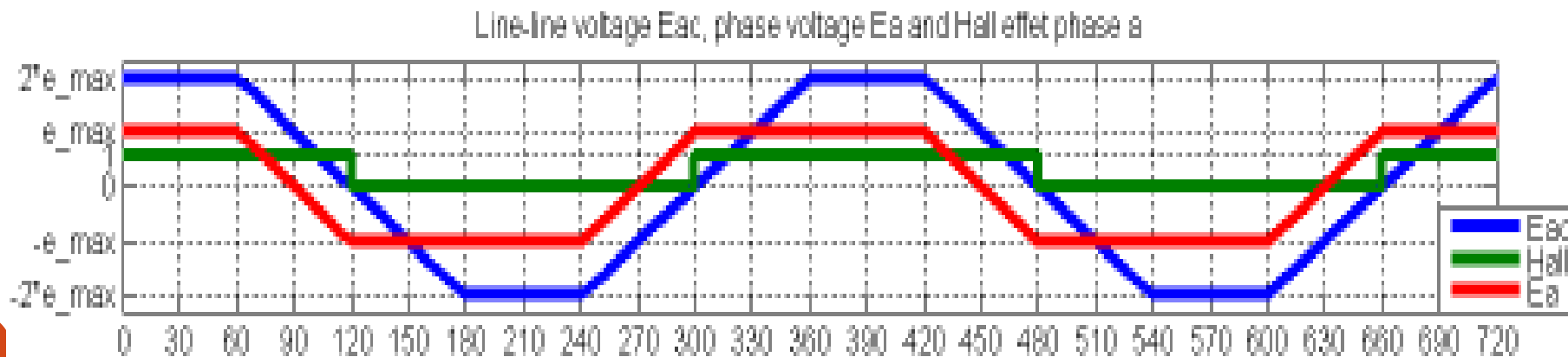
Construction:

- Rotor: the same as sinusoidal PM motor's
- Stator: concentrated windings
- **Trapezoidal shape of the back-EMF wave.**
- **Hall sensors** to detect the rotor position.



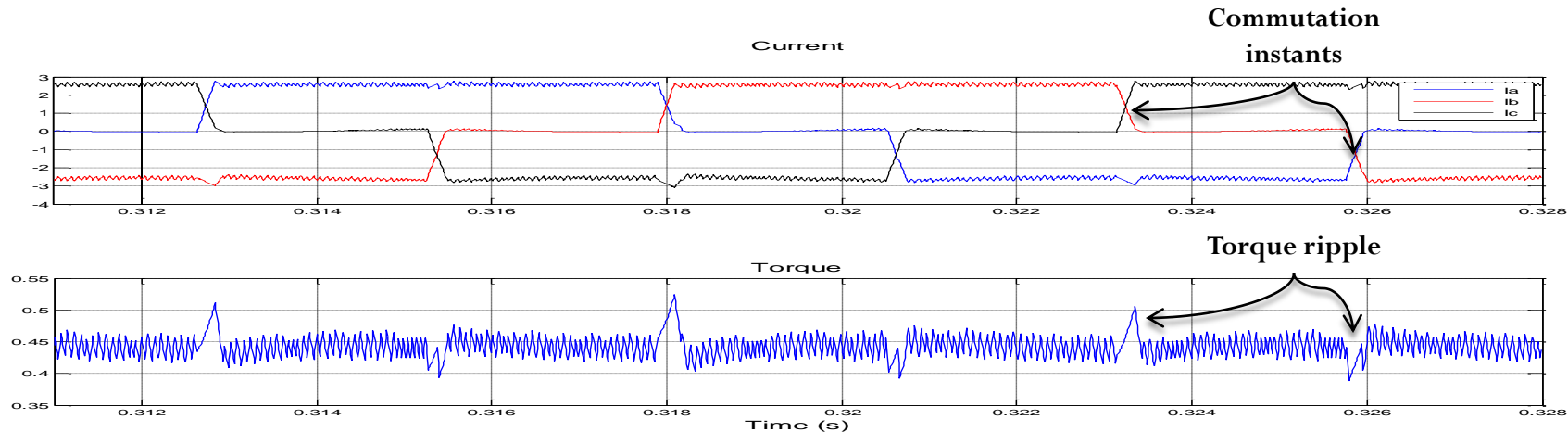
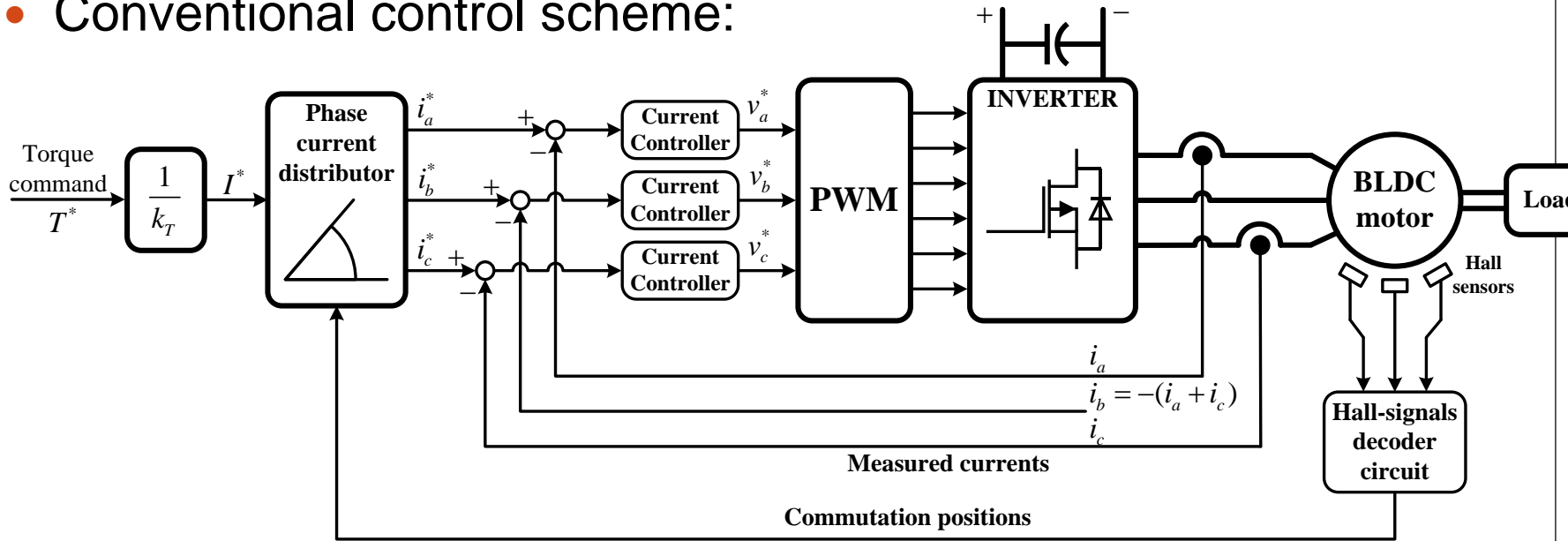
Problems:

- **Torque ripple** due to commutations of stator currents (six times per cycle).
- **High-speed operation.**



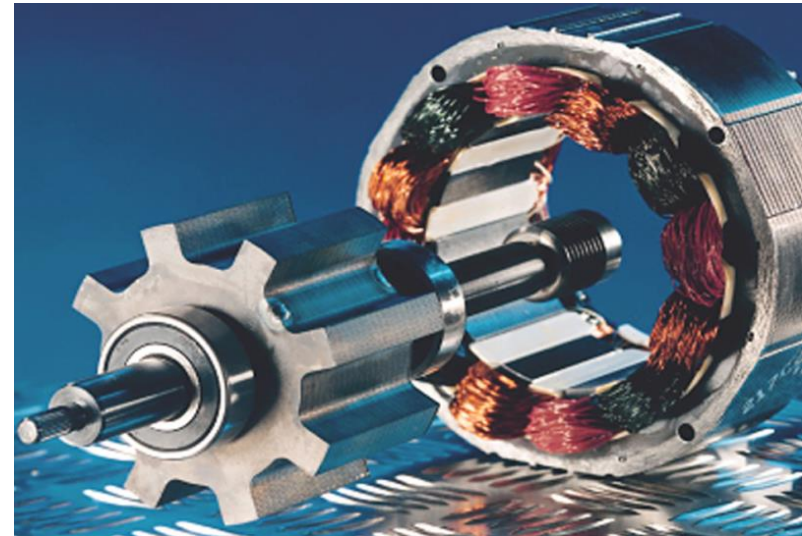
BLDC Motor Control

- Conventional control scheme:



3.4. SRM Control

- **Reluctance Motor** is the motor working in the principle of *variation of Reluctance (Inductance)* of the magnetic circuit – and it is also called *Variable Reluctance Motor*.
- **Construction:**
 - **Stator & Rotor** have **salient poles**
 - Stator: windings on pole (as DC Motors)
 - Rotor: **iron only (no winding, no PM)**
- **Electromagnetic Torque:**
 - Motor torque is **reluctance torque**



$$T_e = \frac{1}{2} i^2 \frac{dL(\theta, i)}{d\theta}$$

SRM Control

Finite Element Analysis of SRM

Parameterization for magnetostatic analysis

$I_{\text{phase_A}}$ 0A to 12A Step: 1A

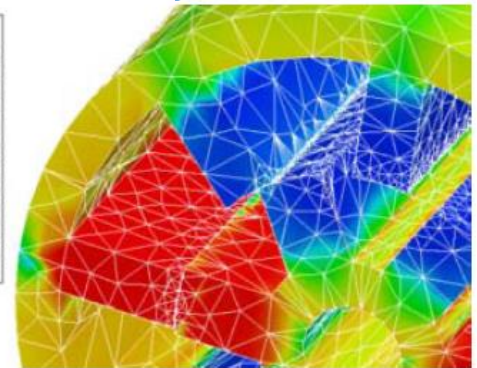
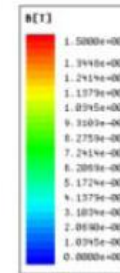
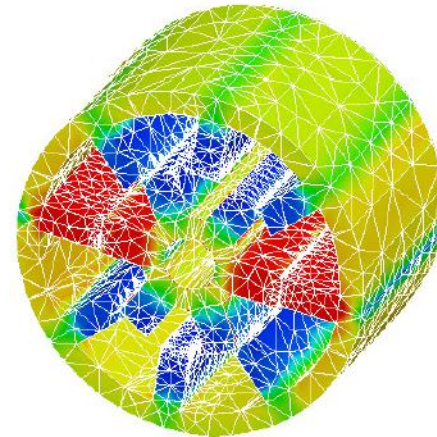
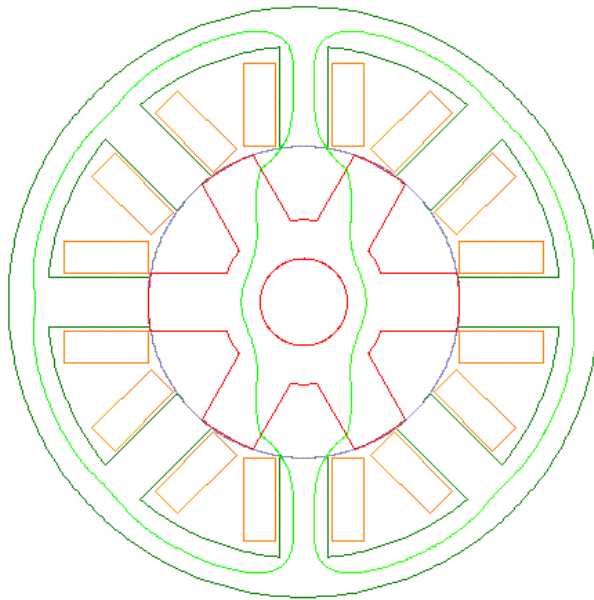
θ 0 deg to 60 deg Step: 1 deg



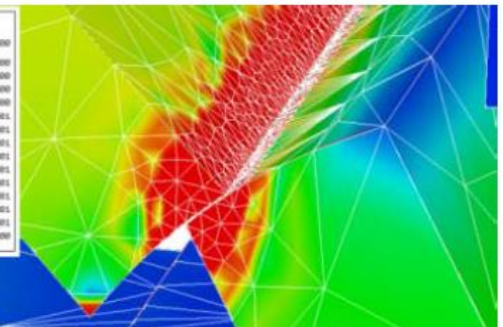
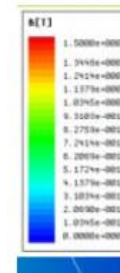
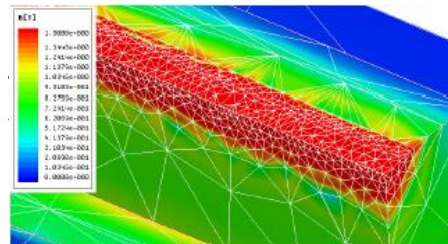
Total: 793 steps

Flux density in 3D analysis

Process of static steps analysis



(a) Aligned position.

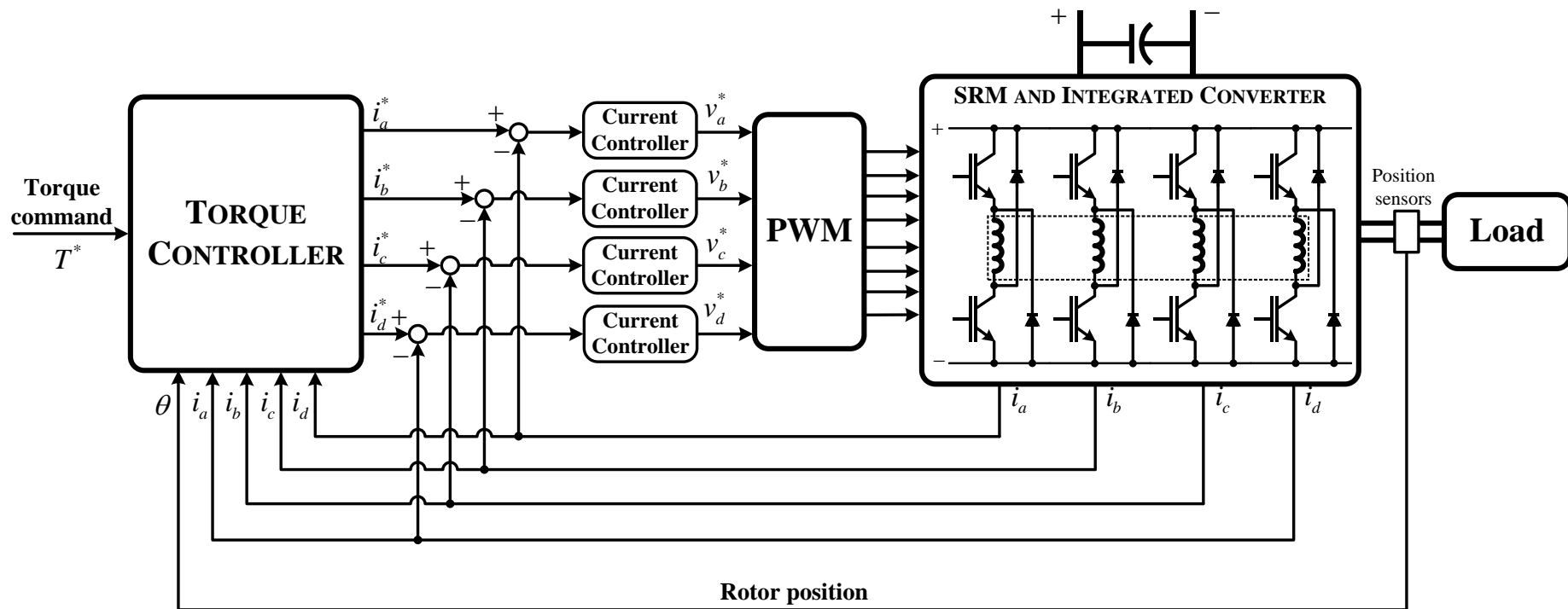


(b) Overlap position.

SRM Control

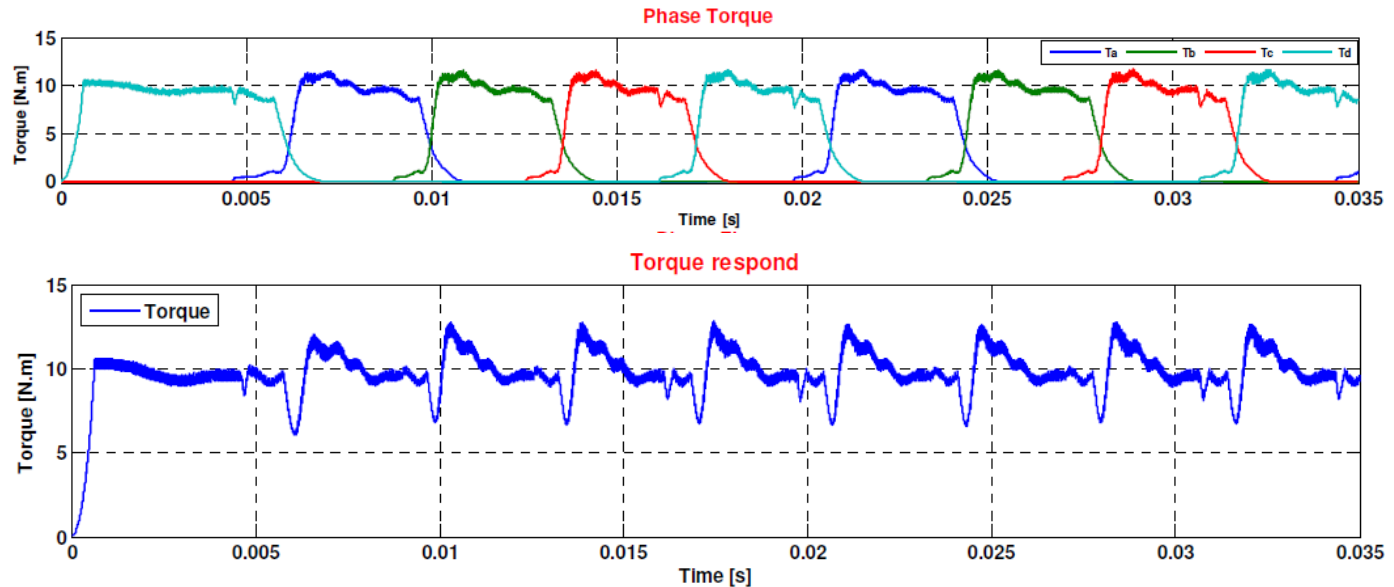
Drive system configuration:

- Asymmetrical bridge power converter
- Current controller: PI control or hysteresis (bang-bang) technique
- Speed control loop is neglected for simplicity.



SRM Control

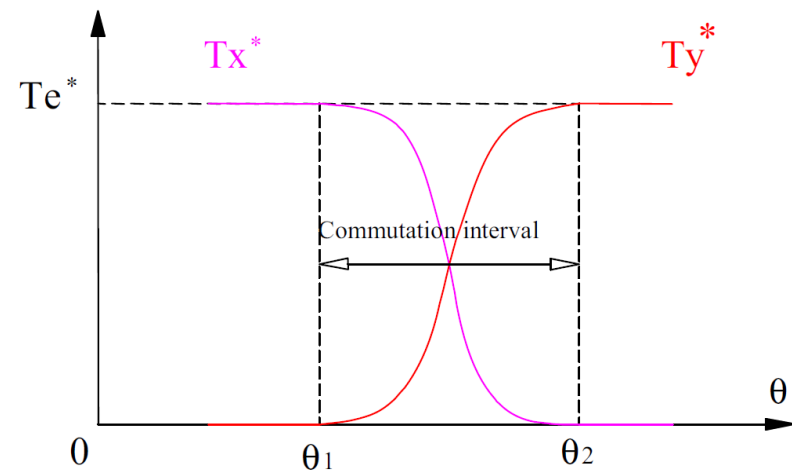
Conventional control: Phase currents are excited sequentially → **High torque ripple**



Torque Distribution Control technique

$$T_e^* = T_x^* + T_y^*$$

$$T_e^* = T_e^* \cdot f_x(\theta) + T_e^* \cdot f_y(\theta)$$



SRM Control

Improved Torque Distribution Control - TDF III method:

Distribution
functions:

$$f_x = \frac{g_x^2}{g_x^2 + g_y^2}$$

$$f_y = \frac{g_y^2}{g_x^2 + g_y^2}$$

Where

G-functions:

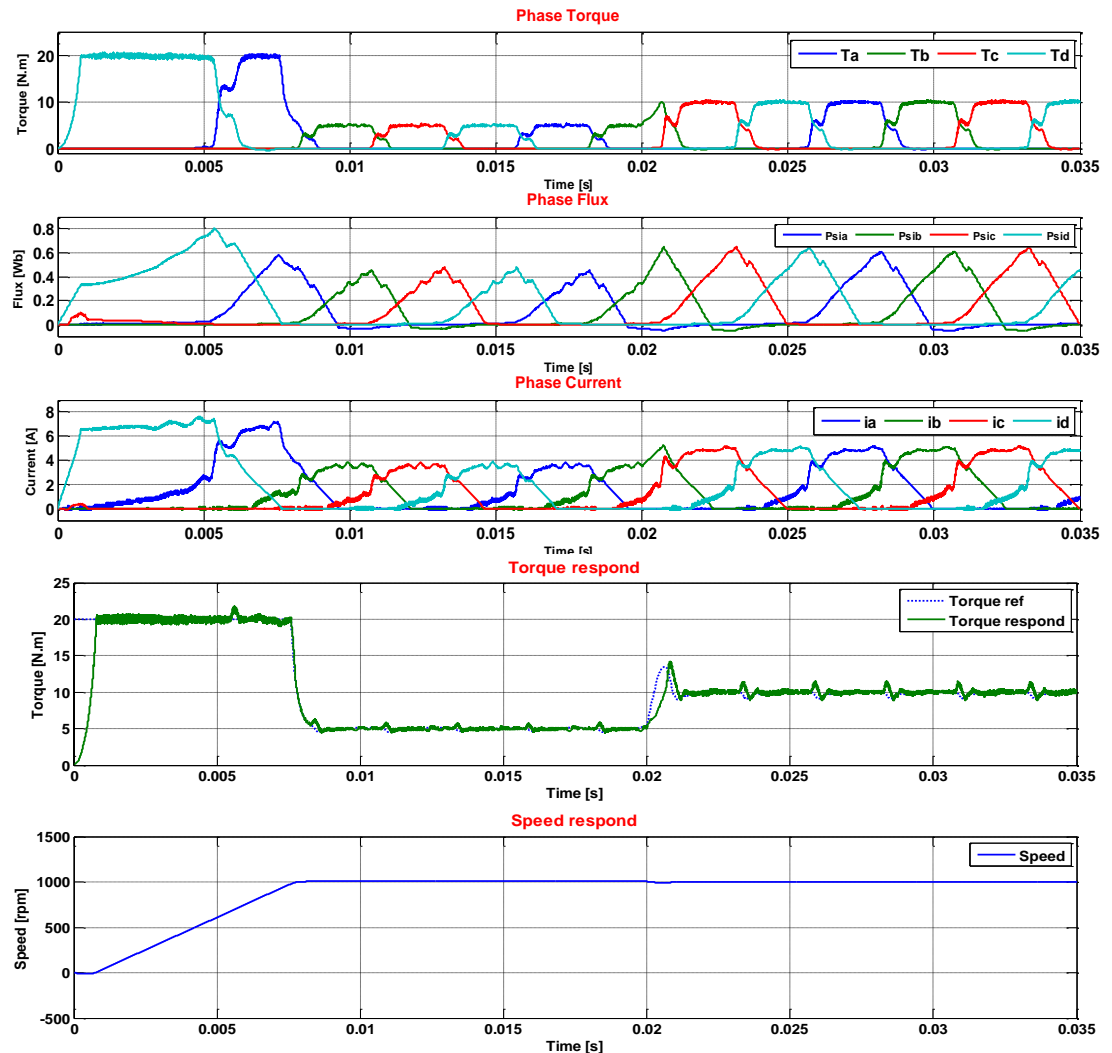
$$g_x = \frac{\partial L_x(\theta, i_x)}{\partial \theta}$$

$$g_y = \frac{\partial L_y(\theta, i_y)}{\partial \theta}$$

Reference
currents:

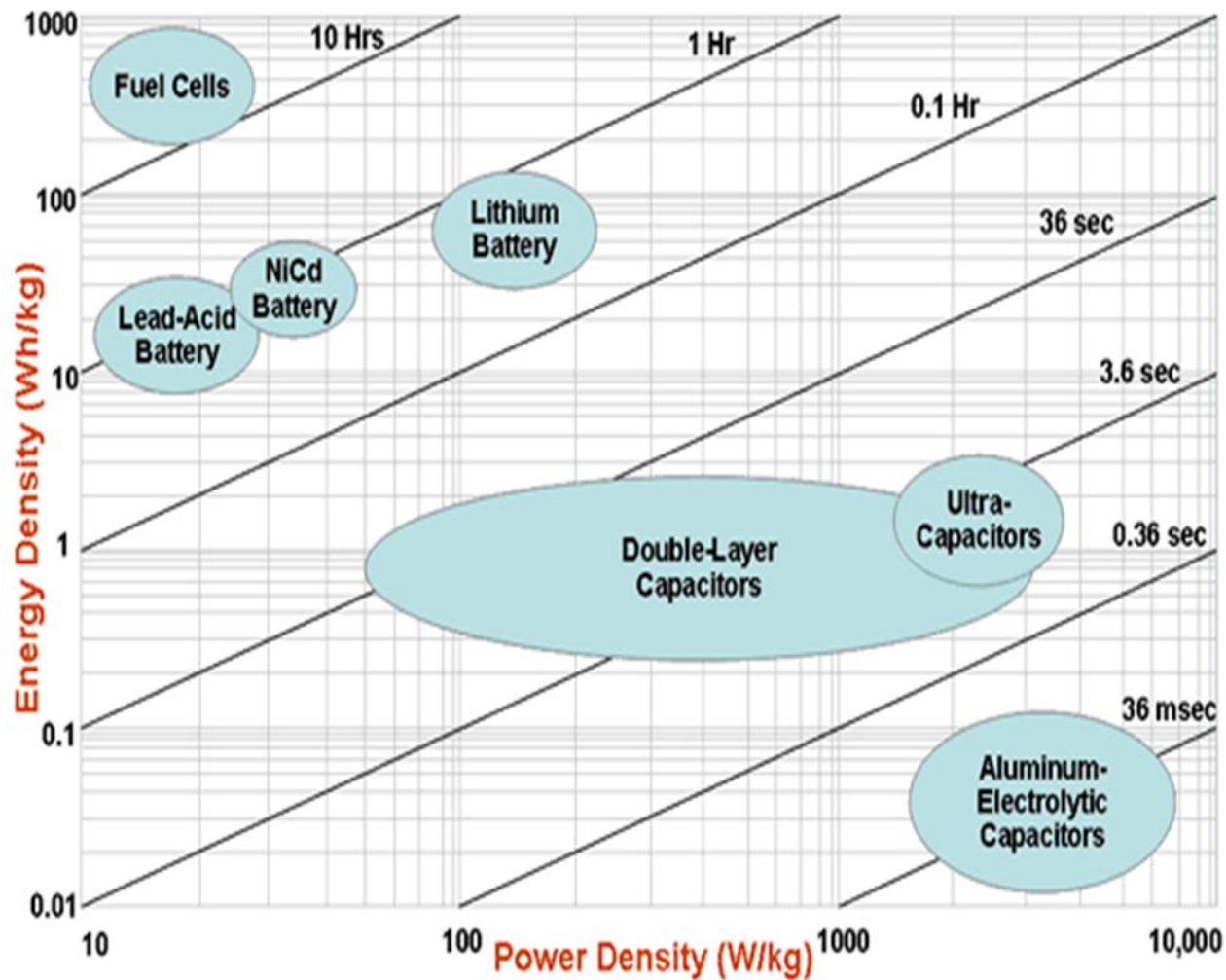
$$i_x^* = \sqrt{\frac{2T_x^*}{g_x}} = \sqrt{\frac{2g_x T_e^*}{g_x^2 + g_y^2}}$$

$$i_y^* = \sqrt{\frac{2T_y^*}{g_y}} = \sqrt{\frac{2g_y T_e^*}{g_x^2 + g_y^2}}$$

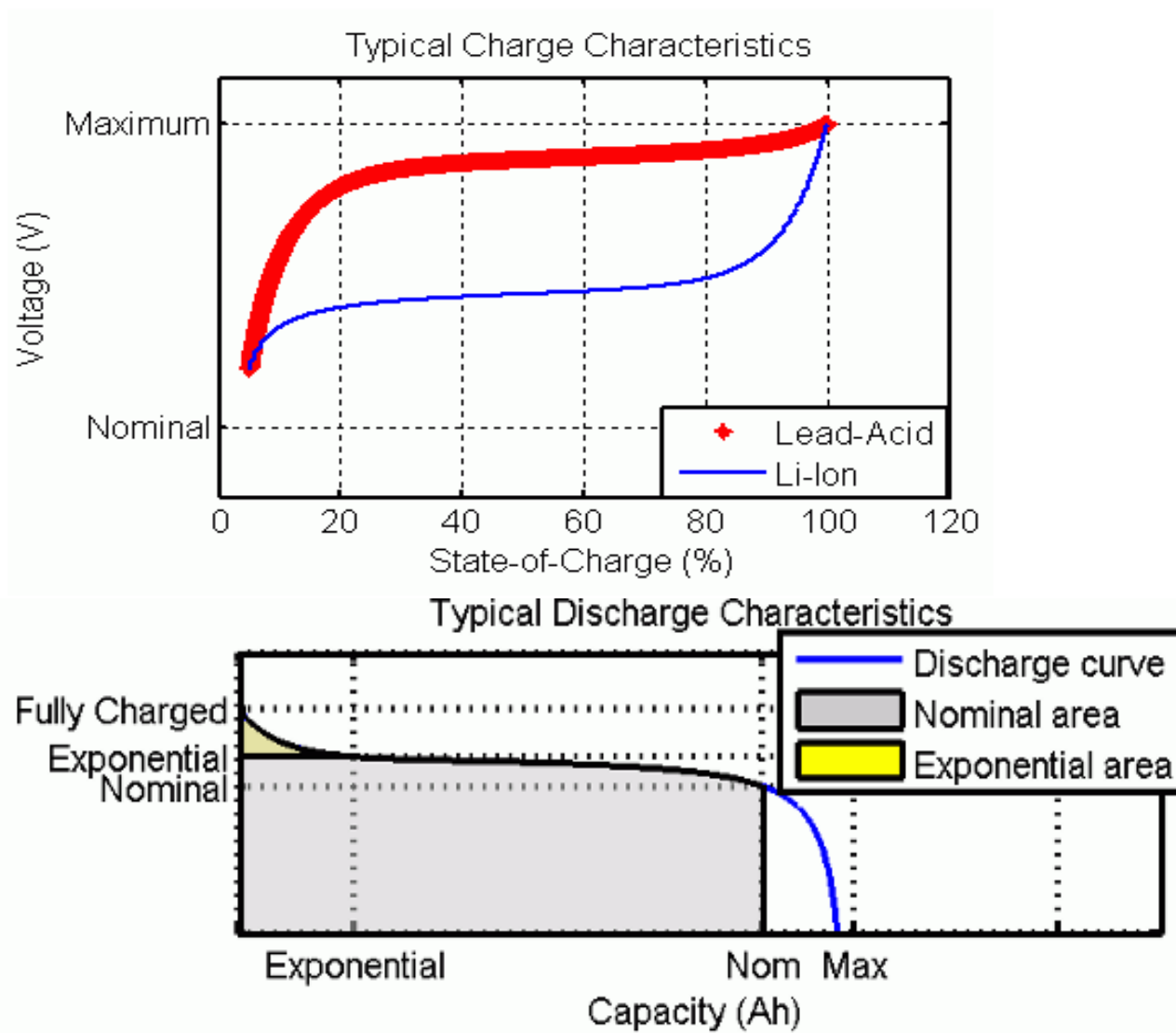


4. Storage and Charging Systems

4.1. Storage Technology



Battery: charge and discharge



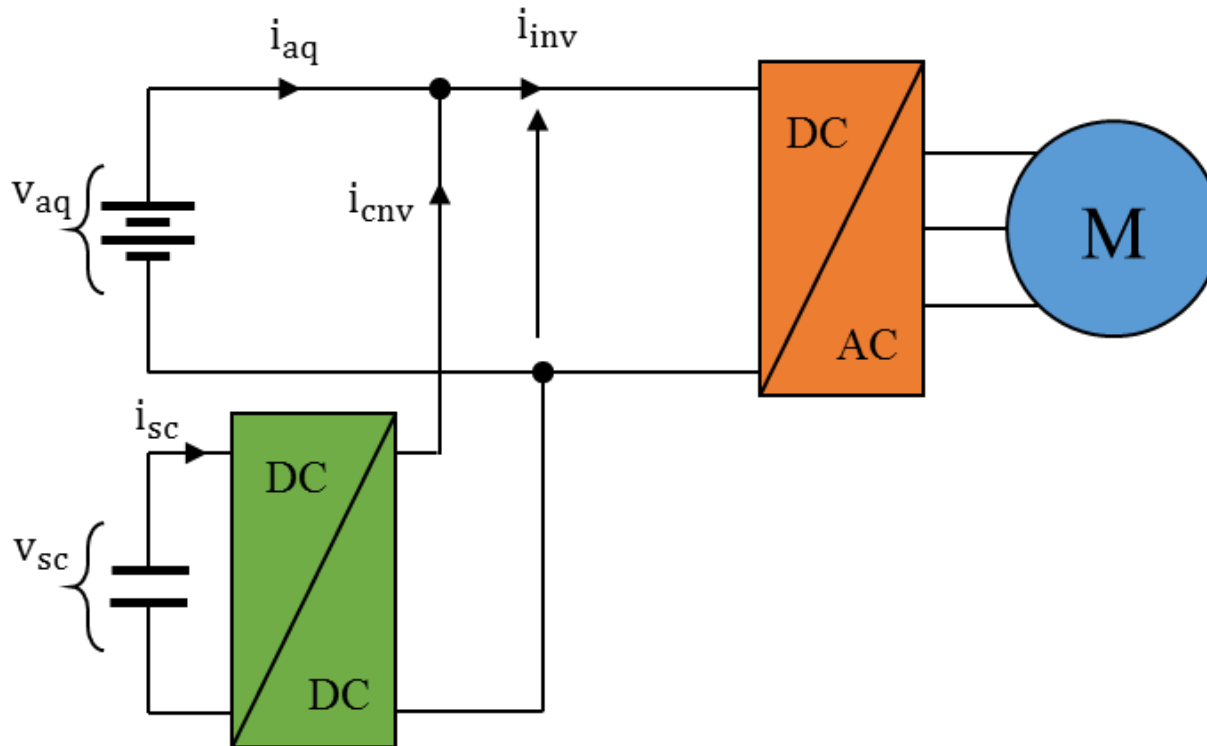
Charging stations

- Charging station



Recent Technology: Energy management

- Energy management: Hybrid Electrical Storage System (HESS)



Conclusion

Electric Vehicles:

- Old history, New challenges
- EV control: Motor control & Motion control
- Actual problem of EV: Energy storage

Solution ?

- Quick charging station
- New form of storage (fuel cells)
- New materials
- Dynamic Power Transfer (WTP) = Electric route

Solution for Vietnam:

- E-Buses, Electric cars, E-motorcycles
- A collaboration of:
 - Government: Policy, Infrastructures
 - Enterprises: Production, Infrastructures
 - Universities/Research Institutes: Research, Technology Transfer

R&D: Enterprises + Universities

Thanks for your intention !

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