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Dr. Liaw was born in Taichung, Taiwan, ROC, on June 19, 1951. He received the B.S. degree in electronic engineering from Tamkang College of Arts and Sciences, Taipei, Taiwan, in 1979, and the M.S. and Ph.D. degrees in electrical engineering from National Tsing Hua University, Hsinchu, Taiwan, in 1981 and 1988, respectively. In 1988, he joined the faculty of National Tsing Hua University as an associate professor in electrical engineering. Since 1993, he has been a professor in the Department of Electrical Engineering. His areas of research interest are Power Electronics, Motor Drive and Electric Machine Control. Dr. Liaw is a life member of the CIEE, a member of the IEEE an editor of International Journal of Electrical Engineering, ROC. and an editorial board member of IET Power Electronics.

Publication List

1. Journal Papers:

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2. Conference Papers:

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[55] “Optimal design for traction system of a light-rail vehicle (II),” Supported by Chung Shan Science Research Institute, (93.01.01~93.12.31), 2004.
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[64] “Development of sensorless control technology for sinewave driven permanent-magnet synchronous motor (I),” (95.03.16-95.11.30, NT$ 490,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2006.
[65] “Application of a battery energy storage system to a distributed power system,” (95.01.01-95.12.31), Supported by Nuclear Science Council, 2006.
[66] “Development of sensorless control technology for sinewave driven permanent-magnet synchronous motor (II), (96.03.01-96.11.30, NT$ 490,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2007.
[67] “Control strategy study for energy saving of freezer and Refrigerator- 1,” (96.03.01-96.07.02, NT$ 190,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2007.
[68] “Control strategy study for energy saving of freezer and Refrigerator- 2,” (96.09.01-96.11.30, NT$ 190,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2007.
[69] “Establishment of reaction wheel system and its robust dynamic control,” Supported by

Chung Shan Science Research Institute, (96.03.05~96.12.15), 2007.

[70] "Development of some key technologies for modular inverter building blocks (1/2)," Supported by National Science Council, (95.8.1-96.7.31), 95-2221-E-007-260-MY2, 2007.

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[72] "Development of some key technologies for modular inverter building block (1/2,2/2)," Supported by National Science Council, (95.8.1-97.7.31), 95-2221-E-007-260-MY2, 2008.

[73] "Key tuning control technology and application studies for permanent-magnet synchronous motor drive (1/3)," Supported by National Science Council, (96.8.1-97.7.31), 96-2221-E-007-172-MY3, 2008.

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[75] "Control strategy study for energy saving of freezer and Refrigerator- 4," (97.10.16-97.12.15, NT$ 160,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2008.

[76] "Development of sensorless control technology for sinewave driven permanent-magnet synchronous motor (III), (97.03.05-96.11.30, NT$ 430,000), Supported by Energy and Environment Laboratories, Industrial Technology Research Institute, 2008.

4. Other Publications:

[1] "System parameter estimation from sampled data" Control and Dynamic Systems, Vol. 63, pp. 161-195, Academic Press, 1994.

[2] "Fuzzy control with reference model following response", Academic Press, Fuzzy Theory Systems: Techniques and Applications, Vol.1, pp.129-158, 1999.

5. Patents:

[1] "A multi-functional small battery energy storage system" (81153), (with Mr. C. M. Lee), 1993.3.21-2003.3.20. (with Mr. C. M. Lee).

6. 榮譽：

(1) 教學：傑出教學獎(80年、84年)

(2) 研究：

- 國科會優等研究獎 (80年、81年、82年、83年)
- 國科會甲等研究獎 (84年、85年、86年、87)
- 國科會傑出研究獎 (88年、89年)
- 國科會傑出研究獎 (92年、93年、94年)

Current Projects

Project Title: Development of some key technologies for modular inverter building blocks
Principal Investigator: C. M. Liaw
Funding Source: National Science Council, ROC. (08/2006-07/2008)

Project Title: Key tuning control technology and application studies for permanent-magnet synchronous motor drive
Principal Investigator: C. M. Liaw
Funding Source: National Science Council, ROC. (08/2007-07/2010)

Project Title: Development of sensorless control technology for sinewave driven permanent-magnet synchronous motor (III)
Principal Investigator: C. M. Liaw
Funding Source: Energy and Environment Laboratories, Industrial Technology Research Institute, ROC. (03/2008-11/2008)

Abstarct: In recent years, permanent-magnet synchronous motor (PMSM) has been gradually employed to replace the induction motor as the actuator for home appliances. The air conditioner compressor is a typical example. In PMSM driving control, the development trends for improving its driving performance and reducing torque ripple as well as acoustic noise lie in: (i) sinewave current excitation; (ii) brushless operation with proper commutation tuning; (iii) DSP-based digital control for realizing advanced tuning control algorithms; and (iv) position sensorless control. Other affairs to enhance the performance and miniaturization of commercialized motor drives include: (i) the motor drive is equipped with switch-mode rectifier (SMR) front-end to boost its DC-link voltage and possess power factor correction control function; (ii) common power module for multi-stage power converters; (iii) common DSP for realizing multi-stage power converters; (iv) simplification of driving and dynamic controls for PMSM drive to reduce its configuration and cost.

However, to obtain a high-performance PMSM drive, it is very important to accomplish the proper match between system constituted components, the suitable tuning for key parameters, and the match between theoretical and practical issues in DSP digital control, etc. Although some academic progress in PMSM driving control has been established in our country, there still exist some key technologies to be established for the industries, such as: the development of power module for realizing converter circuit; the match between motor design and inverter-fed driving control, the development of DSP dedicated for PMSM drive control and the familiarization of control application. The major purposes of this project are emphasized on: (i) the use of domestic manufactured DSP to establish a sensorless sinewave PMSM drive with satisfactory vector control; (ii) to develop PMSM control software and to make performance evaluation for facilitating the development of commercial PMSM drive.

Project Title: Control strategy study for energy saving of freezer and refrigerator- 3
Principal Investigator: C. M. Liaw
Funding Source: Energy and Environment Laboratories, Industrial Technology Research Institute, ROC. (03/2008-07/2008)

Teaching Laboratory – Electric Machines Lab.

(Room:103, EE – CS Building)

Supported Courses:

(1). EE3830- Electrical Power Engineering
(2). EE3840- Electrical Machines Lab (V)
(3). EE4830- Power Electronics
(4). EE4840- Electric Machine Control
(5). EE4710- Electrical Power System

Facilities:

(1). MG set
(2). Power scope
(3). Power analyzer
(4). RLC load
(5). Power transformer
(6). Motor
(7). Generator
(8). Eddy-current brake
(9). Frequency converter
(10). Wattmeter
(11). Clip-on AC power meter
(12). Digital power analyzer
(13). PLC
(14). Control unit
(15). Power supply
(16). X-Y recorder
(17). Plotter
(18). Step motor
(19). Digital torque meter
(20). Spectrum analyzer
(21). Synchroscope
(22). Function generator
(23). Clamp tester
(24). Digital techometer

Research Laboratory – Electric Machine Control

(Room: 503, EE – CS Building)

Research Topic:

Electric Motor Drives and Power Converters.

Facilities:

(1). PCs
(2). Scanner (X1)
(3). Hp Laser printer (X2)
(4). Digital oscilloscape (X4)
(5). Power supply (X12)

(6). Function generator (X4)
(7). White noise generator (X1)
(8). Control system analyzer (X1)
(9). Programmable AC source (X1)
(10). Smart electric load (X1)
(11). EMI receiver (X1)
(12). Isolated amplifier (X1)
(13). Power waveform monitor (X1)
(14). Current gun (X3)
(15). Current probe amplifier (X2)

Supporting projects:

(1). Development of some key technologies for digitally controlled PWM converters.
(2). Performance improvement study of converter and control for switched reluctance motor drive.
(3). Operating performance improvement study for invert-fed motor driven air conditioner.
(4). Researches of advanced control techniques for motor drives.
(5). Optimal design for traction system of a light-rail vehicle (II).
(6). Development of digital controlled DC/DC converter.

■ 研究內容

- **轉換器及電源供應器數位控制：**

  經由計畫之執行，協助業界(台達公司、康舒公司、立錡公司等)建立轉換器之數位控制機構與控制法則之設計有關基礎，有益於未來產品之開發能力建立。

- **轉換器之一些關鍵技術開發與轉換器之 DSP 多模組並聯控制：**

  經由計畫之執行，協助業界建立了轉換器之：(1) 電路分析與設計、模式化、控制器設計與實現；(2) DSP並聯分流數位控制有關基礎，諸如：各式並聯分流控制技巧之探究比較、待並聯轉換器模組之動態模式建立、所提並聯分流控制技術之研擬、適當數位信號處理器之選定及數位控制環境之建立、數位分流控制機構之組立及偵錯、所提轉換器並聯系統之組立、所提分流控制法則之實現、所提分流控制器之性能量測及修正、以及既有類比分流控制電源供應器之數位化等。

- **線性直流無刷馬達驅動系統之建立、定位強健控制、應用：**

  (1) 促使磁滯比較 PWM 機構有能力應用於精密定位控制應用上。

  (2) 協助中科院建立了線性直流無刷馬達驅動系統之有關技術，諸如：DSP 為主馬達驅動系統之建立、定位之量化與強健控制、未知質量下之大命令定位控制、線性馬達之實際應用等。

- **隨機 PWM 調制技術及諧波頻譜整型技術之開發：**

  (1) 提出隨機 PWM 機構之量化設計技術以及開發諧波頻譜之整型技術。

(2) 將上列技術應用於多種設備，諸如：馬達驅動系統、線性直流無刷馬達驅動系統、振動機、切換式整流器。

- **輕軌車之組成系統之搭配及設計、其驅動特性模擬系統建立研究：**

協助中科院從事輕軌電車儀電系統最佳化設計研究，建立了一些關鍵基礎，如：了解輕軌電車之組成及其驅動操控特性、輕軌車之規格整理與分析、行車控制電路分析、馬達及其變頻切換控制分析、馬達驅動與煞車電能轉換分析、輕軌車機電系統之建模及模擬、輕軌車牽引系統之測試及偵錯、輕軌車之電力系統及電力品質分析、輕軌車之輔助電源電路分析、輕軌車系統組成元件之匹配及最佳化分析設計等。協助從事現場量測、開辦有關訓練課程。

- **電磁閥之設計與激勵控制：**

一個閥驅動系統之操控性能甚受線圈之激磁電流響應特性、電磁閥之磁路及機械設計、被驅動系統組成與閥驅動特性之配合等方面之影響，唯有妥善之搭配始能獲得理想之總體性能。截至目前已有許多研究有關於電磁螺線管閥驅動性能之精進，諸如：驅動電源電路、電磁閥之磁路分析與設計、被驅動負載之動態特性、動態模式化及控制、模擬等。然而欲得一較佳之電磁閥驅動系統操控性能仍然有許多值得再研究之處。透過計畫之執行協助中科院從事具高速反應電磁閥機構之磁路分析設計、驅動電路之研製、以及電磁閥伺服定位驅動控制等，以獲得所欲之推進響應特性。

- **無感測直流無刷馬達驅動系統之開發：**

(1) 協助工研院能資所提升空調機驅動特性之精進，開發一弦波激磁之無感測內置磁石永磁式同步馬達(IPMSM)驅動系統，並從事其特性改善研究。有關研究項目含馬達結構特徵、動態模式及參數估測、電流強健控制、激磁及換相調控、無感測控制等。首先，從 IPMSM 的結構特徵和主導方程式，可以發現 IPMSM 具有凸極效應，使其轉矩產生能力優於 SPMSM。再者，IPMSM 之轉矩產生能力可藉由激磁場和換相時刻之適當調整而予以提升。等效電路係從事分析與設計所不可或缺者，計畫提出估測方法，可估測得到 IPMSM 之等效電路參數，尤其是隨轉子位置變化之線圈電感。為了從事特性測試，計畫組立一以 DSP 為主之 IPMSM 直流無刷馬達驅動系統。在操控特性改善上，為了增進驅動能力，首先設計一強健電流控制 PWM 機構，使線圈電流能緊密地追隨其弦波電流命令，且電流之追蹤響應特性能較不受馬達參數變化和馬達電動勢擾動之影響。激磁場和換相時刻之變化對馬達驅動性能之影響，先經由理論分析和實驗觀察，並證明調整換相角度有等效於調整激磁場之效用；再根據觀察到之現象，提出一智慧型之換相角度自動調整控制技巧來獲得最小之馬達引入電流，亦即獲得最大之轉矩產生能力。在 IPMSM 之無感測控制方面，計畫著重於應電勢法，但藉由感測線圈相電壓取代馬達反電動勢施行控制，避免微分器因雜訊影響而不易實現之問題。適當的設計同步馬達啟動及速度估測機構，並加上強健電流控制器以提升其驅動性能。為了消除從同步馬達模式切換到直流無刷馬達模式時之過大暫態電流，計畫提出一無跳躍轉移控制策略。

(2) 從事應用於空調機之脈幅/脈寬調制變頻器之研製、變頻馬達驅動空調機之運轉

性能改善研究、及其他效率增進可行性探究。變頻空調機係一整合系統，組件間需妥適搭配。在馬達方面，宜有合適之變頻器與切換控制方式，而對其關鍵參數適當之調適可得較佳之轉矩產生能力、冷凍特性、轉換效率等。其他性能指標善含：電力品質、噪音、電磁干擾等。變頻器之直流鏈如由前端切換式整流器建立可調其電壓，如施行 PAM 及 PWM 混合切換控制，可得全速度及負載範圍之高效率驅動特性，以及高電力品質入電特性。大部分現有之切換式整流器均係定壓調控，故本計劃從事動態昇壓及穩態電壓調控事務之研究。在 PAM 及 PWM 混合切換控制方面，目前已有者大致為高速重載下採 PAM，低速輕載下以 PWM 調控溫度，計畫亦探究較佳之混合切換控制策略。

(3) 多級電力電路之共同 DSP 數位控制。

(4) 特殊應用之 PMSM 驅動系統研製，如衛星反應輪、冷凍冷藏設備等。

- **再生能源分散式配電系統及其緩衝除能系統。**

- **開關式磁阻馬達之先進轉換器及驅動控制技術開發：**

(1) 從事下列研究：(a)探究暨有之電源介面轉換器；(b)開關式磁阻馬達、轉換器、電源間之能源轉換與搭配實務考量研究；(c)具增壓與充電功能之雙向電源介面轉換器之研擬與電路設計；(d)設計所提轉換器電路之切換控制機構；(e)設計所提轉換器電路之電流控制機構；(f)設計所提轉換器之電壓控制機構；(g)設計所提轉換器電路之電力品質調控控制機構；(h)強健控制技術之開發。

(2) 從事下列研究：(a)探究暨有硬切式轉換器電路及脈寬調變控制技術、軟式轉換器電路及其切換控制技術；(b) 所提硬切式轉換器電路之脈寬調變控制技術之開發；(c) 隨機脈寬調變於開關式磁阻馬達驅動系統之效用探究；(d) 開發隨機脈寬調變控制技術及其於開關式磁阻馬達驅動系統之應用；(e)所提軟切式轉換器電路之開發；(f)所提軟切式轉換器之電路與切換機構之設計、製作；(g) 開關式磁阻馬達驅動系統之模式估測與動態控制。

(3) 從事下列研究：(a) 開關式磁阻馬達轉換器及切換機構之模組化研究；(b) 換向時刻移動調整與弱磁之等值性探究；(c)直流輸入電壓增壓配合換向調控對開關式磁阻馬達操控性能影響之探究；(d) 直流輸入電壓增壓配合電流波形規劃之切換控制探究；(e)研擬及實現所提之調控法則；(f) 馬達之動態模式研擬與估測；(g)分析及設計所提之電流及速度控制器；(h)變動效應之消除補償控制；(i)速度之強健控制；(j) 噪音及振動之消除控制；(k)隨機PWM切換控制。

(4) 開關式磁阻發電機。

(5) 以既有三相IPM建構SRM驅動系統轉換器電路。

(6) 電池供電用於EV之SRM驅動系統研製。

(7) 利用SRM驅動系統既有電力元件及線圈建構On-board SMR 充電器。

■ 其他協助產業技術發展之具體績效

Teach some training courses (1999~2008):

RichTeh Company: Parallel operation control of converters, Switching converters: analysis, design and control, Introductory digital control for power electronic converters.

Tze-Ching Foundation of Science & Technology: Computer control of machines and processes, Power electronic technology, Mechatronics, Analysis and design of switching power supplies, PWM switching techniques for inverter-fed motor drives.

Taiwan Semiconductor Manufacturing Company Ltd.: Mechatronics, Power system.

Powerchip Semiconductor Corp.: Analysis of switching power supplies.

Industrial Technology Research Institute, Energy & Resources Laboratories: Power electronics technology, Sensorless control of BDCM, PWM techniques for inverter-fed motors, Current-mode control and parallel operation for power converters, Motor drives and their key technologies, Driving controls and applications for PMSM and BDCM drives (96.12.03-04).

Fukuta Electric & Machinery Corp.: Induction servo motor drive.

Chung Shan Science Research Institute: Motor Drive Training Course, Power electronic system grounding and shielding, Comparative driving characteristics and application selection for motors.

UMAX Data Systems Inc.: Stepping motor and its driving control.

Winbond Electronics Corp.: Battery technology.

MACRONIX International Corp.: Stepping motor and its driving control, Analysis of switching power

Yungtay Co.,Ltd.: Permanent-magnet circuit analysis and permanent-magnet synchronous motor driving control

Wu's Tech. Co.,Ltd.: DC motor driving control.

Winbond Tech. Co.,Ltd.: Introductory motor driving control principle and applications.

Delta Electronics: Power electronics Technology.

Rechi Precision Co. Ltd.: Brushless DC motor drive (2004.11.23).

ANPEC Electronics Corporation: Sensorless Brushless DC motor drives (2004.12.07).

Learning & Development, Vanguard International Semiconductor Corporation: Introductory Power Electronics.

Current Research Plants (Research Laboratory – Electric Machine Control)

(Room: 503, EECS Building)

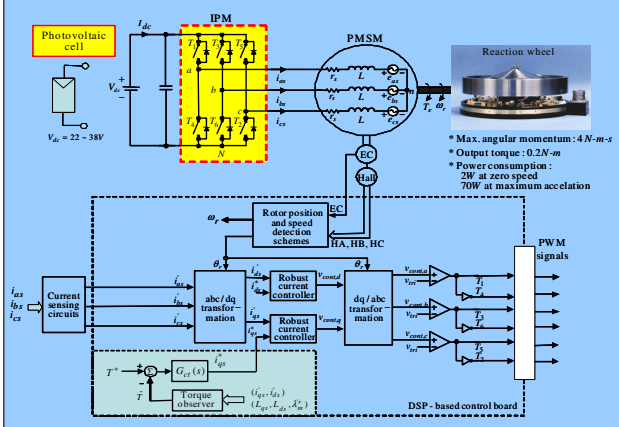
電機控制實驗室 (*Electric Machine Control Lab.*)

地 點: 資電503室　　負責老師: 廖聰明 (C. M. Liaw)

研究項目: *Power Converters, Motor Drives, Electric Machine Control*

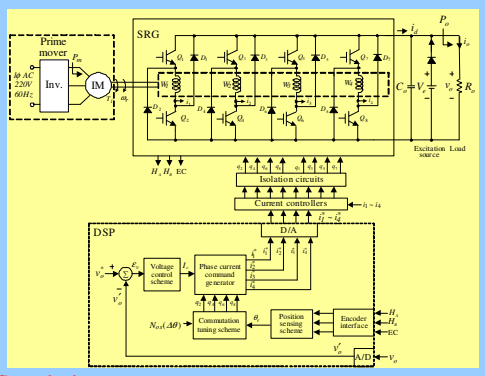
Permanent-Magnet Synchronous Motor Driven Satellite Reaction Wheel

- *PV cell powered PMSM drive.*
- *IPM-based inverter.*
- *Robust current control.*
- *Adaptive internal model control.*
- *Observed torque control.*
- *DSP-based digital control.*
- *Satellite reaction wheel.*

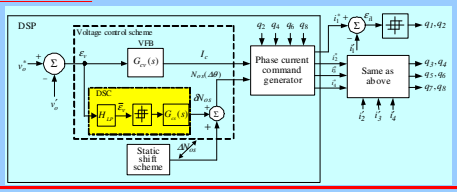


Switched-Reluctance Generator

- *Modeling, DC-link ripple, power circuit design.*
- *Dynamic model estimation, quantitative voltage control.*
- *Dynamic commutation shift.*



Control scheme



Battery Powered Switched-Reluctance Motor Drive using Embedded Components for EV Propulsion with Voltage Boosting and Buck-Boost PFC Charging

- *Battery powered SRM drive using embedded components.*
- *Motoring mode: voltage boosting, winding de-magnetized energy recovery, common DSP.*
- *Charging mode: charger using buck-boost switch-mode rectifier formed by embedded components.*

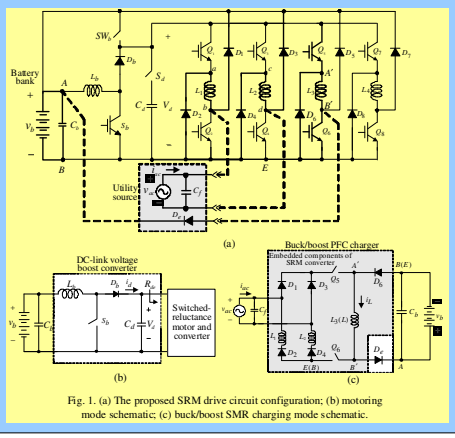
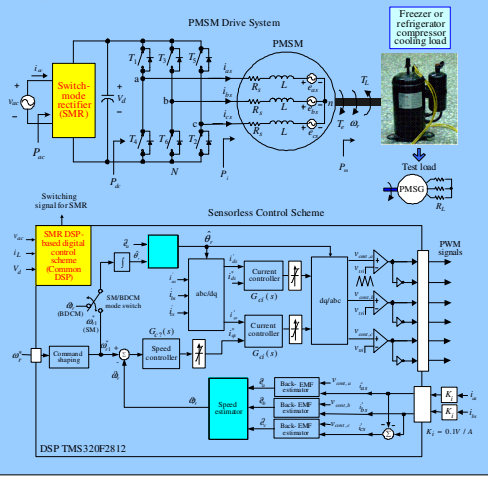


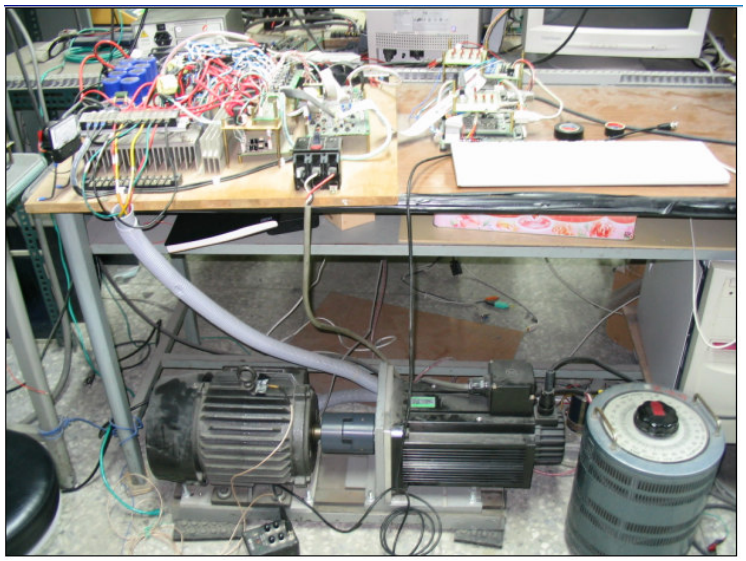
Fig. 1. (a) The proposed SRM drive circuit configuration; (b) motoring mode schematic; (c) buck/boost SMR charging mode schematic.

Sensorless Controlled PMSM Drive for Freezer and Refrigerator Applications

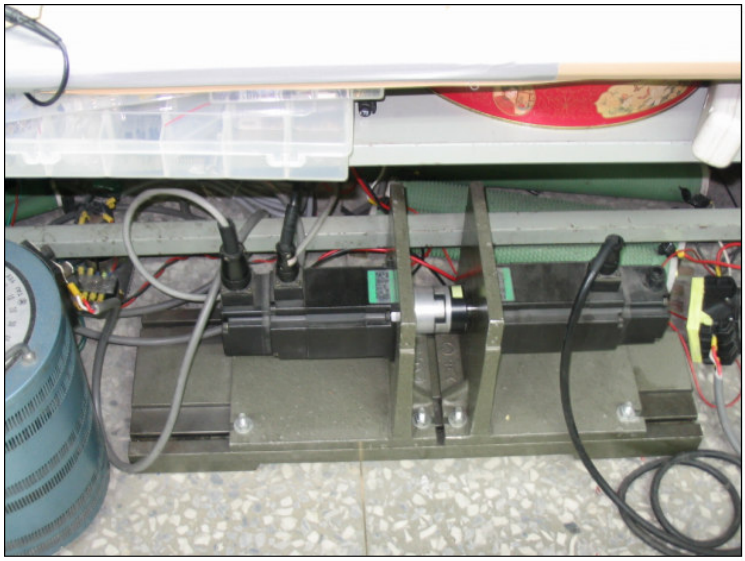
- *Observed back-EMF based sensorless control.*
- *Commutation instant tuning.*
- *Speed estimation, soft starting.*



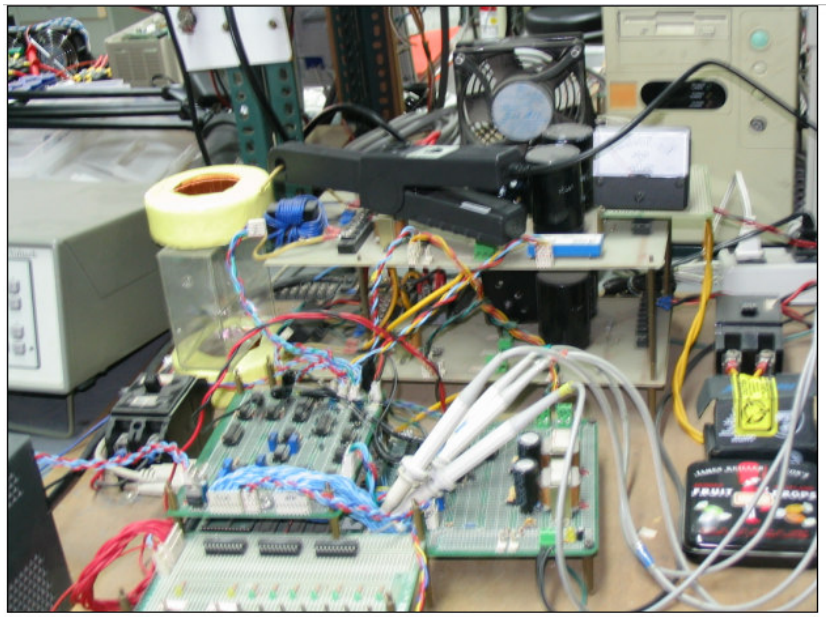
Switched-reluctance motor drive



Rotary permanent-magnet synchronous motor drive



Switch-mode rectifier



Inverter systems