Keys to Success in PhD Research

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PhD Student Resources
Power Engineering Briefing Notes

http://www.eleceng.adelaide.edu.au/research/power/pebn/

- the slides for this talk
- "Art of Electric Machine Research" booklet
  - 2. Conductors, 3. Magnetics and 4. Equivalent Circuits
  - basic theory and plenty of worked examples
- short notes on variety of machines, power electronics topics etc.

My Story

Adelaide
- high school : electronics
- Electrical Eng. degree
- defence RF engineer (7 months)

United Kingdom (3 years)
- PhD, Glasgow, electric motors

United States (5 years)
- research engineer (GE)

Adelaide (15+ years)
- academic (20 research students)
- how help new PhD students?

Outline

- Background
- Ten Keys to Success in a PhD
- Three Keys to Success as an Engineer
- Conclusions

Academics and PhD Students

- What is the key function of an academic?
  - learn, and …
  - pass it on.
  - also true for research students
- Why do academics supervise research students?
  - learn: by working with students on their research
  - pass it on: training and mentoring, publications

learn, and pass it on!

Key Outcomes of a PhD

- significant contribution to knowledge -> publications
  - engineering : material for one or two strong journal papers
- become a good researcher
  - passionate about research, independence, persistance
  - effective communicator (written and verbal)
  - critical thinking and logical reasoning (problem solving)
  - planning, analysis, design and experimental skills

a key part of doing a PhD is learning to become a good researcher

Key Challenges in a PhD

- Uncertain outcome
- How much is enough?
- Far less structured than undergraduate coursework
  - No fixed timeline or milestones
- Supervisors have limited time
- Increasing pressure to finish by time limit

10 Keys to Success in a PhD

- 1. Continuous Writing
- 2. Build Your Thesis Step by Step
- 3. Know the Big Picture
- 4. Outstanding Figures
- 5. Write Great Papers
- 6. Passion, Excel, Improve, Critique
- 7. Seek Insight by Analysis
- 8. Understand Literature Reviews
- 9. Effective Management
- 10. Ethics and Sustainability

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Key #1. Continuous Writing

writing is an essential skill as a PhD is judged on the thesis

- Remember your thesis is the goal
  - starting working on it from day one
- Practice constantly to improve
  - set aside time regularly to write, e.g. 1hr/day
- Write to document your work
  - write up material as you go: understand; get feedback; thesis

start writing your thesis from day one!

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Key #2. Build Your Thesis Step-by-Step

a strong thesis is commonly built up slowly

- significant contribution to knowledge
  - can be a completely new idea, or …
  - but more often many small improvements
- sometimes repeating relevant past work (analysis, simulations, experiments) can give new ideas

theses are usually built up of a number of small contributions

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Key #3. Know the “Big Picture”

3 min thesis: in 3 mins and one slide explain your PhD!

- What is the background?
- What are you trying to do?
- What difference will your research make?
- Use a single figure to explain your work
- Regularly review it and check direction

write a short “big picture” explanation, put in on the wall, review it regularly

3.1. System Block Diagram

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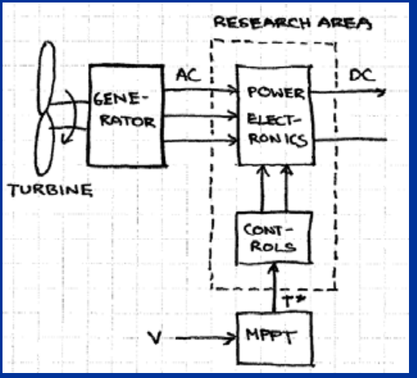
a system block diagram is a powerful method for describing

- how what you are doing fits into a bigger system
- the key components and variables you are studying



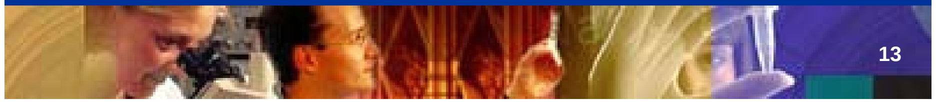
produce a simple figure to illustrate your “big picture” explanation

Key #4. Outstanding Figures

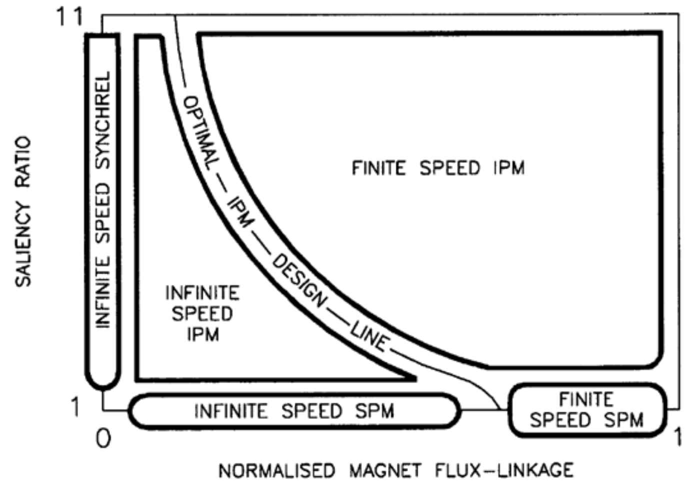
great figures form the foundation for PhD theses

- Find your "killer" figure
  - one figure can get you a PhD!
- Use figures to tell the story
  - they carry the plot of your argument
- Select the right figure type
  - be aware of the wide variety of options

figures are essential to prove you have achieved something!



4.1. Killer Figures : My PhD

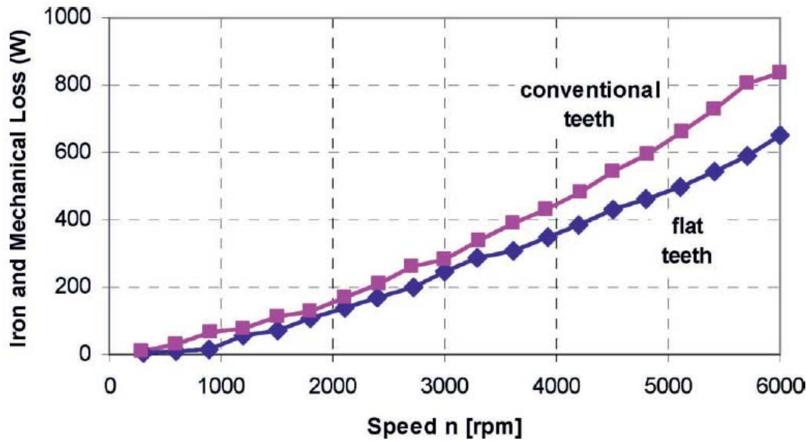


Analytical study on effect of motor parameters on field-weakening performance

[1] W. L. Soong, "Design and Modelling of Axially-Laminated Interior Permanent Magnet Motor Drives for Field-Weakening Applications," Ph.D., University of Glasgow, 1993.

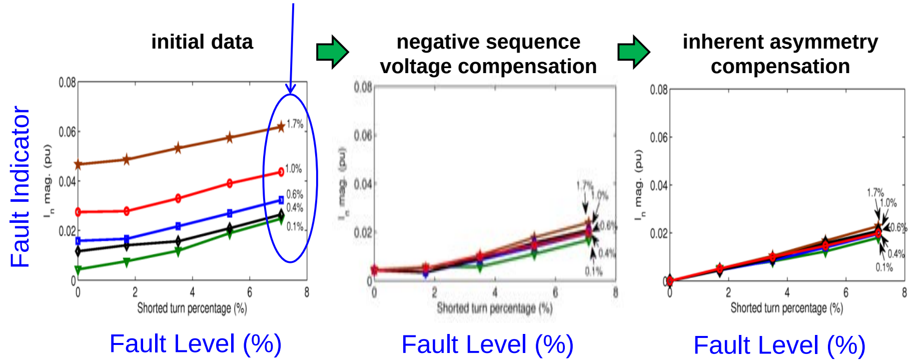
4.1.1. Killer Figures : Vlatka PhD

Changing IPM machine design improves performance



4.1.2. Killer Figures : Syaiful PhD

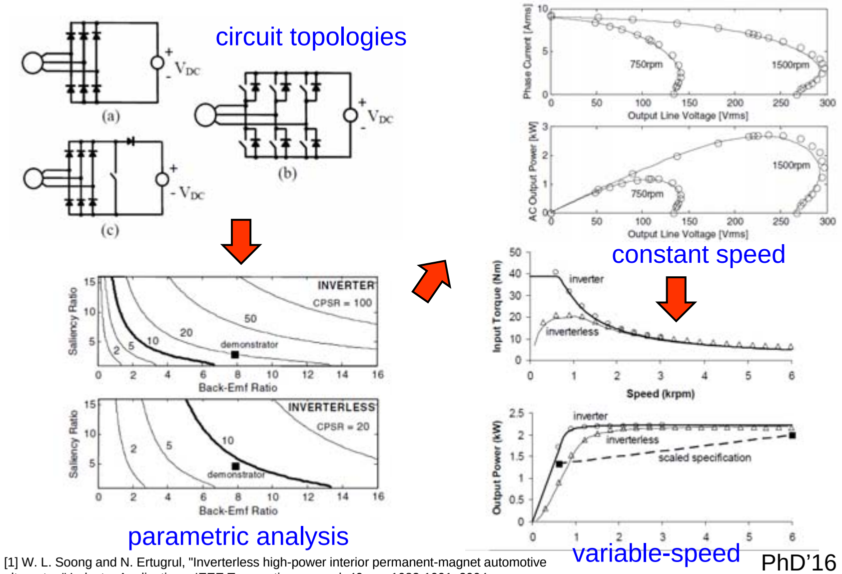
disturbance factor



compensating for "disturbance" factors produces a linear relationship between fault signal and shorted-turn fault level

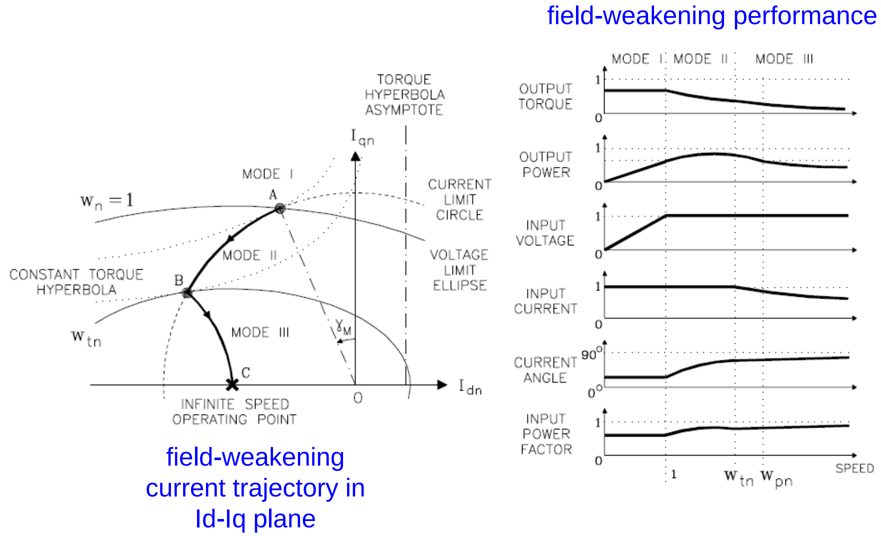
S. Bakri : PhD Research on Using Negative Sequence Current to Detect Stator Faults, 2012

4.2. Figures Tell the Story



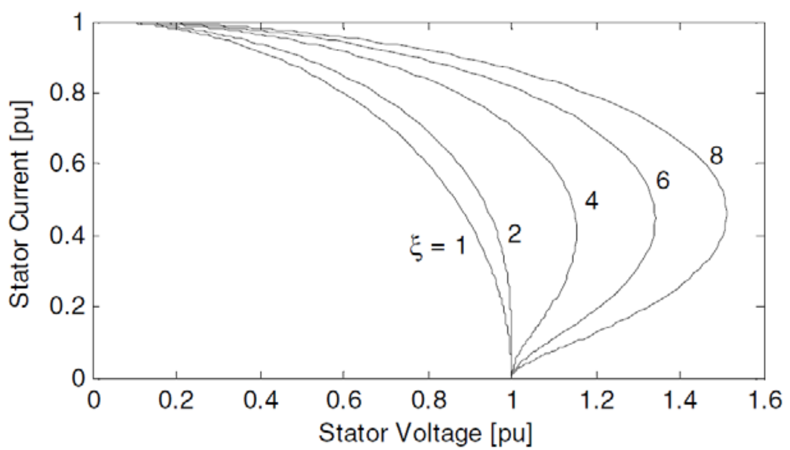
[1] W. L. Soong and N. Ertugrul, "Inverterless high-power interior permanent-magnet automotive alternator," Industry Applications, IEEE Transactions on, vol. 40, pp. 1083-1091, 2004.

4.3. Figure Gallery: Analytical Results



[1] W.L. Soong, "Design and Modelling of Axially-Laminated Interior Permanent Magnet Motor Drives for Field-Weakening Applications," Ph.D., University of Glasgow, 1993.

4.3.1. Varying One Parameter

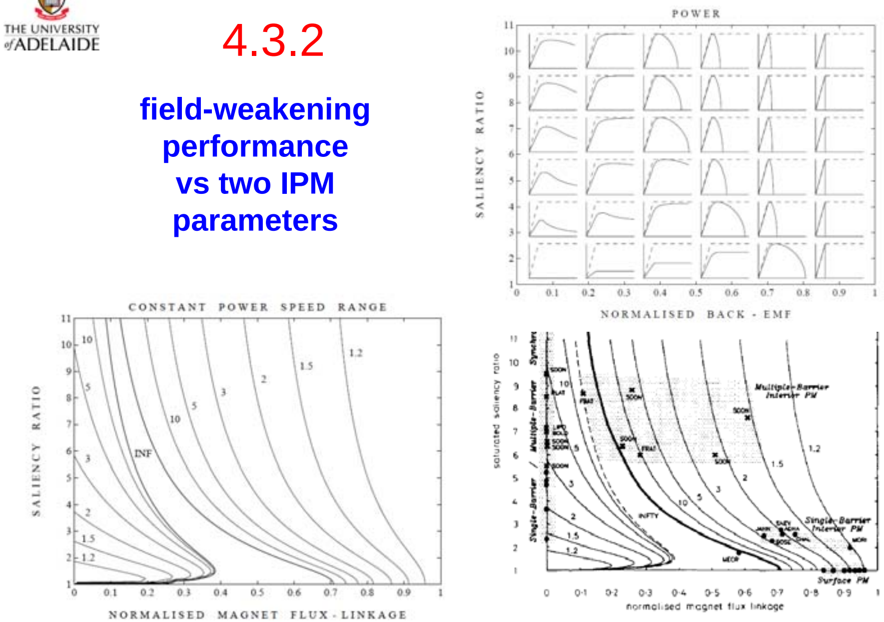


effect of IPM saliency ratio on "voltage overshoot"

[1] C.-Z. Liaw, W. L. Soong, B. A. Welchko, and N. Ertugrul, "Uncontrolled generation in interior permanent-magnet Machines," Industry Applications, IEEE Transactions on, vol. 41, pp. 945-954, 2005.

4.3.2

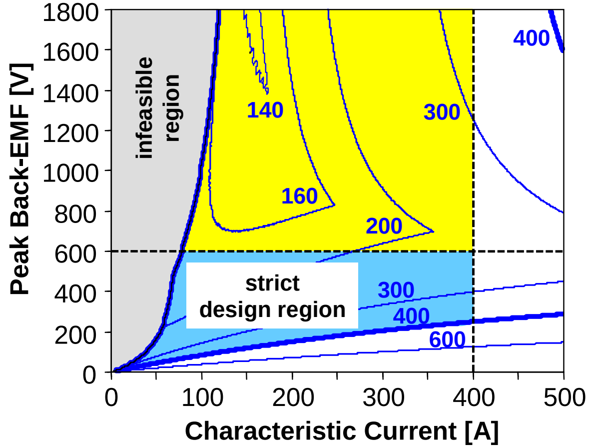
field-weakening performance vs two IPM parameters



[1] W. L. Soong, "Design and Modelling of Axially-Laminated Interior Permanent Magnet Motor Drives for Field-Weakening Applications," Ph.D., University of Glasgow, 1993.

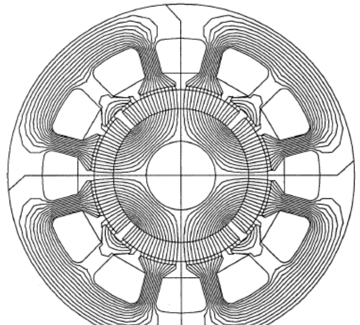
4.3.3. Parameter Plane

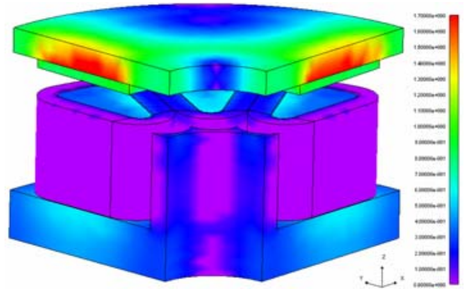
required stator current to meet traction specification versus IPM parameters



[1] W.L. Soong, P.B. Reddy, A.M. El-Refaie, T.M. Jahns and N. Ertugrul, "Surface PM Machine Parameter Selection for Wide Field-Weakening Applications", in Rec. of 2007 IEEE Industry Applications Society Annual Meeting, New Orleans, Sept. 2007.

4.3.4. Simulation Results



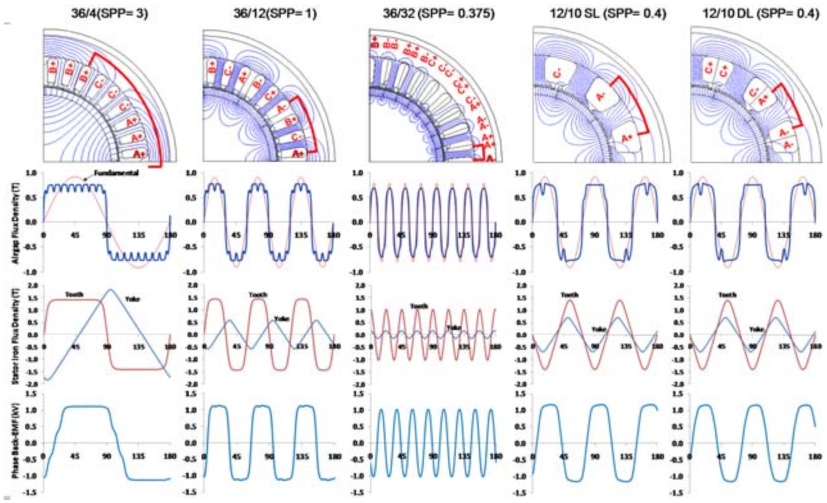


[1] T. J. E. Miller, Brushless Permanent Magnet and Reluctance Motor Drives: Oxford University Press, 1989.

[2] G.S. Liew, N. Ertugrul and W.L. Soong, "3D Design and Performance Comparison of an Axial Field Brushless Permanent Magnet Machine Configuration Utilizing Soft Magnetic Composites," Int'l Electric Machines and Drives Conf., IEMDC 2007, pp. 153-158.

4.3.5. FE Analysis Summary

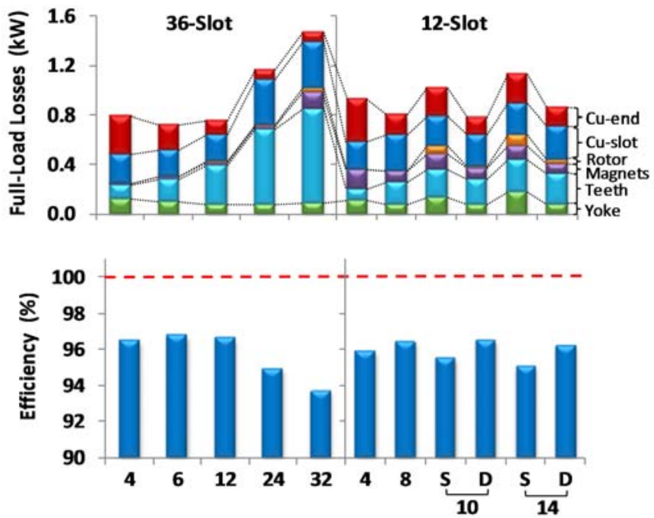
comparison of different slot-pole combinations



[1] C. Tang, W. L. Soong, G. S. Liew, and N. Ertugrul, "Effect of Pole and Slot Number Changes on the Performance of a Surface PM Machine," presented at the Electric Machines, International Conference on, Marseille, France, 2012.

4.3.6. Example : Loss Breakdown

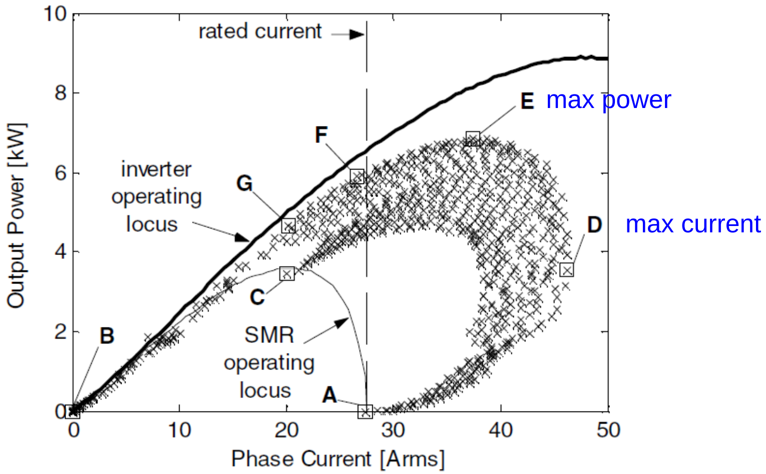
comparison of different slot-pole combinations



[1] C. Tang, W. L. Soong, G. S. Liew, and N. Ertugrul, "Effect of Pole and Slot Number Changes on the Performance of a Surface PM Machine," presented at the Electric Machines, International Conference on, Marseille, France, 2012.

4.3.7. Changing Control Parameters

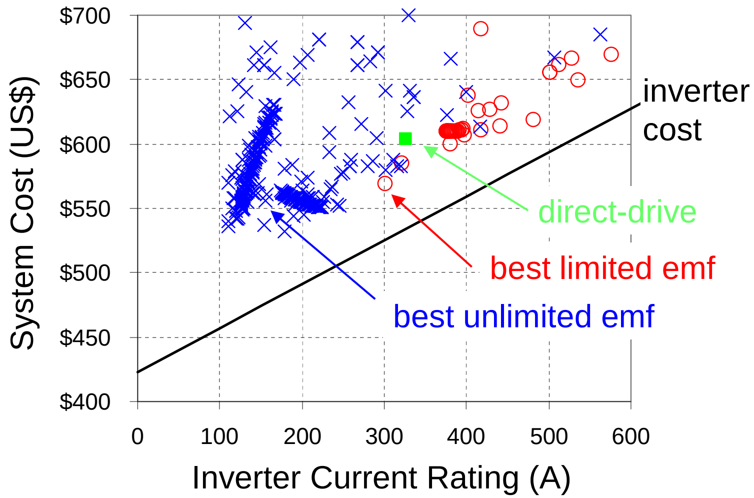
possible output power vs phase current operating points



[1] C. Z. Liaw, W. L. Soong, and N. Ertugrul, "Low-Speed Output Power Improvement of an Interior PM Automotive Alternator," in Industry Applications Conference, 2006. 41st IAS Annual Meeting. Conference Record of the 2006 IEEE, 2006, pp. 27-34.

4.3.8. Optimisation

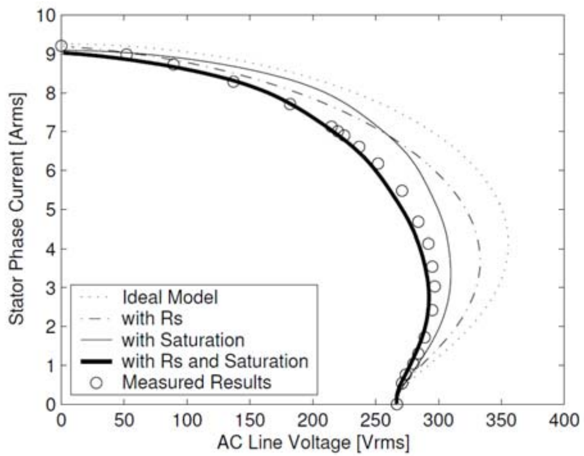
"pareto" front of optimisation results on cost vs current



[1] C. Z. Liaw, W. L. Soong, and N. Ertugrul, "Low-Speed Output Power Improvement of an Interior PM Automotive Alternator," in Industry Applications Conference, 2006. 41st IAS Annual Meeting. Conference Record of the 2006 IEEE, 2006, pp. 27-34.

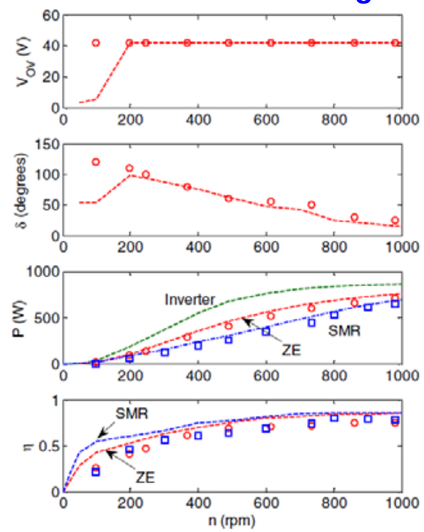
4.3.9. Simulation Comparisons

investigate two non-ideal effects (resistance and saturation) using simulation, with validation



4.3.10. Control and Performance

test and simulation results for range of parameters



[1] M. Pathmanathan, W. L. Soong, and N. Ertugrul, "Output power capability of surface PM generators with switched-mode rectifiers," in Sustainable Energy Technologies (ICSET), 2010 IEEE International Conference on, 2010, pp. 1-6.

Key #5. Write Great Papers

papers give shorter term deadlines and focus ideas

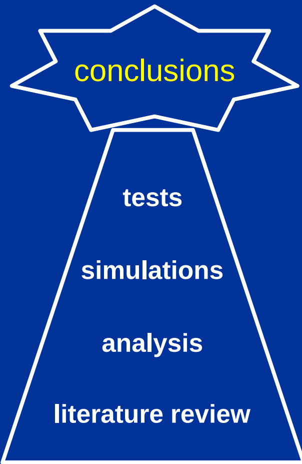
- Identify and focus on original contributions/conclusions
  - everything in the paper targets and showcases these
- Start with a paper skeleton
  - title, abstract, key figures, dot-points and conclusions
- Keep writing concise and clear
  - constantly revise and clarify

great papers are focussed, concise and clear

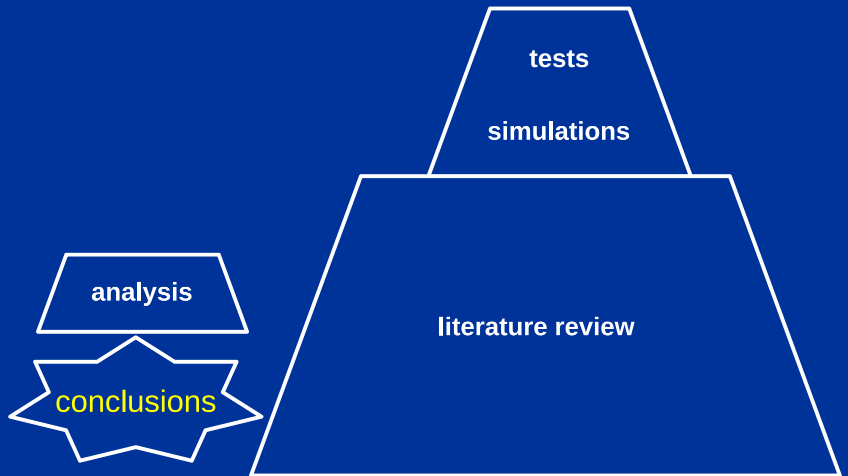
5.1. "Good" Paper Structure

the content of a paper is there to support the original contributions

- suggest "starting from the end"
  - write the conclusions/contributions
  - plan the test results
  - plan the supporting simulations
  - plan the supporting analysis
  - write a literature review
- result: a concise, focussed paper



5.2. "Poor" Paper Structure



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5.3. "Contribution" Statement

Aim

- investigate output power reduction of wind turbines under rapidly changing wind speeds due to their inertia preventing them operating at the optimal maximum power point tracking speed

Key Contributions

- analytical derivation of small-signal time constant …
- analytical derivation of power reduction …
- numerical simulation of power reduction …

Importance/Applications

- allow rapid estimation of output power reduction …
- understanding the relationship between …

clearly define your paper's aims, contributions and importance

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8. Understand Literature Reviews
9. Effective Management
10. Balance and Sustainability

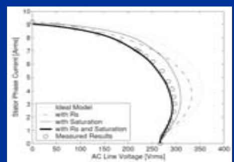
Key #6. Passion, Excel, Improve, Critique

develop passion about your work, continually seek to excel and improve, develop critical thinking skills

- Passion and excellence: seek enjoyment from your work, do it the best you can, and continually improve!
  - important also in an engineering career!
- Critical thinking: seek a deeper understanding, ask why?
  - recognize strengths but also shortcomings; see flaws in logic

these characteristics separate good from great researchers!

Key #7. Seek Insight by Analysis



seek understanding and insight

- Start from first principles
  - begin with simplest models and build up
- Have curiosity, seek to really understand
  - ask "why?", constantly check method, understand limitations
- Investigate parametric modelling
  - powerful technique for certain applications

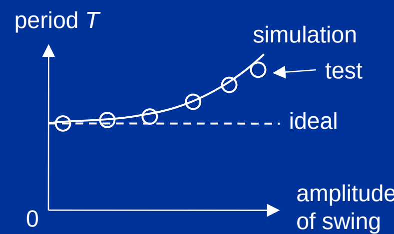
great engineers have understanding and insight!

7.1. Analyse, Simulate and Test

Example : simple pendulum

$$T \approx 2\pi\sqrt{\frac{l}{g}}$$ for small swings

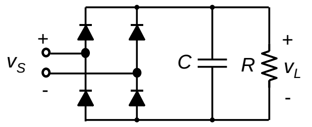
- Analysis : equation of motion
- Simulation
  - E.g. numerical
- Experiments
  - test pendulum



when modelling, start simple then add complexity, and validate results

7.2. Parametric Analysis

powerful approach in analysis of engineering systems is to use graphs with carefully chosen <u>dimensionless</u> parameters

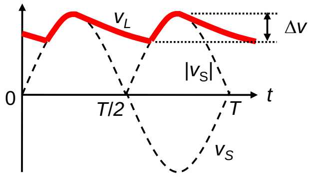


Example : consider a full-wave diode rectifier with a 1ph AC voltage input

a) <u>four</u> input parameters
- supply voltage peak, V_p
- supply voltage period, T
- capacitance, C
- resistance, R

b) output parameters
- ripple voltage, Δv
- mean output voltage, v

relationship?



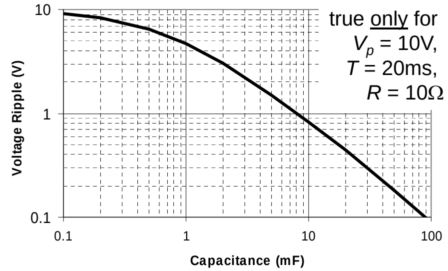
dimensionless parameters capture physical principles and meaning

7.2.1. Parametric Analysis

1) <u>particular</u> case

choose example values, V_p = 10V, T = 20ms, R = 10 ohms, analyse for Δv as function of C

only applicable to particular values chosen

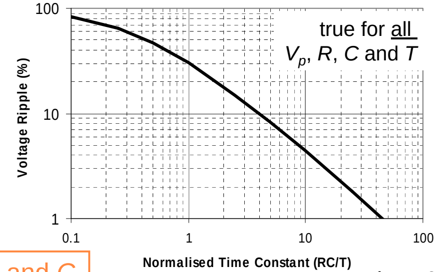


2) <u>general</u> case

use physical understanding of system to scale the above graph to produce dimensionless parameters

y-axis : use voltage ripple $\Delta v/V_p$

x-axis : C to RC to RC/T



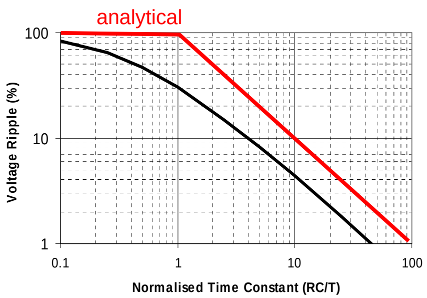
generalised solution for all V_p, T, R and C

7.2.2. Extending Results

1) Analytical Result

add curve for simplified analytical prediction, $\Delta v/|V| = T/RC$

analytical curve is conservative by a factor of about two

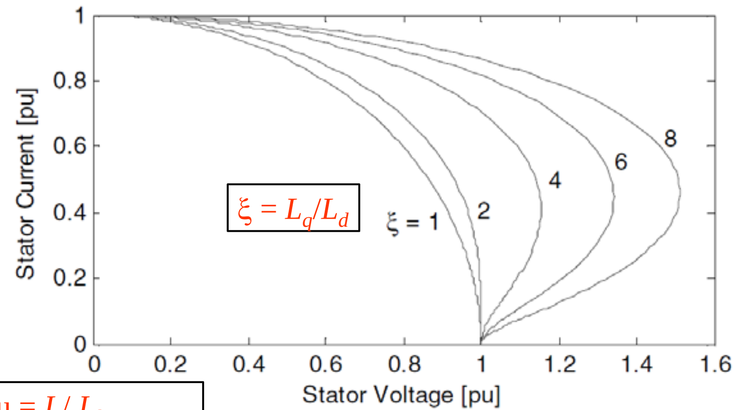


2) Examine Variations
- half wave vs full-wave rectifier
- effective of non-ideal effects e.g. diode voltage drop

Machine Example
- Carter's co-efficient for slotting effects

7.3. Parametric Example #1

normalised parameters used to generalise "voltage overshoot" effect VI locus for all interior PM machine designs



I in pu = $I / I_{short\text{-}circuit}$

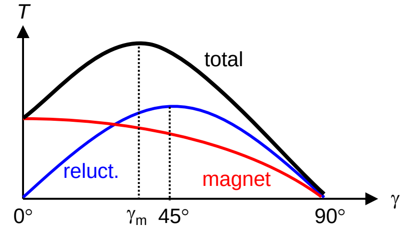
V in pu = V / V_{rated}

[1] C.-Z. Liaw, W. L. Soong, B. A. Welchko, and N. Ertugrul, "Uncontrolled generation in interior permanent-magnet Machines," Industry Applications, IEEE Transactions on, vol. 41, pp. 945-954, 2005.

7.4. Parametric Example #2

- study maximum torque per ampere control of interior PM machines
- three parameters : Ψ_m, L_d, L_q
- with constant current I, torque varies with current angle
- two contributions
  – magnet torque : peak value is $T_{mp} = \Psi_m I$
  – reluctance torque : peak value is $T_{rp} = 0.5(L_q - L_d) I^2$
- maximum torque per ampere current angle is give by

$$T = mp\left[\underbrace{\Psi_m I\cos\gamma}_{\text{magnet}} + \underbrace{\frac{1}{2}\left(L_q - L_d\right)I^2\sin 2\gamma}_{\text{reluctance}}\right]$$



$$\sin\gamma_m = \frac{-\Psi_m + \sqrt{\Psi_m^2 + \left(L_q - L_d\right)I^2}}{4\left(L_q - L_d\right)}$$

max torque-amp current angle is function of four parameters: Ψ_m, L_d, L_q and I

7.4.1. Parametric Example #2

1. "Standard" equation
   – function of three machine parameters
   – hard to grasp meaning

$$\sin\gamma_m = \frac{-\Psi_m + \sqrt{\Psi_m^2 + \left(L_q - L_d\right)I^2}}{4\left(L_q - L_d\right)}$$

$$T_{rp} = \frac{1}{2}\left(L_q - L_d\right)I^2 \qquad T_{mp} = \Psi_m I$$

2. First Revision
   – express as function of peak magnet torque and peak reluctance torque
   – improved understanding

$$\sin\gamma_m = \frac{-T_{mp} + \sqrt{T_{mp}^2 + 32T_{rp}^2}}{8T_{rp}}$$

3. Second Revision
   – express as function of ratio of peak magnet torque to peak reluctance torque
   – most physically meaningful

$$\sin\gamma_m = -\frac{1}{8}\left(\frac{T_{mp}}{T_{rp}}\right) + \sqrt{\frac{1}{64}\left(\frac{T_{mp}}{T_{rp}}\right)^2 + \frac{1}{2}}$$

max torque-amp current angle is function of one parameter (T_{mp}/T_{rp})

Key #8. Understand Literature Reviews

purpose: show you understand background and can demonstrate innovation and significance

- Classify the existing literature
  – identify relevant categories, classify previous work
- Clarify original contribution with respect to most relevant work and
- Demonstrate significance and importance

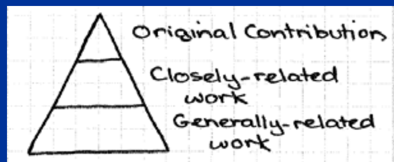
highlight your original contributions and their significance

8.1. Literature Review

- Classification of existing work
  – identify relevant factors
- Clarification of contribution
  – how does your work fits in?
  – identify relevant work in the field
  – contributions and short-comings
- Significance
  – why is your work important?

TOPOLOGY

	RECTIFIER	SMR	INVERTER
SURFACE PM	[1], [2]	[3], [4] [5]	[6]
INTERIOR PM		[7] [8]	



Key #9. Effective Management

completing a PhD is made much easier if you are able to efficiently manage and organise yourself, and others

- Manage yourself
  - planning and tracking (e.g. goals PhD, month), time mgmt
  - efficiently organise and back-up results and email
- Manage your supervisor(s)
  - meeting management

effective self and people management skills are essential for your future career

9.1. Utilise "Parallel" Processing

- performing analysis, simulations and experiments in parallel may speed both understanding and progress

classical approach: literature → analysis → simulation → experiment

alternative approach: literature | analysis | simulation | experiment (in parallel)

9.2. Meetings with Supervisor

- Meet regularly, especially in early part of studies
- Before meeting, suggest preparing:
  - short summary of progress, issues and future work
  - detailed reports/documentation of work done
- At end of meeting,
  - define work to be done before next meeting
  - set time for next meeting

help your supervisor help you!

Key #10. Ethics and Sustainability

ethics are important…

- be honest and upfront in all your work
- discuss both positive and negative aspects

doing a PhD is like going on a long journey …

- be prepared for delays, detours and dead-ends
- balance your work with your personal life
- seek to learn something new everyday!
- find things to enjoy in the journey!

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Keys to Success as an Engineer

3 Keys to Success : #1 Technical

good engineers have an strong grasp of fundamentals and broad understanding of their area

- Keep learning – your education is continuing!
  - ask questions, attend seminars/course, read books/papers…
- Keep passing it on - document what you learn
  - clarify understanding
  - reference for yourself and others

continuously develop your technical skills during your career

3 Keys to Success : #2 Communication

no matter how much you know, if you can't communicate it then your knowledge has limited value

- proposals, presentations, emails, calls, meetings, conversations

- who is the audience and what is the purpose?
- concise – what needs to be said, what can be left out?
- clear and logical presentation
- learn from good role models

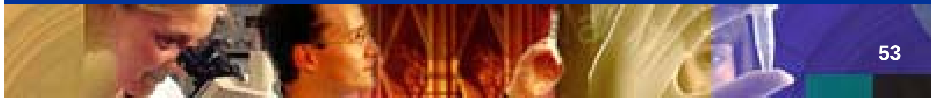
continuously seek to improve your communication skills

3 Keys to Success : #3 Environment

success as an engineer is more than solving technical issues

- understand the “big” picture
  - global, industry, company, management and customers
  - how things work in company (mentoring can help here)
- know the “bottom line” of company
  - satisfy customer needs and make a profit
- consider further training – management, finance etc.

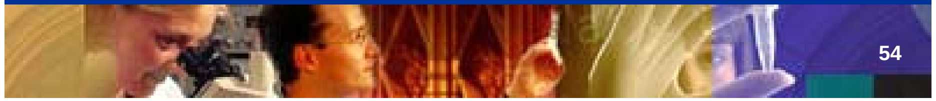
successful engineers have a strong grasp of relevant non-technical factors



Summary

- Role of Academic
  - Learn, and pass it on
- Ten Keys to Success – PhD Student
- Three Keys to Success – Engineer
  - Technical, Communication, Environment

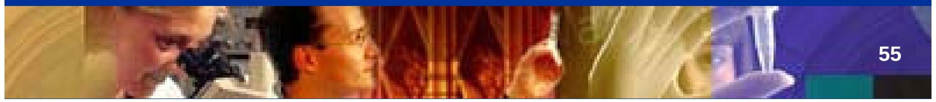
the bottom line: “learn, and pass it on”



PhD Student Resources
Power Engineering Briefing Notes

http://www.eleceng.adelaide.edu.au/research/power/pebn/

- the slides for this talk
- “Art of Electric Machine Research” booklet
  - 2. Conductors, 3. Magnetics and 4. Equivalent Circuits
  - basic theory and plenty of worked examples
- short notes on variety of machines, power electronics topics etc.



Keys to Success in PhD Research

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