Electric Machinery (EE3820)
(電動機械)

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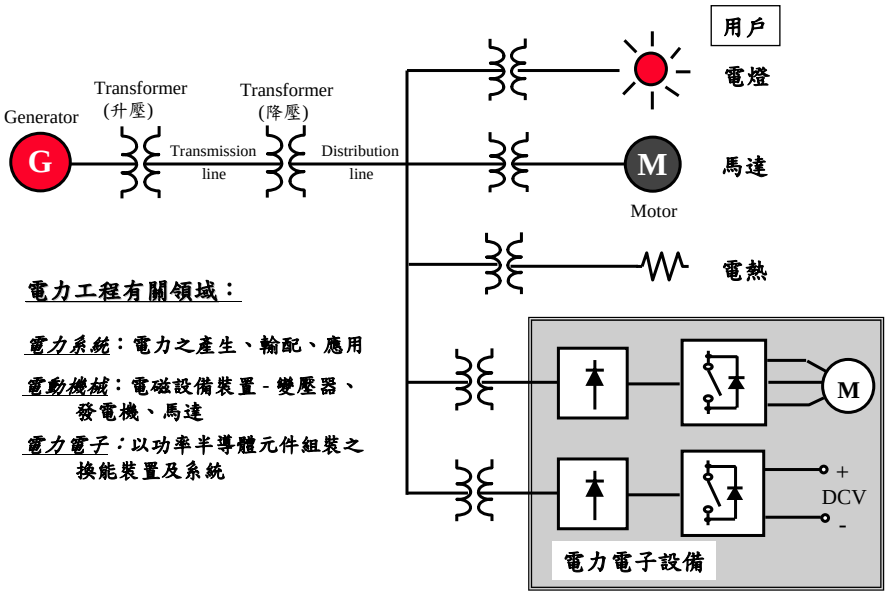
電動機械簡介 (Introduction to Electric Machinery)

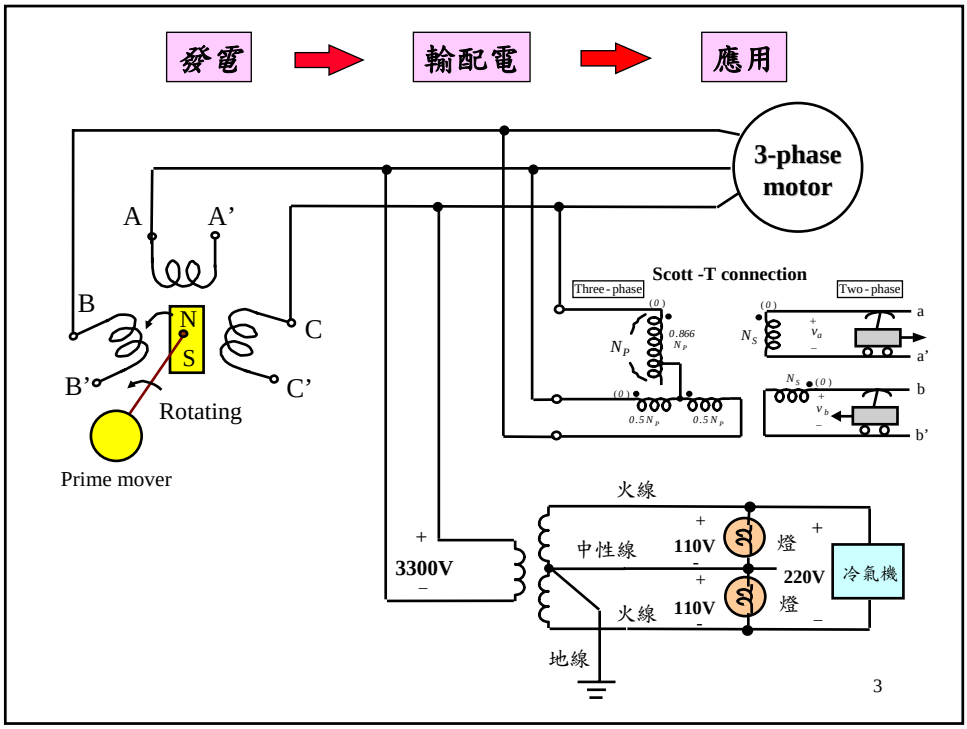


電力工程有關領域：

電力系統：電力之產生、輸配、應用

電動機械：電磁設備裝置 - 變壓器、發電機、馬達

電力電子：以功率半導體元件組裝之換能裝置及系統



電動機械課程概要

■ 課程目的

電動機械(Electric Machinery) 主要介紹藉電磁作用做能量轉換之裝置，含運動型(線型及旋轉型)電機、靜止電機型(變壓器)。

(1) 運動(線型及旋轉型)電機：

發電機 (Generator)： 電能 ← *磁能* ← 機械能

電動機(馬達)(Motor)： 電能 → *磁能* → 機械能

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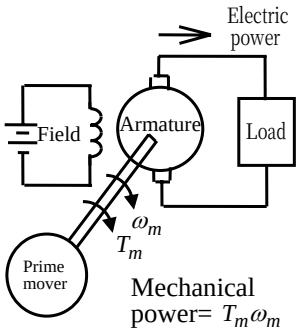
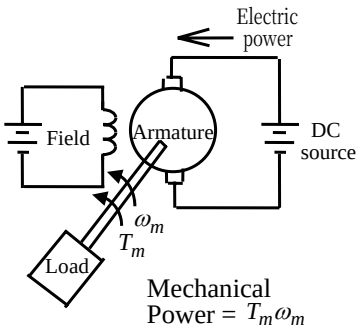
以直流電機為例

直流發電機



Mechanical
power= $T_m\omega_m$

直流電動機



Mechanical
Power = $T_m\omega_m$

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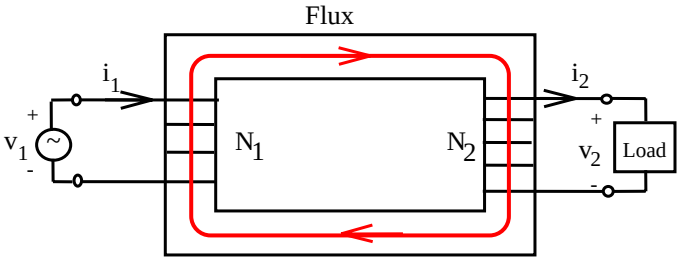
(2) 靜止電機：

變壓器(Transformer)：電能 → *磁能* → 電能



變壓器之主要功能：

- ☒ **變壓或變流：V1/V2= I2/I1= N1/N2。**
- ☒ **阻抗轉換(Impedance transformation)。**
- ☒ **隔離(Isolation)。**

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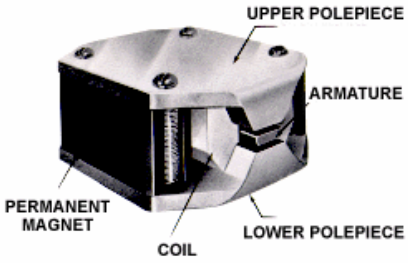
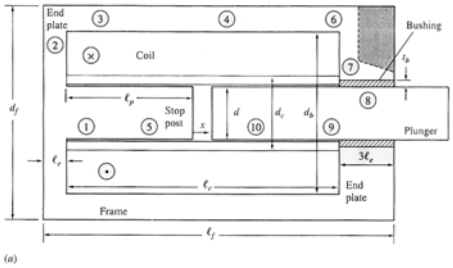
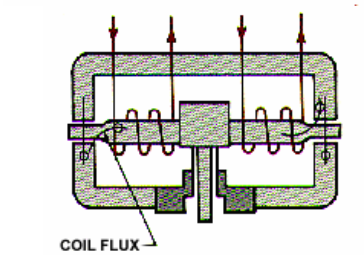
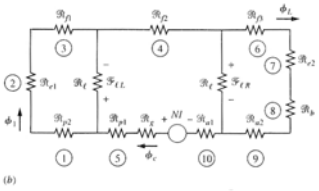
Linear Actuators

❑ **Electromagnetic Valves**









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發電機與電動機之分類

- 發電機與電動機在結構上一樣，僅作用方式不同。兩者在機械結構上，均具有定子(Stator)與轉子(Rotor)；在電磁作用上，具有磁場繞組(Field winding)與電樞繞組(Armature winding)。磁場繞組與電樞繞組設置於定子與轉子之方式有兩種方式：

Case 1: 如直流機		Case 2: 如同步機	
磁場繞組	定子	磁場繞組	定子
電樞繞組	轉子	電樞繞組	轉子

- 發電機與電動機在作用之方式上為：

電動機	發電機
在磁場中之導體通以電流，產生力進而使承載導體之轉子產生轉矩.	在磁場中之導體被外力帶動，產生電動勢，可供給電負載產生電流.

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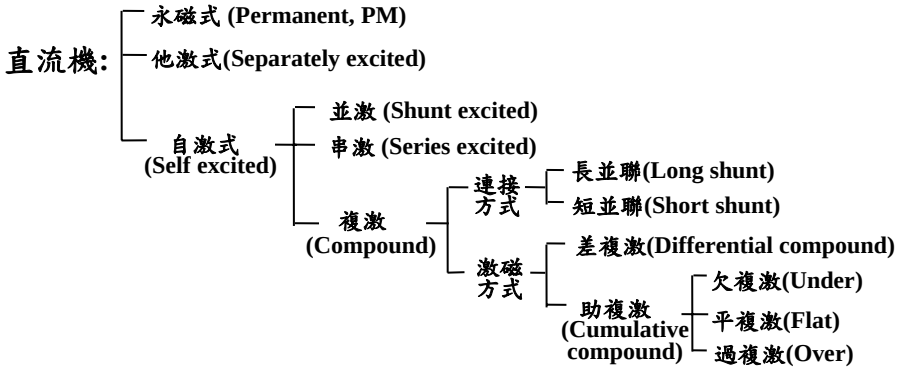
旋轉電機（發電機與電動機）



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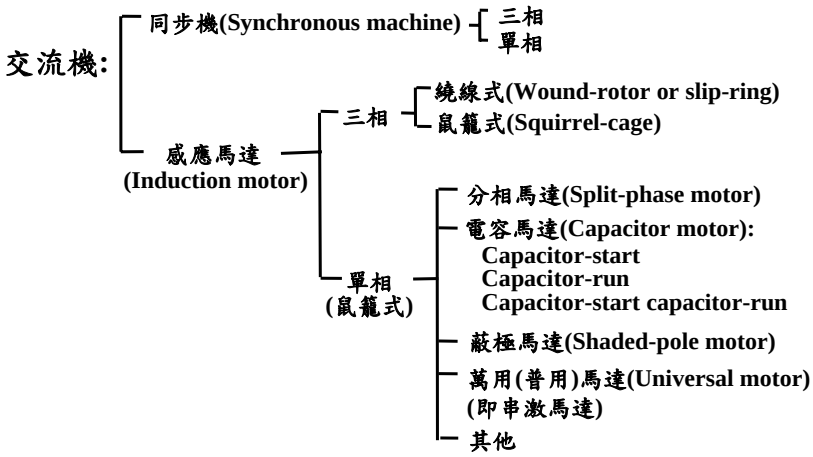

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變 壓 器 (Transformers)

- 非隔離式變壓器: 自耦變壓器(Autotransformer)
- 隔離式變壓器

- 單相變壓器
- 三相變壓器

- 儀錶變壓器
  - 比壓器(Potential transformer, PT)
  - 比流器(Current transformer, CT)
- 脈衝變壓器(Pulse transformer)
- 其他

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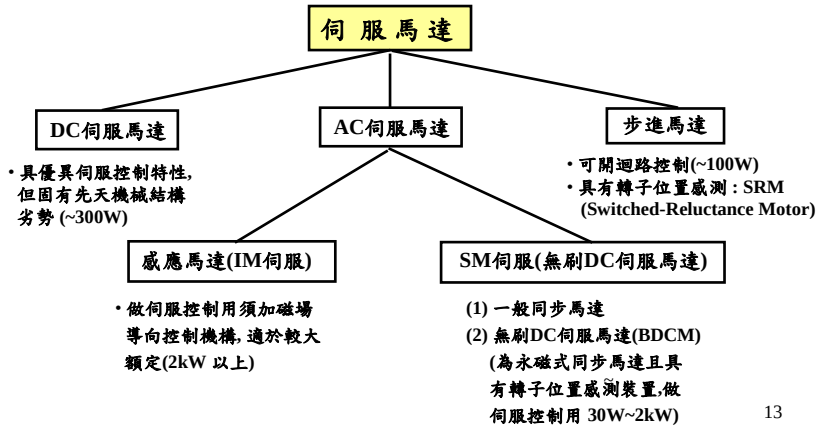
馬達驅動系統

- 在馬達驅動系統中，電動機作為機電介面，為一重要之致動器(Actuator)，也用到了隔離變壓器。馬達驅動系統可分為速度控制驅動系統與伺服控制驅動系統，適合用為伺服控制之馬達如下：



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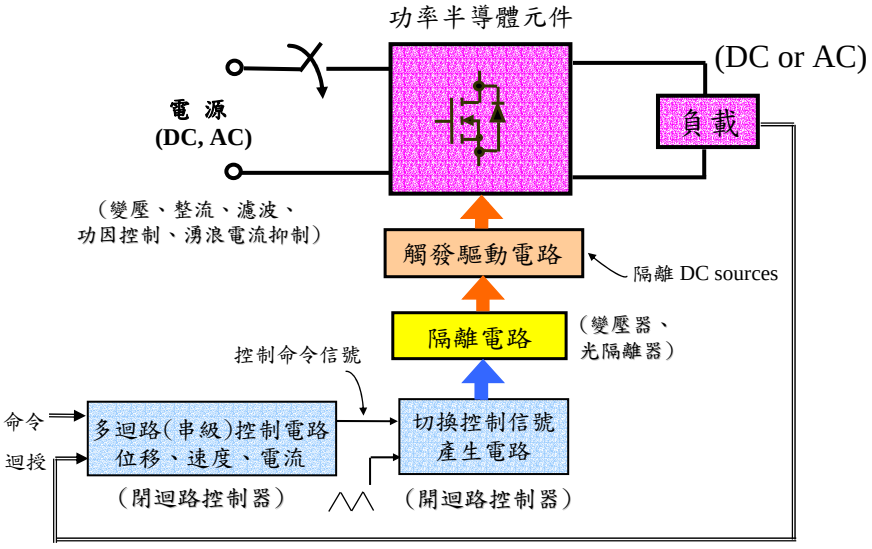
電力電子系統基本組成



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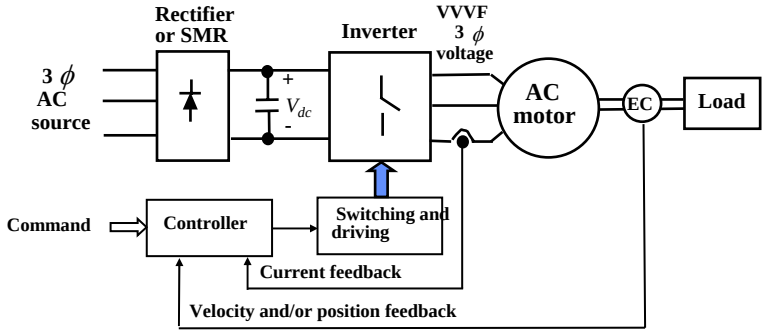
馬達驅動系統

- 為一含*馬達、機械、轉換器、控制器、感測與轉換*等之整合系統，唯有馬達本身之適當設計與驅動系統組件間之妥善搭配，始可得優良之運轉控制性能



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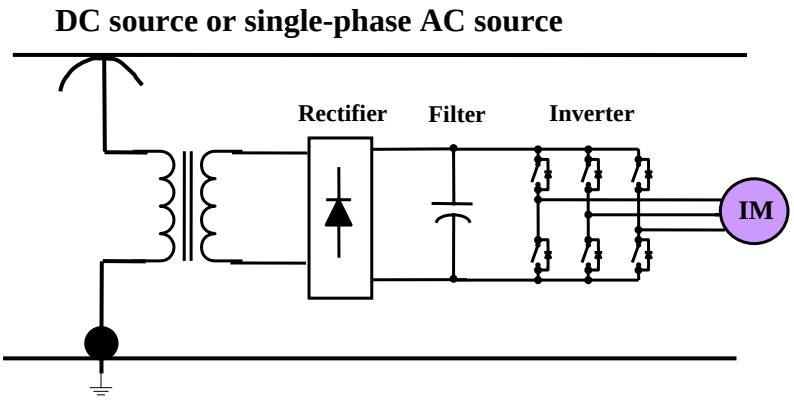
軌道車輛馬達驅動供電系統



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台灣自強號:
EMU-100的基本資料

製造廠商	英國GEC公司
製造年份	1979
單組配置	(南端)EP-EM-ET-ET-ED(北端)
最高車速	120km/h
出力	1275 kw/1710 hp
單組全長	101.8公尺
車輛編組	EP-駕駛動力車 EM-馬達客車 ET-拖車*2 ED-駕駛拖車
保安裝置	自動警告/自動停車輔助系統 ATW/ATS 警醒裝置 運轉專用無線電話
軔機系統	西屋西碼式氣軔系統
座位	EP-44位 EM-52位 ET-52位 ED-44位
現有車數	63輛13組(資料有誤,其實更少)
編組運用	最多可三組重作總控制運轉

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Japan - Osaka

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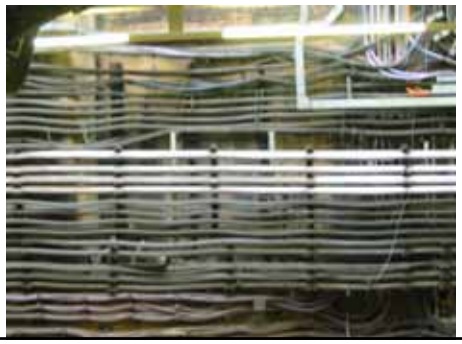
London






Hong Kong

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Vienna

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Germany

台灣輕軌電車LRV-II

Light rail (**streetcar**, **tramway**, or **trolley**) is lightweight passenger rail cars operating singly (or in short, usually two-car, trains) on fixed rails in right-of-way that is not separated from other traffic for much of the way. Light rail vehicles are typically driven electrically with power being drawn from an overhead electric line via a trolley or a pantograph.

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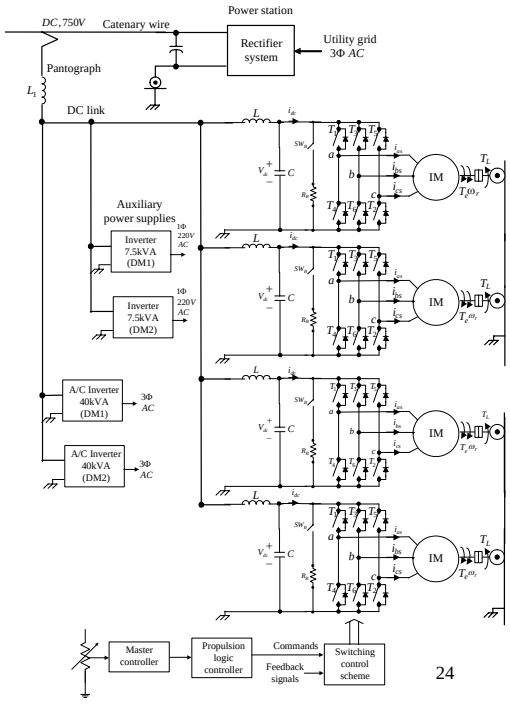
變頻器供電三相感應馬達驅動之LRV系統

☒ 由直流鏈、動態煞車電路、變頻器供電之馬達及其機械耦合、輔助電源供應器等組成。



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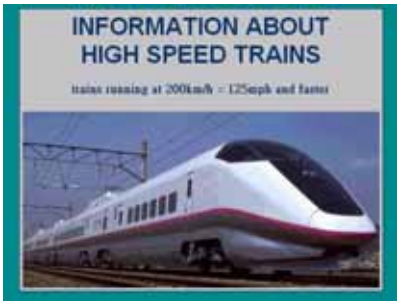

USA: Amtrak's Acela (245 km/h = 150mph)

Sweden: Arlanda Express (200km/h = 125mph)

Spain: Renfe's Alaris Tilting Trains (220 km/h = 135 mph)

Sweden: x2000 (200 km/h = 125 mph)

USA: California High Speed (320 km/h = 200 mph)

Italy: High Speed Train ETR 500 (300 km/h = 190 mph)

Finland: RHK's Pendolino (220 km/h = 135 mph)

Florida Overland Express FOX (320km/h = 200mph)

Norway: The Gardermoen line (210 km/h = 130 mph)

Germany: InterCity Express ICE (300 km/h = 190 mph)

Australia: Queensland Rail's High Speed Line

Japan: JR Central's Shinkansen (270km/h = 170mph)

Australia: Speedrail High Speed Railway (320km/h = 200mph)

Switzerland: Tilting High Speed Trains (200 km/h = 125 mph)

Taiwan: High Speed Railway Administration (300 km/h =186 mph)

France: SNCF's TGV Train Grande Vitesse (300 km/h = 186 mph)

South Korea: Korean National Railroad's TGV (300 km/h = 186 mph)

Benelux/German/France: Thalys PBKA (300 km/h = 186 mph)

UK: Railtrack's West Coast Main Line (225 km/h = 135 mph)

China: High Speed (250 km/h = 155 mph)

Japan- 山陽新幹線

Japan- 九州新幹線

Typical ratings of High-speed trains

ICE2

locomotive mass 78 t
2nd class car 47.4 t (806)
power (cont.) 5000 kW
tractive eff. 200 kN
top speed 280 km/h
mass/length 2.035 t/m
mass/seat 1.13 t/seat
power/mass 11.96 kW/t
power/seat 13.51 kW/seat

Source http://mercurio.iet.unipi.it/ice/ice2.html

ICE 3

Data for type 403 train

Max axle load 16 t
Length 200.32 m
Width 2.95 m
Height 3.89 m
Mass (empty) 409 t
Power (cont) 8000 kW
Top speed 330 km/h
Mass/length 2.042 t/m

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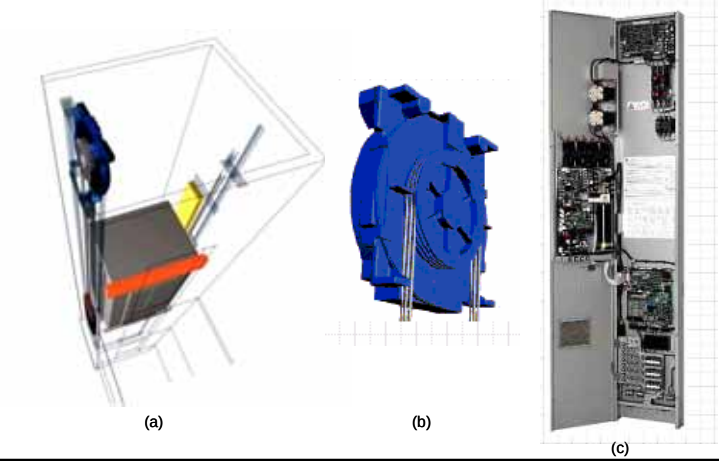
新式電梯馬達驅動系統：

- 不再有專屬之馬達、變頻器及控制盤安裝間。
- 馬達需有扁平薄型化之結構特徵，以方便安裝於梯間之牆壁。
- 馬達之設計朝低銅損、易於散熱、低轉矩漣波、低噪音特性改進。
- 變頻器及控制器朝小型化設計，以方便容設於牆壁內之容室內。



(a) (b) (c)

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Elevator Traction-Machine Motors

- ***Key features of motors:***
  - ☒ Motor drive must have high reliability.
  - ☒ Higher torque for accelerating elevator car and smaller ripple torque to yield comfortable ride.
  - ☒ Compact and thin motor structure for meeting the machine room-less requirement.
  - ☒ Motor type: concentrated armature winding PMSM: the used PM should posses high long-term resistance to demagnetization. The temperature coefficient and aging effect should be considered.

3.7kW, 93rpm

- ***Key issues for ripple torque reduction of PMSM:***
  - ☒ PM shape optimization.
  - ☒ Winding arrangement: the ratio of pole and slot numbers, the skew arrangement.
  - ☒ Thin PMSM motor (thin thickness and large diameter):
    - Concentrated winding.
    - The magnetic saturation effect should be considered: the shapes and dimensions the stator teeth and the shapes of the permanent magnets.
    - Manufacturing tolerances lead to the increase of ripple torque.

Mitsubishi Electric ADVANCE, vol.103, pp. 2-4, 2003.

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Example: phono-motor, outer-rotor motor

Three-phase, square-wave BDCM, Hall sensor

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Example: Fan motor, outer-rotor motor

Two-phase, square-wave
BDCM, Hall sensor

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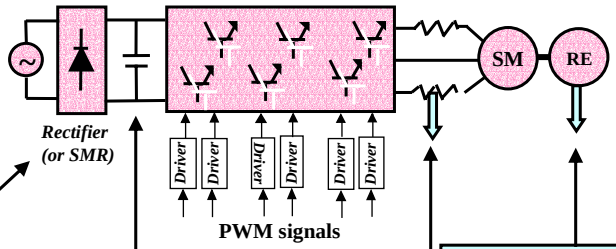
Practical Issues In Inverter Miniaturization



- Line drawn power quality requirement.
- SMR may be needed, which can be used to boost the DC link voltage, but its control scheme realization should be considered.

- Miniaturization of filtering bulk capacitor.
- Braking resistor.

- Isolated coupling for PWM signal.
- Isolated DC sources for IGBT gate driver circuits.

- Incremental or absolute type of position sensors.

- Current sensors and their signal conditioners.

The kinds of lines and connectors.

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Toshiba Products

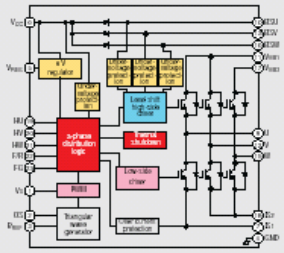
■ *Smaller rating: IGBT module + gate driver + square wave PWM scheme*

Single Chip inverter
TPD4102K / TPD4103

Full integrated bridge for DC Brush Less Motor Drive

Voltage : 500V , 1A (DC) / 2A (PEAK)

TPD4102K outline

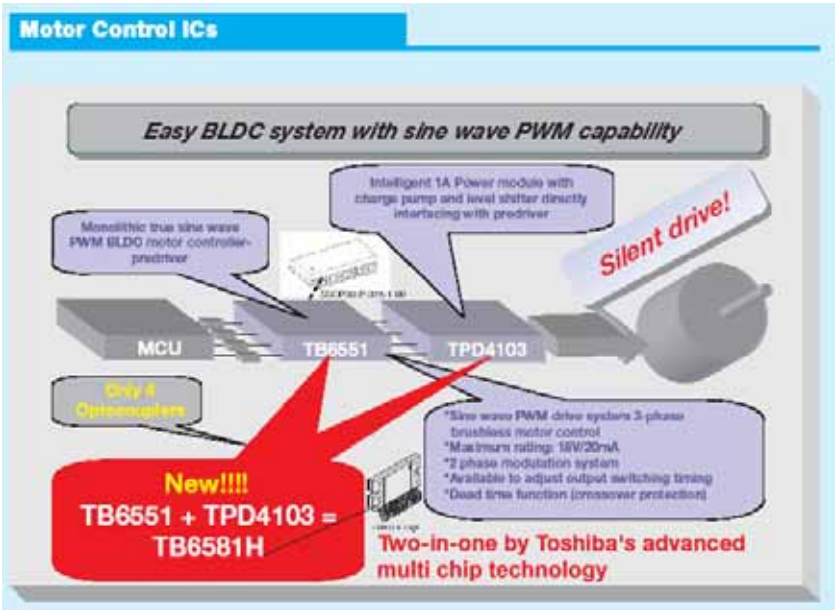


- □PWM circuit and 3 phase matrix are built-in.
- □Utilizing the low saturation lateral IGBTs/FRDs.
- □High side drive power supply is unnecessary by the bootstrap system.
- □High voltage level shifter is built-in.
- □Protection and diagnosis functions :
  output over current / over heating / VCC supply under voltage

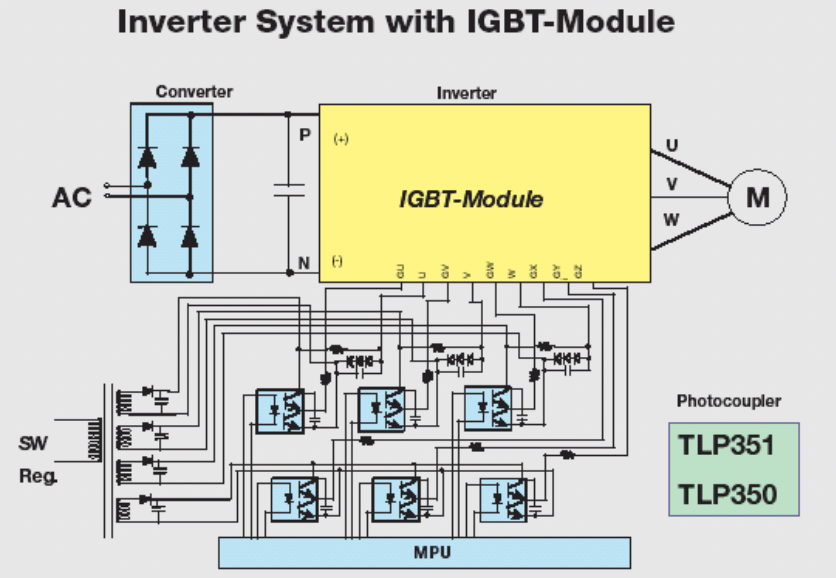
TPD4102K: full inverter incl. square waveform generation (for stand alone usage)
TPD4103K: inverter without wave generator (for MCU generated waveform)
TPD4103AK: like 4103K without overcurrent lockout on board (for sine wave controller IC TB6P551F)

www.toshiba.co.jp/index.htm

■ *Smaller rating: Single chip inverter + sine wave PWM predriver IC*



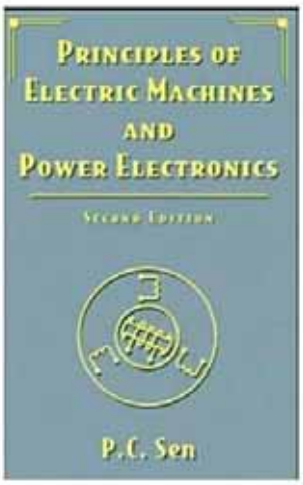
Intelligent Power Module Based AC motor drive



P.C. Sen, Ph. D, Fellow IEEE
PRINCIPLES OF ELECTRIC MACHINES AND POWER ELECTRONICS
Second Edition (1997),
John Wiley and Sons, New York

(This best seller text book, used worldwide, presents a comprehensive coverage on electrical machines with relevant topics in power electronics and electric drive systems. A large number of examples and Problems are included in each chapter. The ten chapters and five appendices are as follows:

Chapter 1: Magnetic Circuits
Chapter 2: Transformers
Chapter 3: Electromechanical Energy Conversion
Chapter 4: DC Machines
Chapter 5: Induction (Asynchronous) Machines
Chapter 6: Synchronous Machines
Chapter 7: Single-Phase Motors
Chapter 8: Special Machines
Chapter 9: Transients and Dynamics
Chapter 10: Power Semiconductor Converters
Appendix A: Windings
Appendix B: Balanced Three-Phase Circuits
Appendix C: Units and Constants
Appendix D: Laplace Transforms
Appendix E: Answers to Odd-Numbered Problems



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