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Keys to Success in PhD Research

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My Story

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Adelaide

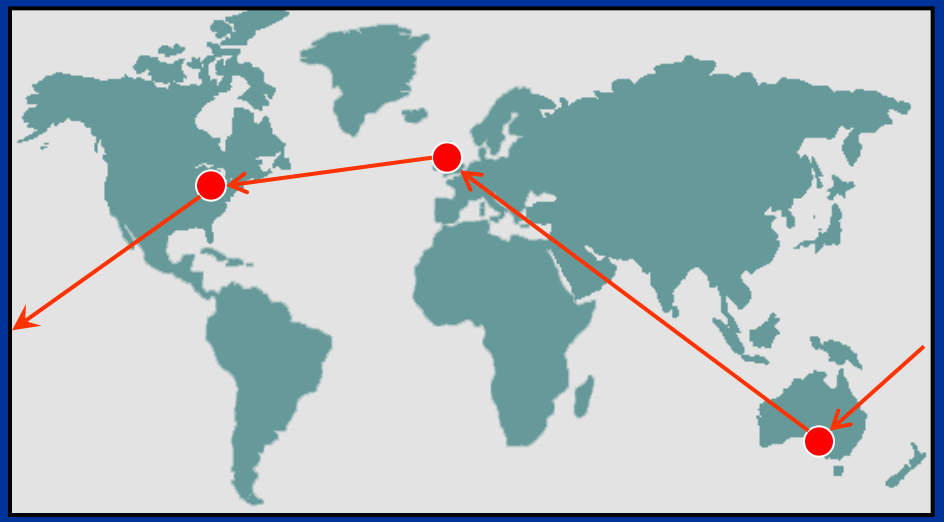
- high school : electronics
- UoA Electrical Eng. degree
- defence RF engineer (7 months)

United Kingdom (3 years)

- PhD (electric motors)

United States (5 years)

- research engineer (GE)



Adelaide (15+ years)

- academic (20 research students)
- how help new PhD students?

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Outline

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

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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

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Key Outcomes of a PhD

- significant contribution to knowledge -> publications
  - engineering : material for one or two strong journal papers
- become a good researcher
  - effective communicator (written and verbal)
  - logical reasoning (problem solving)
  - planning, analysis, design and experimental skills
  - capability to work independently
  - persistence

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Key Challenges in a PhD

- Uncertain outcome
- Far less structured than undergrad coursework
  - No fixed timeline or milestones
- Supervisors have limited time
- Increasing pressure to finish in three years
- How much is enough?

Keys to Success in a PhD

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- 1. Continuous Writing
- 2. Build Your Thesis Step by Step
- 3. Know the Big Picture
- 4. Outstanding Figures
- 5. Write Great Papers
- 6. Seek Insight by Analysis
- 7. Understand Literature Reviews
- 8. Utilise Parallel Processing
- 9. Effective Management
- 10. Balance and Sustainability

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Key #1. Continuous Writing

writing is an essential skill as you are judged on your thesis alone

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

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Key #2. Build Your Thesis Step by Step

a strong thesis is generally built up slowly

- significant contribution to knowledge
  - a completely new idea, or …
  - many small improvements
- repeating past work can give new ideas

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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

3.1. System Block Diagram

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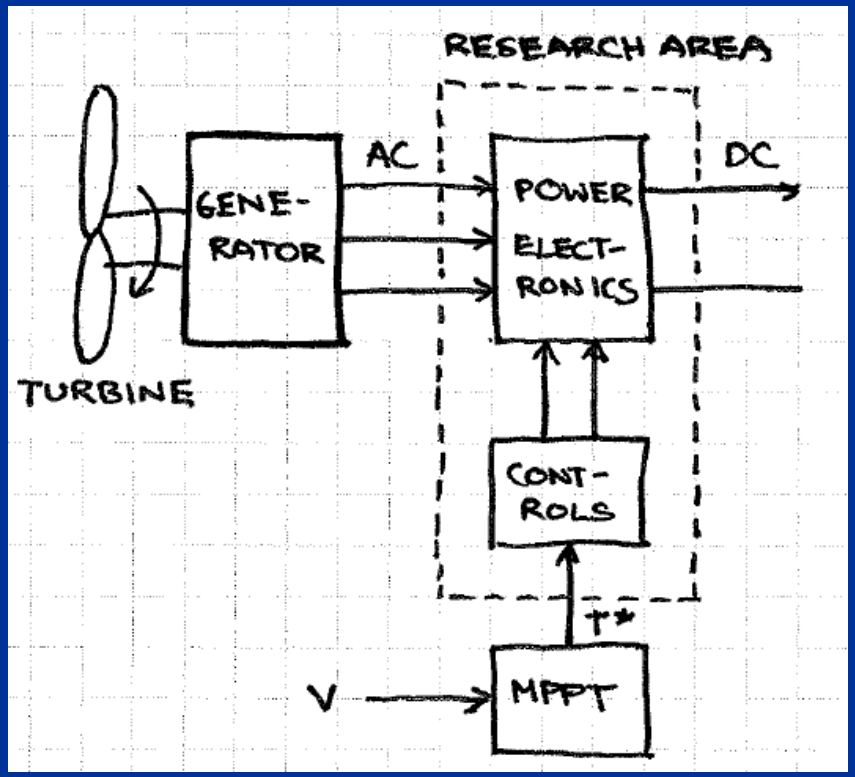
a system block diagram is a powerful method for describing

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



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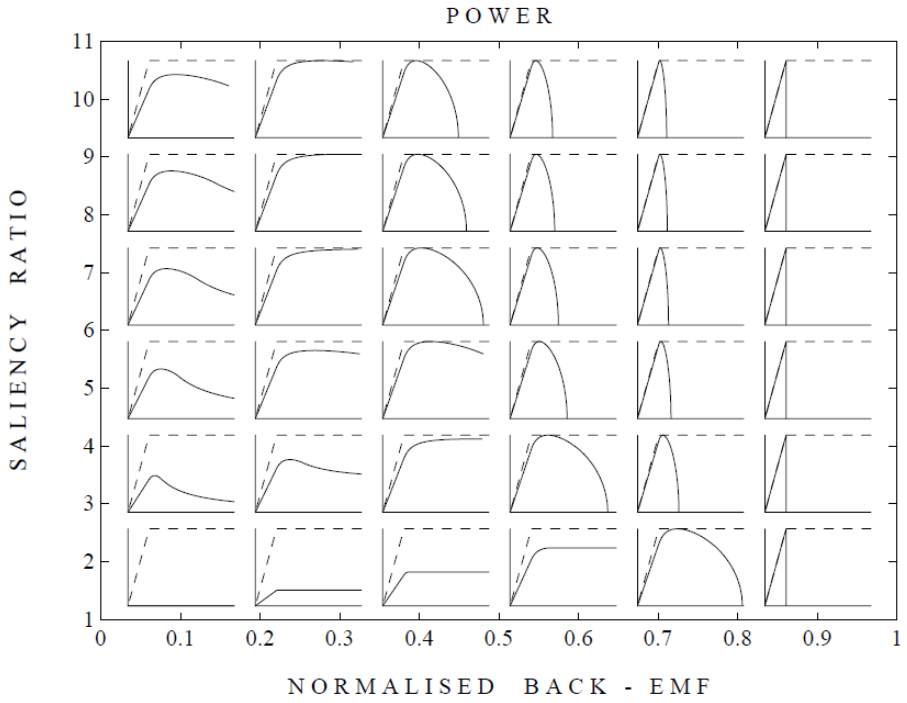
Key #4. Outstanding Figures

great figures form a solid foundation for PhD theses

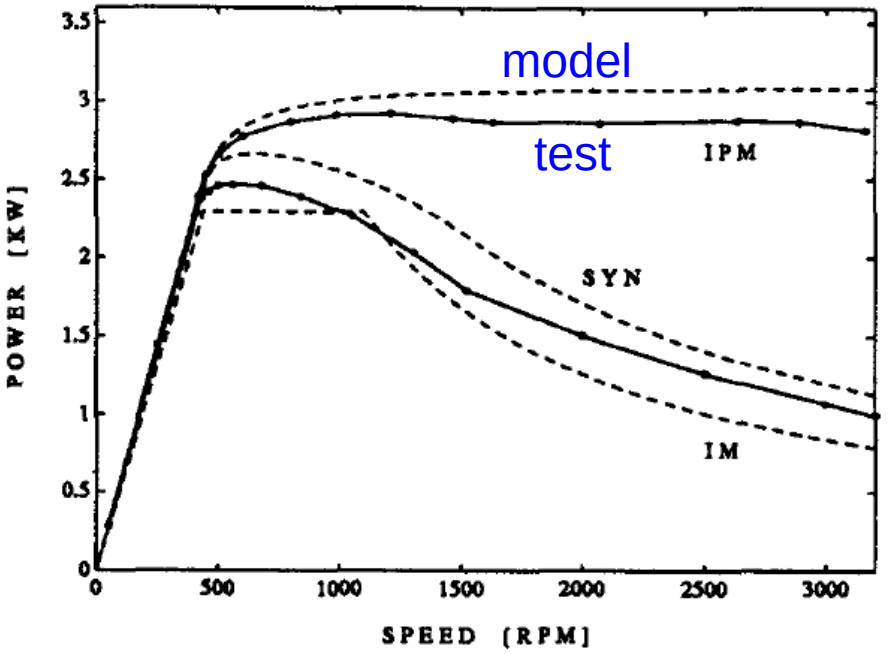
- Find the “killer” figure
  - one figure can get you a PhD!
- Use figures to tell the story
  - they carry the plot of your argument
- Select the right figure type
  - be aware of the wide variety of options

4.1. Killer Figures : My PhD



1. Analytical study of effect of motor parameters on performance

2. Experimental validation



[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.

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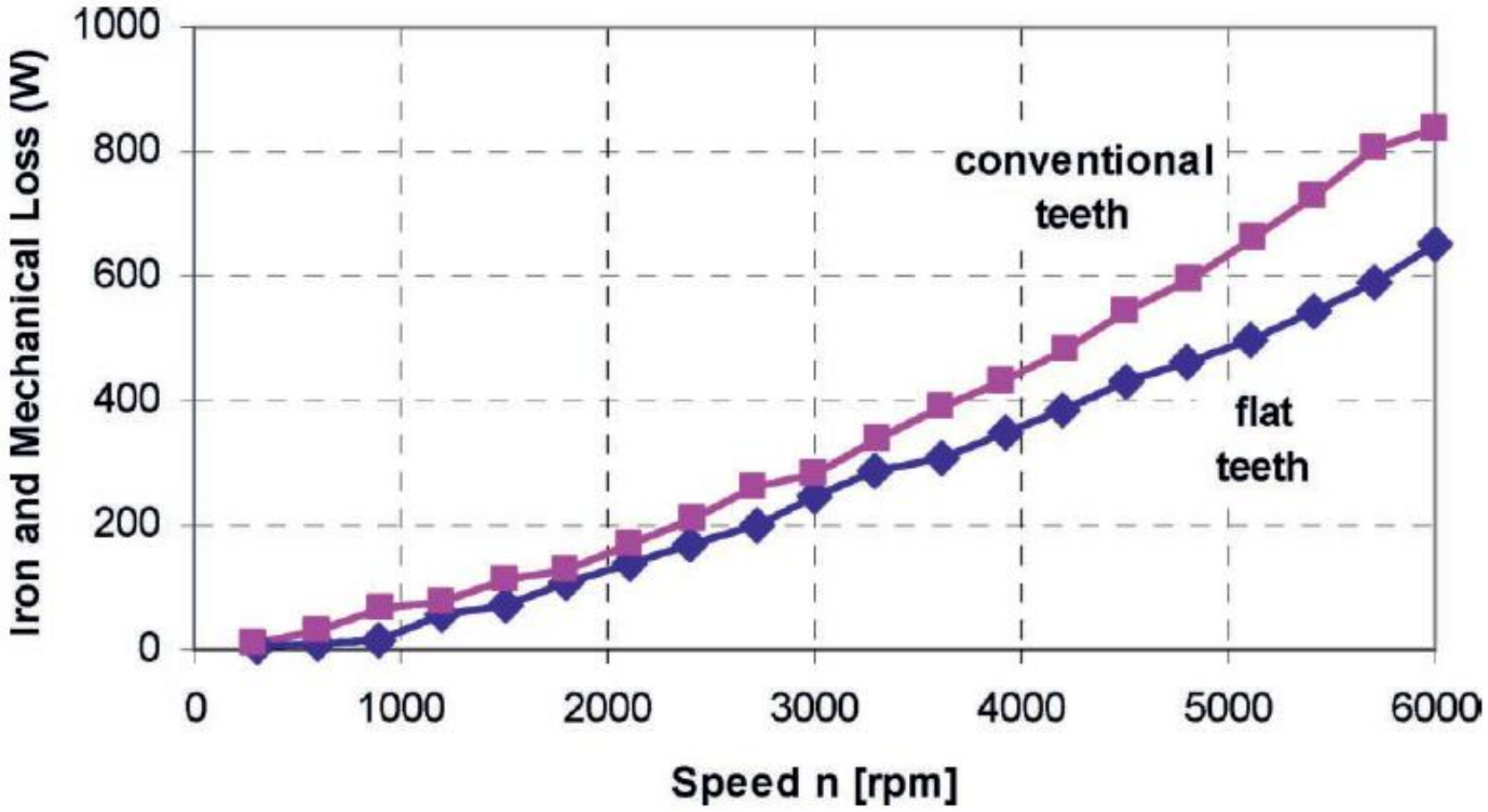
4.1.1. Killer Figures : Vlatka PhD

Changing machine design improved performance

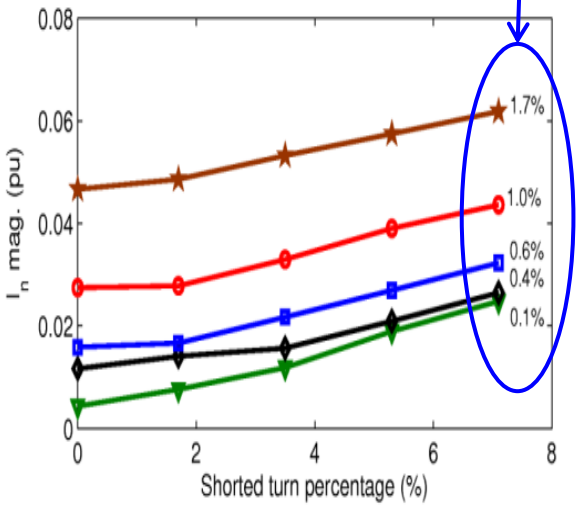


4.1.2. Killer Figures : Syaiful PhD

disturbance factor

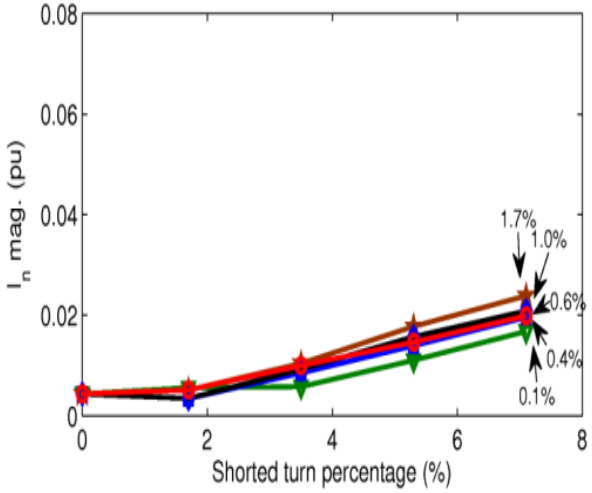
Fault Indicator

initial data



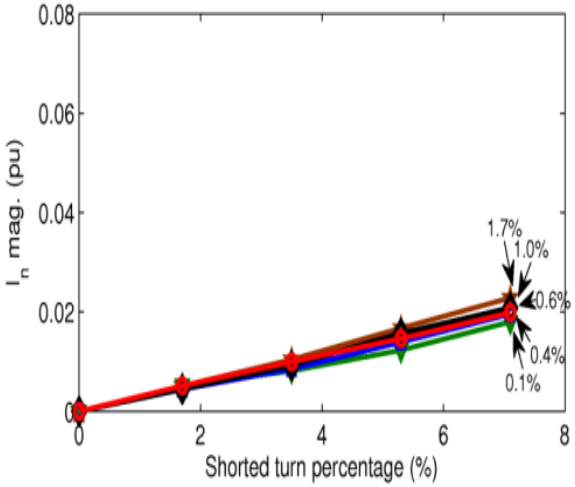
Fault Level (%)

negative sequence voltage compensation



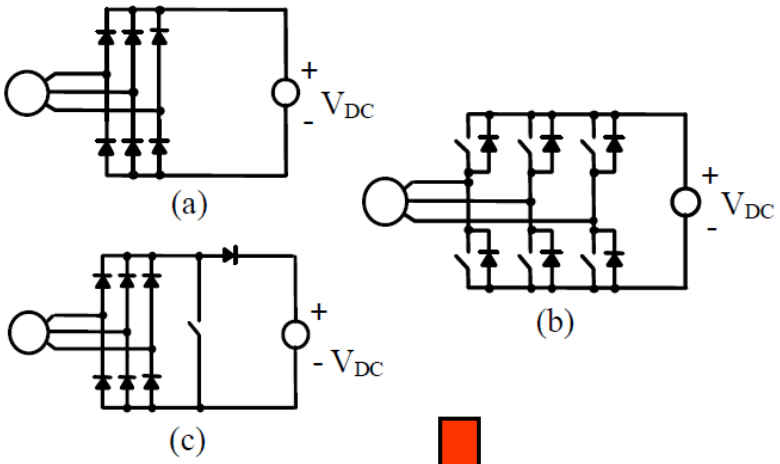
Fault Level (%)

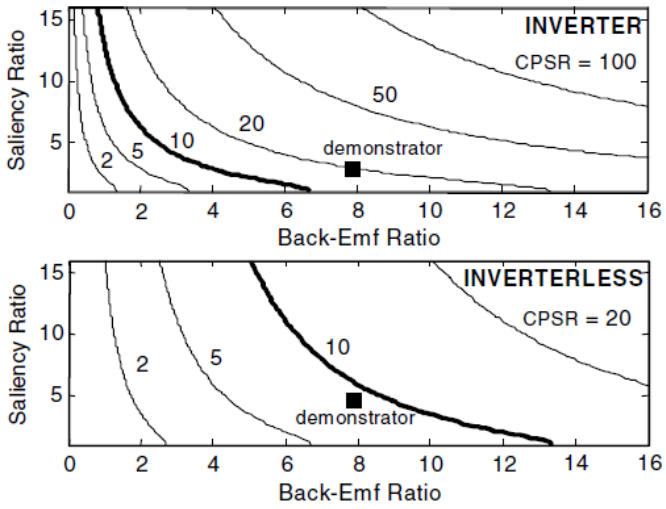
inherent asymmetry compensation

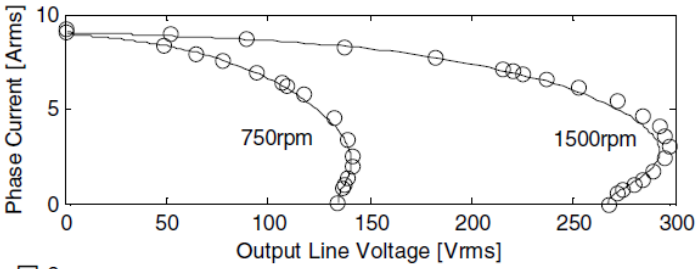


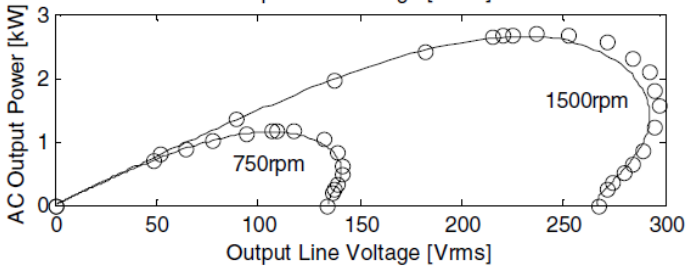
Fault Level (%)

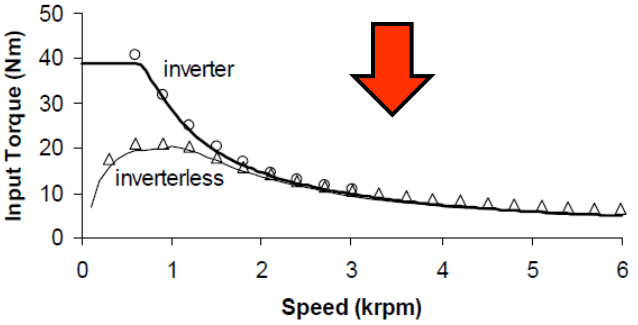
4.2. Figures Tell the Story

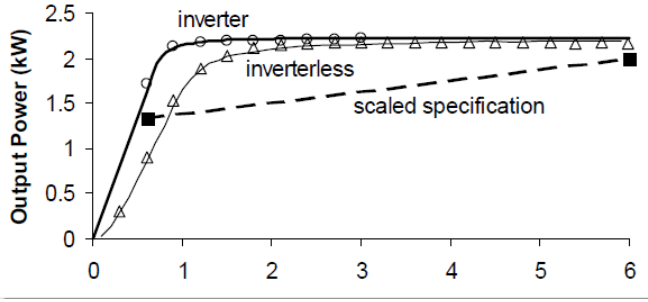






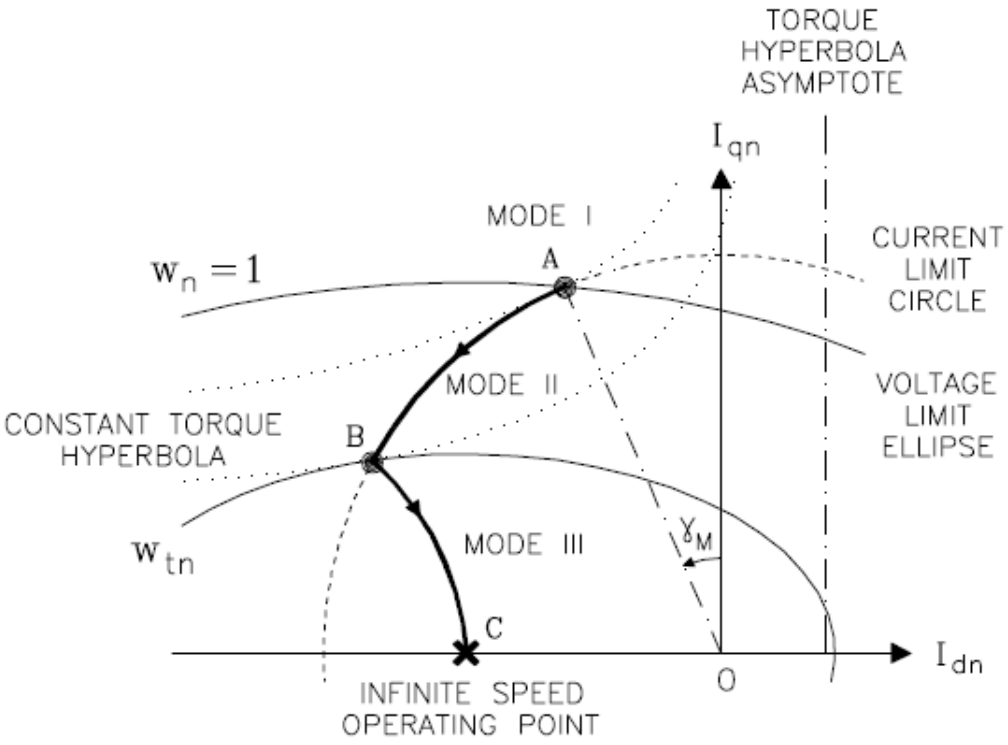


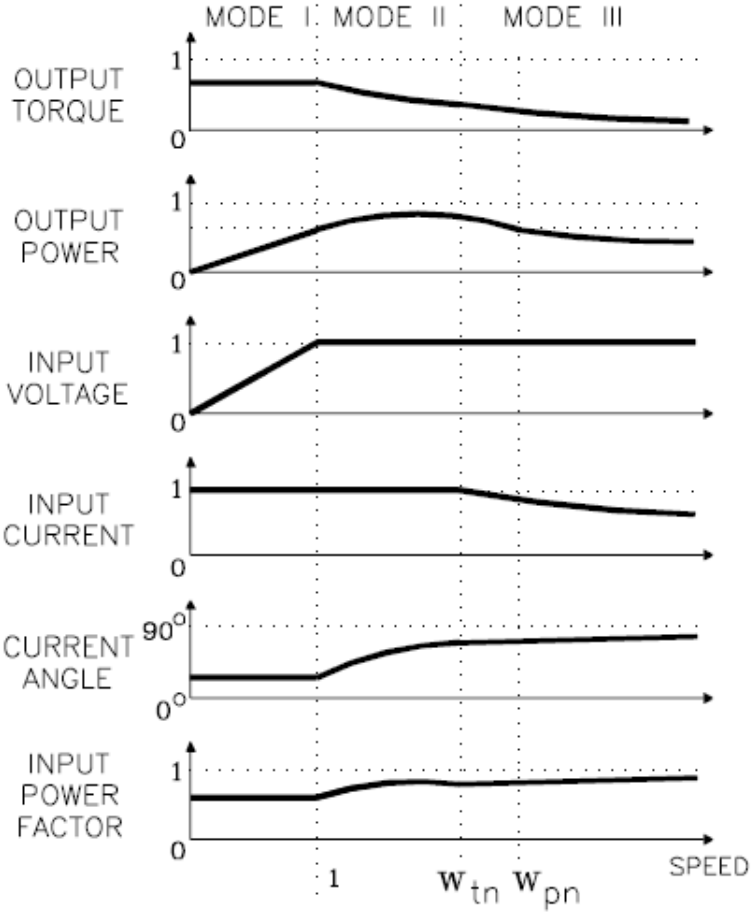




[1] W. L. Soong and N. Ertugrul, "Inverterless high-power interior permanent-magnet automotive alternator," Industry Applications, IEEE Transactions on, vol. 40, pp. 1083-1091, 2004.

4.3. Figure Gallery





[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.

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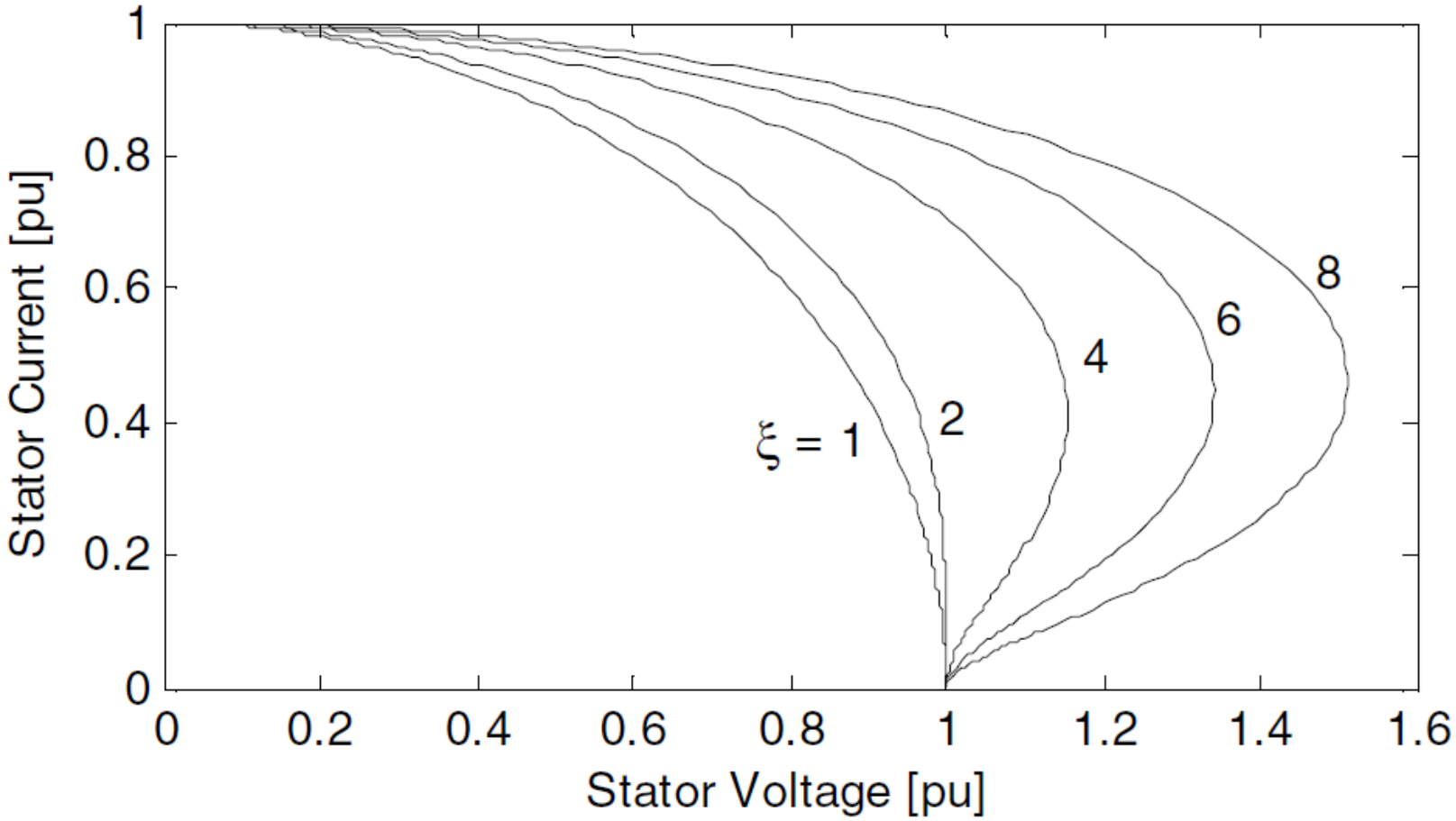
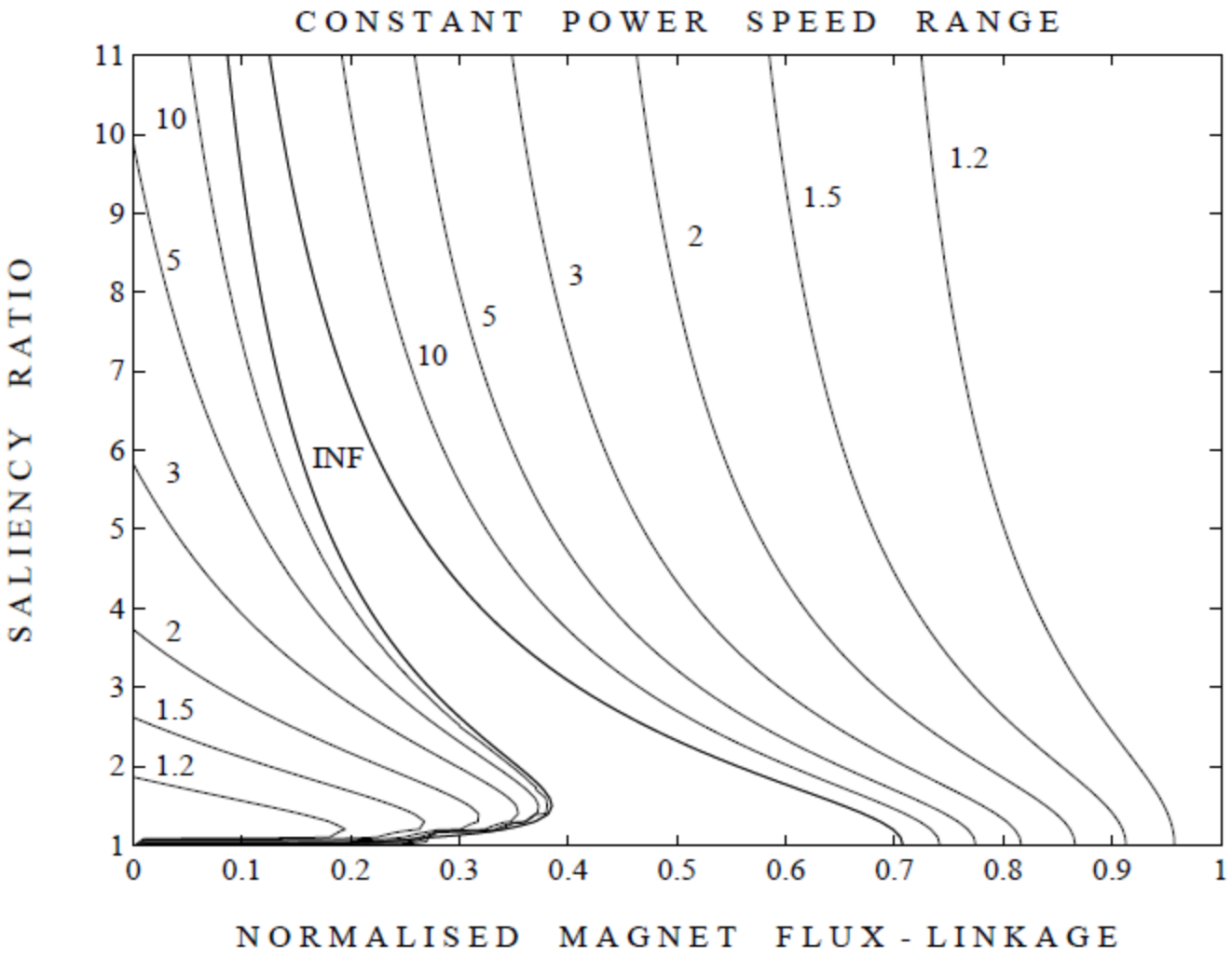
4.3.1. Varying One Parameter



[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. Varying Two Parameters



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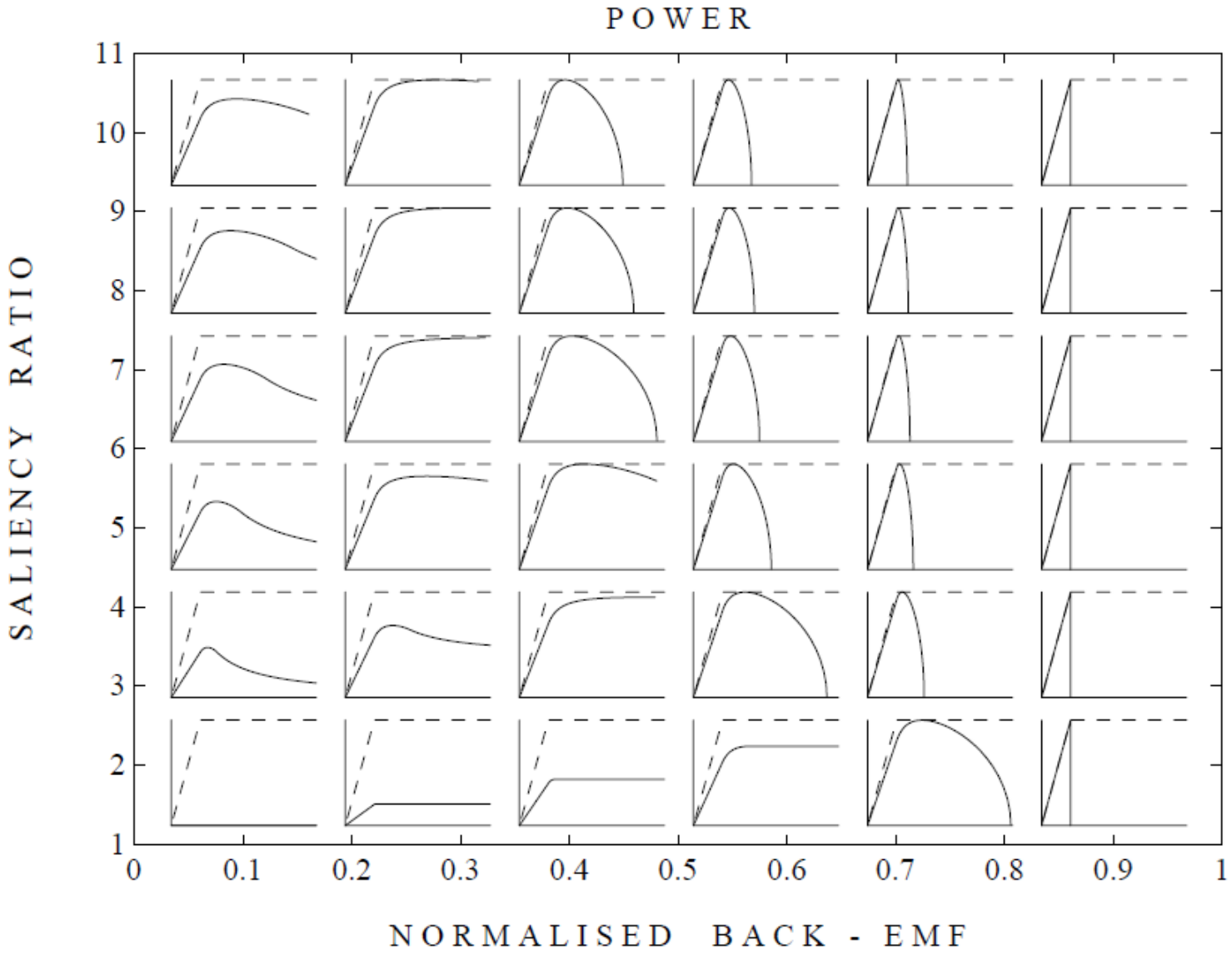
4.3.3. Varying Two Parameters



[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.

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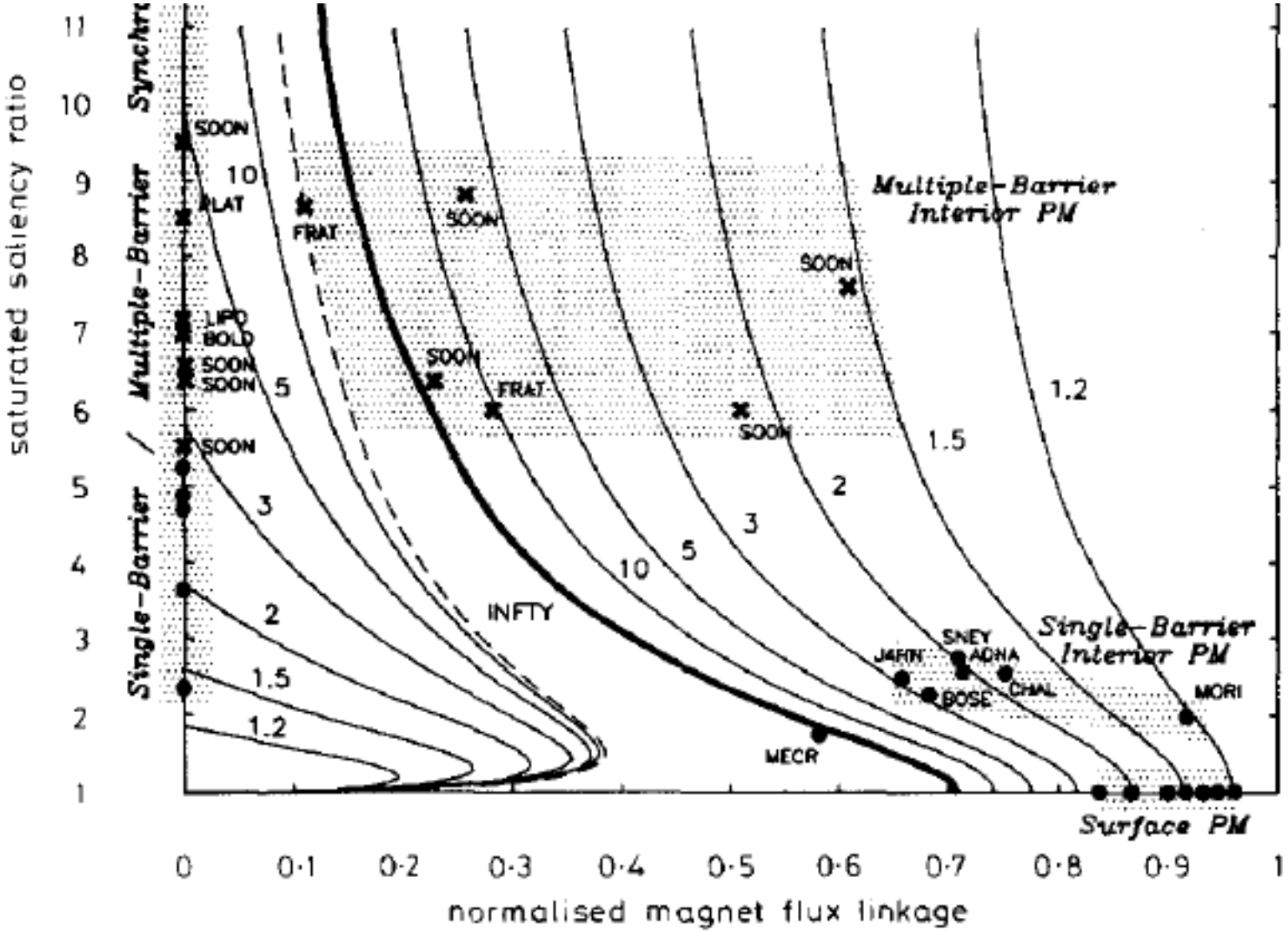
4.3.4. Parameter Plane



[1] W. L. Soong and T. J. E. Miller, "Field-weakening performance of brushless synchronous AC motor drives," Electric Power Applications, IEE Proceedings -, vol. 141, pp. 331-340, 1994.

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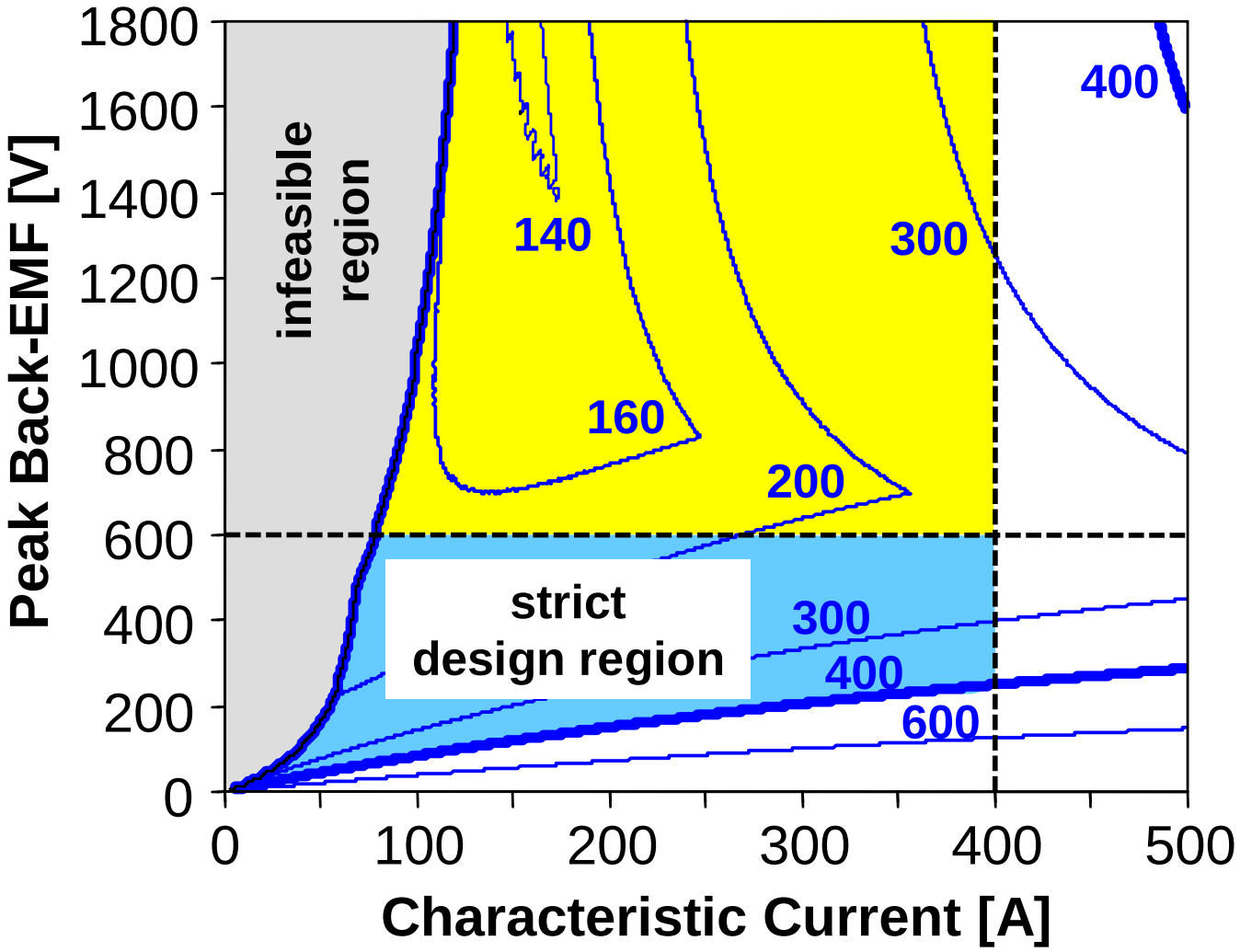
4.3.5. Parameter Plane



[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.

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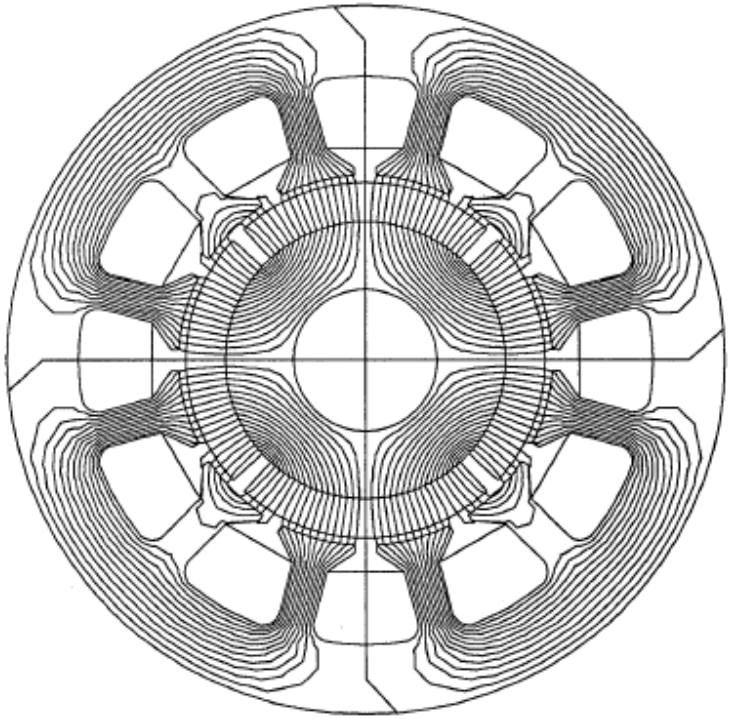
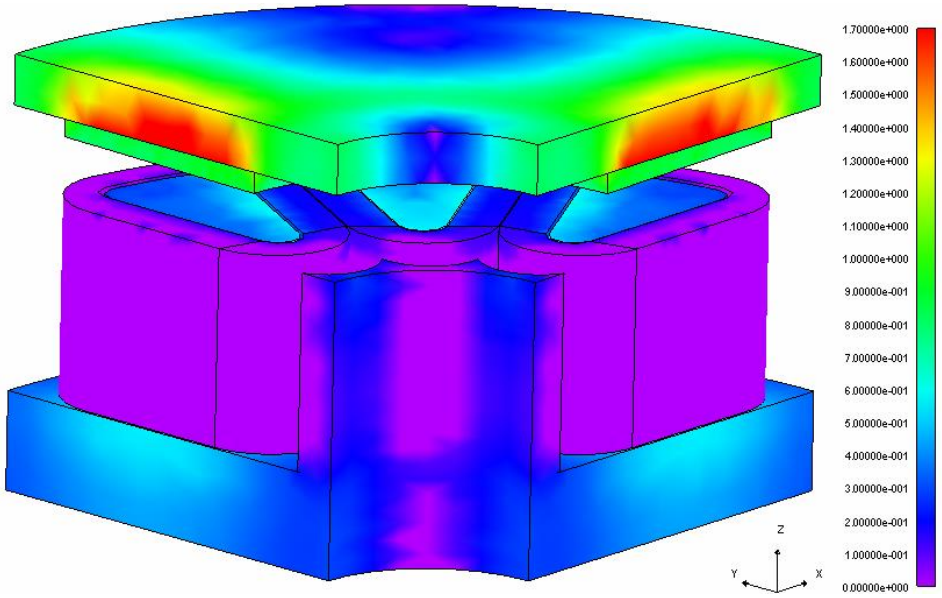
4.3.6. Simulation Results





[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.

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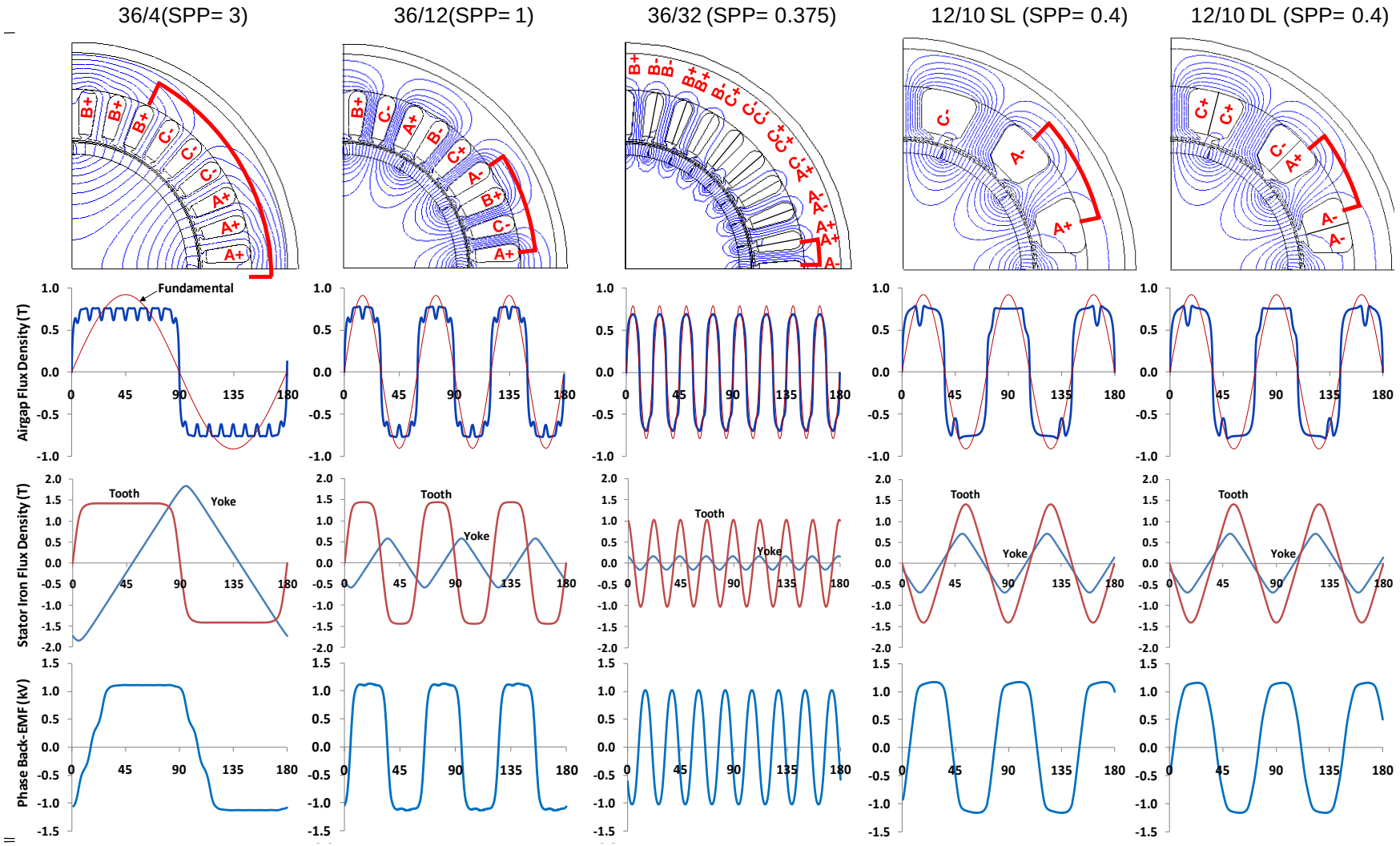
4.3.7. FE Analysis Summary



[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.

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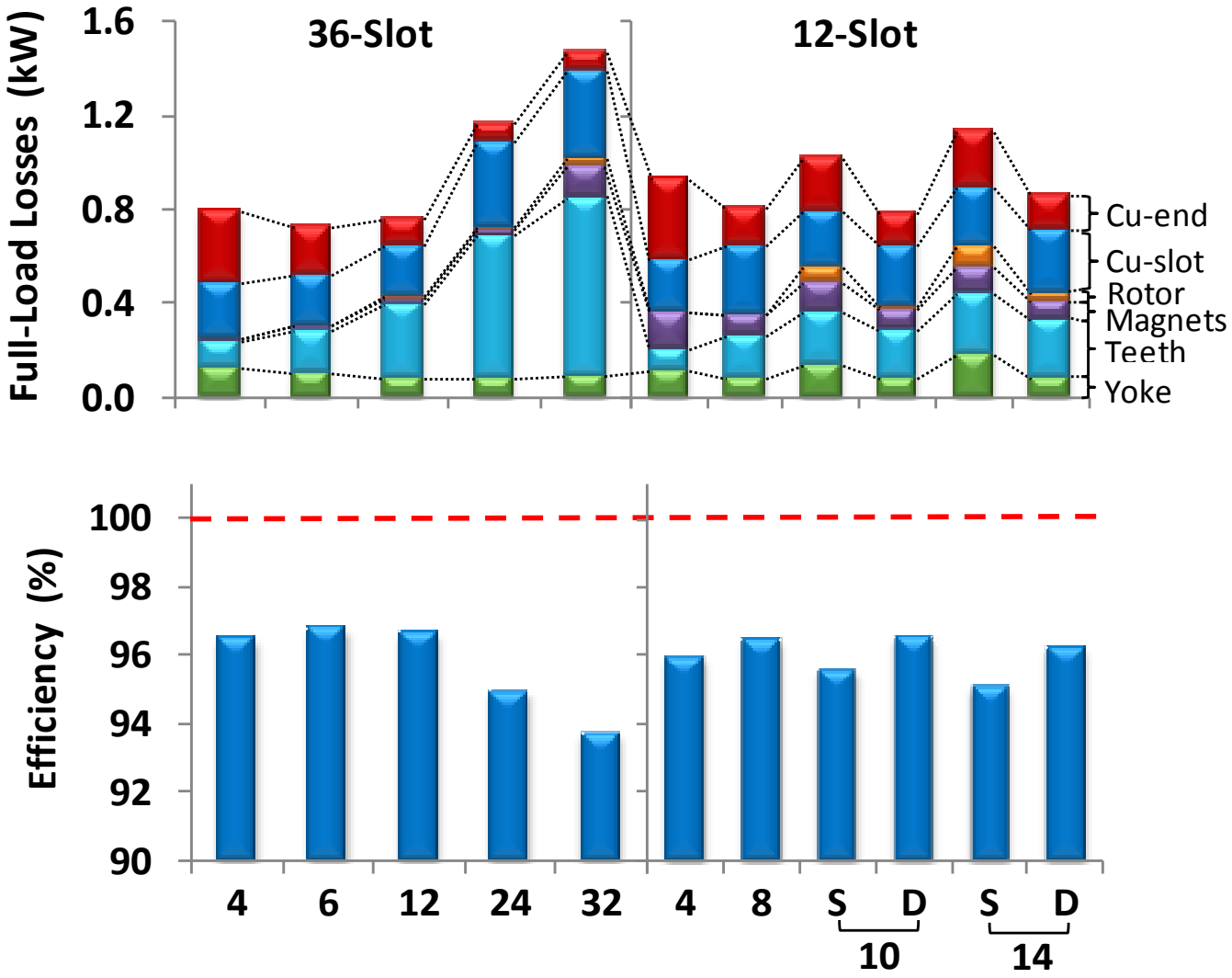
4.3.8. Example : Loss Breakdown



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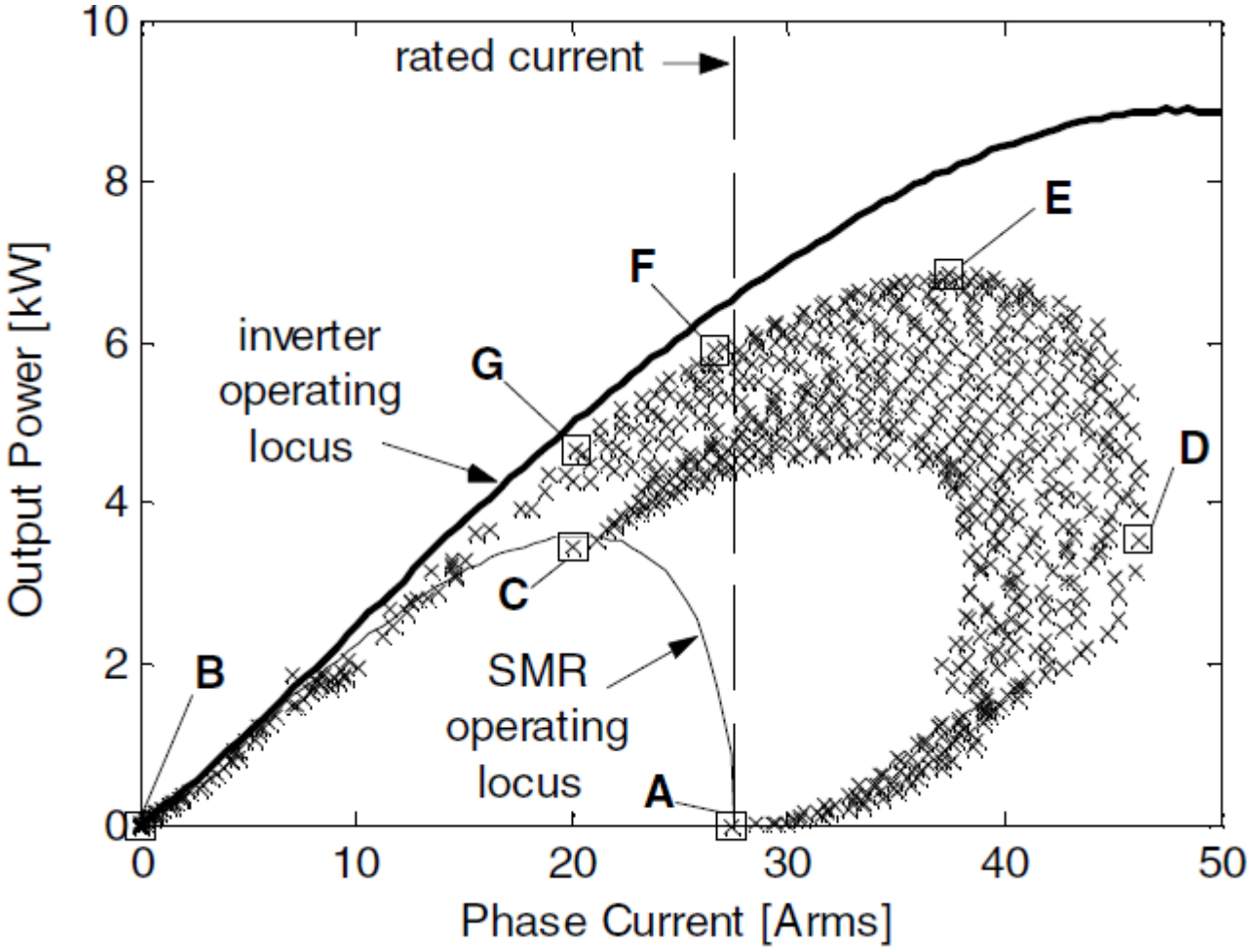
4.3.9. Changing Control Parameters



[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.

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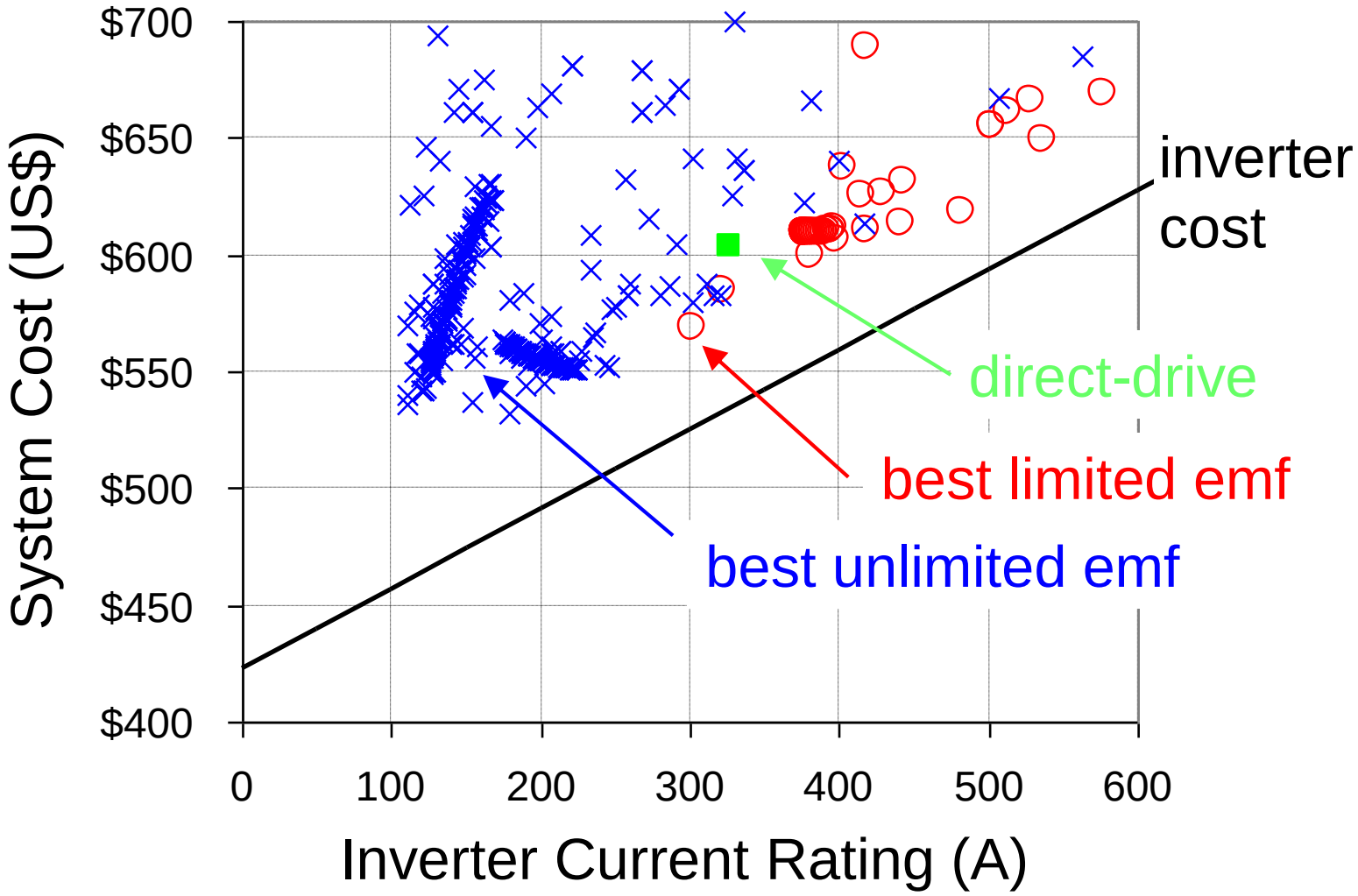
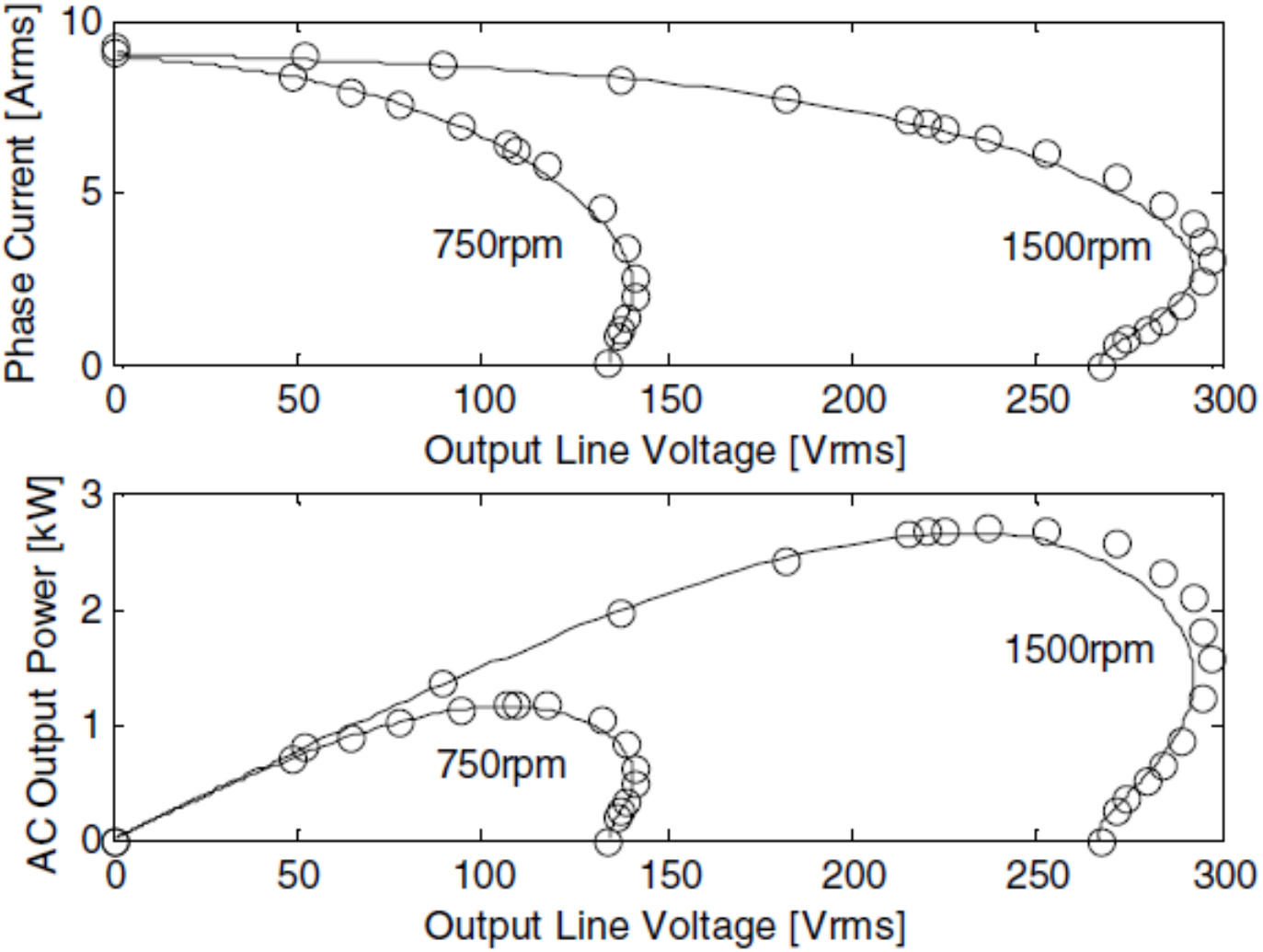
4.3.10. Optimisation



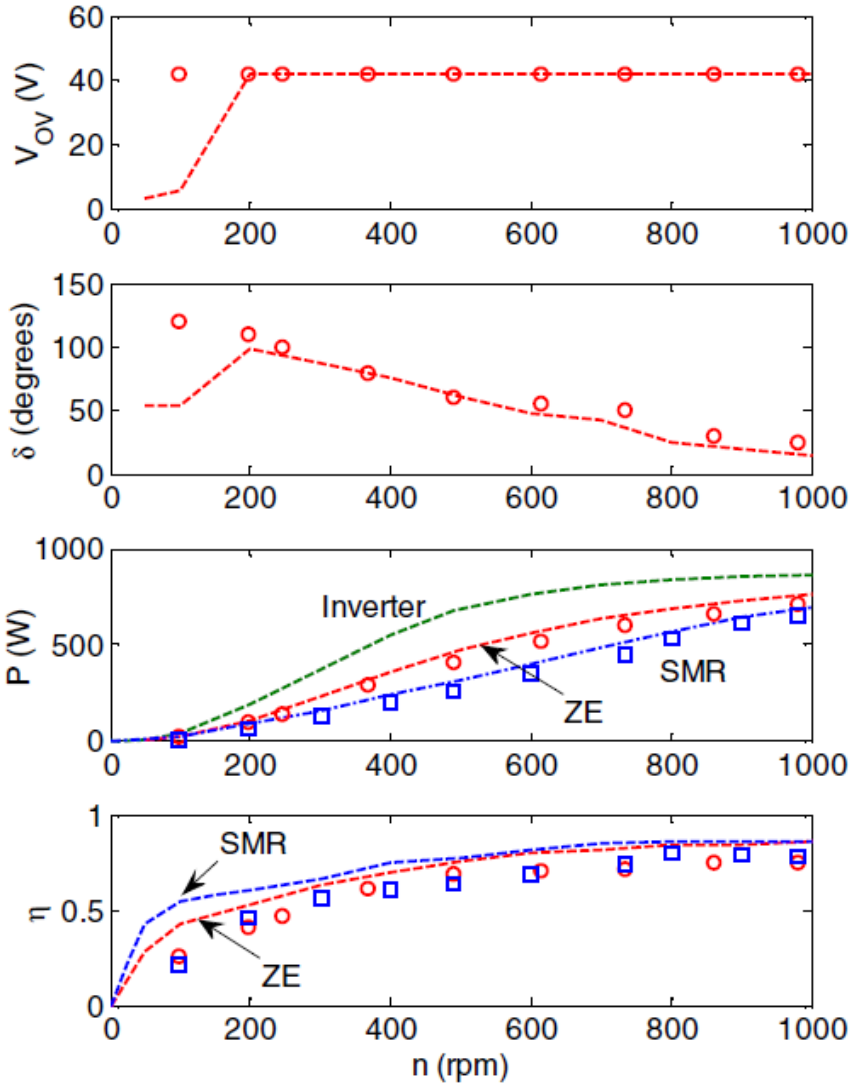
[1] C. Z. Liaw, W. L. Soong, and N. Ertugrul, "Low-Speed Output Power Improvement of an Interior PM Automotive Alternator," in Industry Applications Conference, 2006. 41st IAS Annual Meeting. Conference Record of the 2006 IEEE, 2006, pp. 27-34.

4.3.11. Experimental Comparisons



[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.

4.3.12. Control and Performance



[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.

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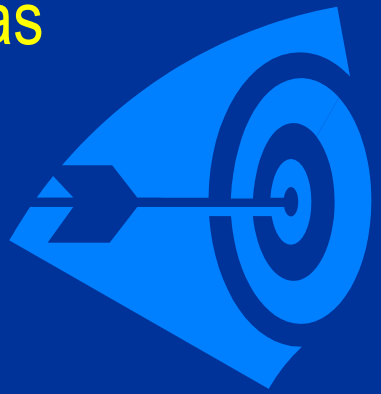
Key #5. Write Great Papers

conference papers give deadlines and focus ideas

- Stay conclusion focussed
  - everything in the paper targets the conclusions
- Start with a paper skeleton
  - title, abstract, key figures, dot-points and conclusions
- Keep writing concise and clear
  - constantly revise and clarify



5.1. “Good” Paper Structure

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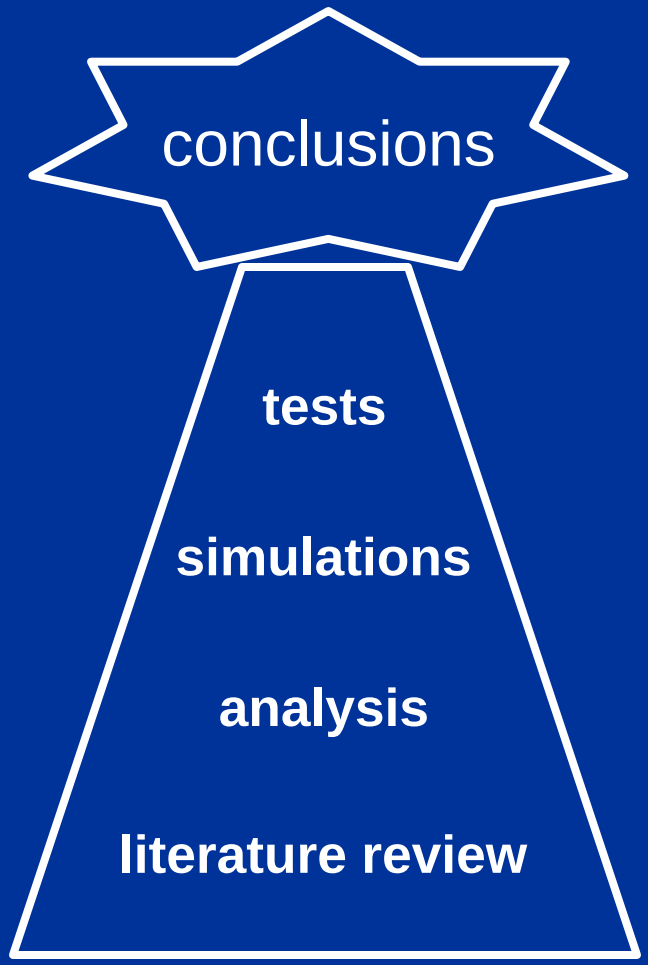
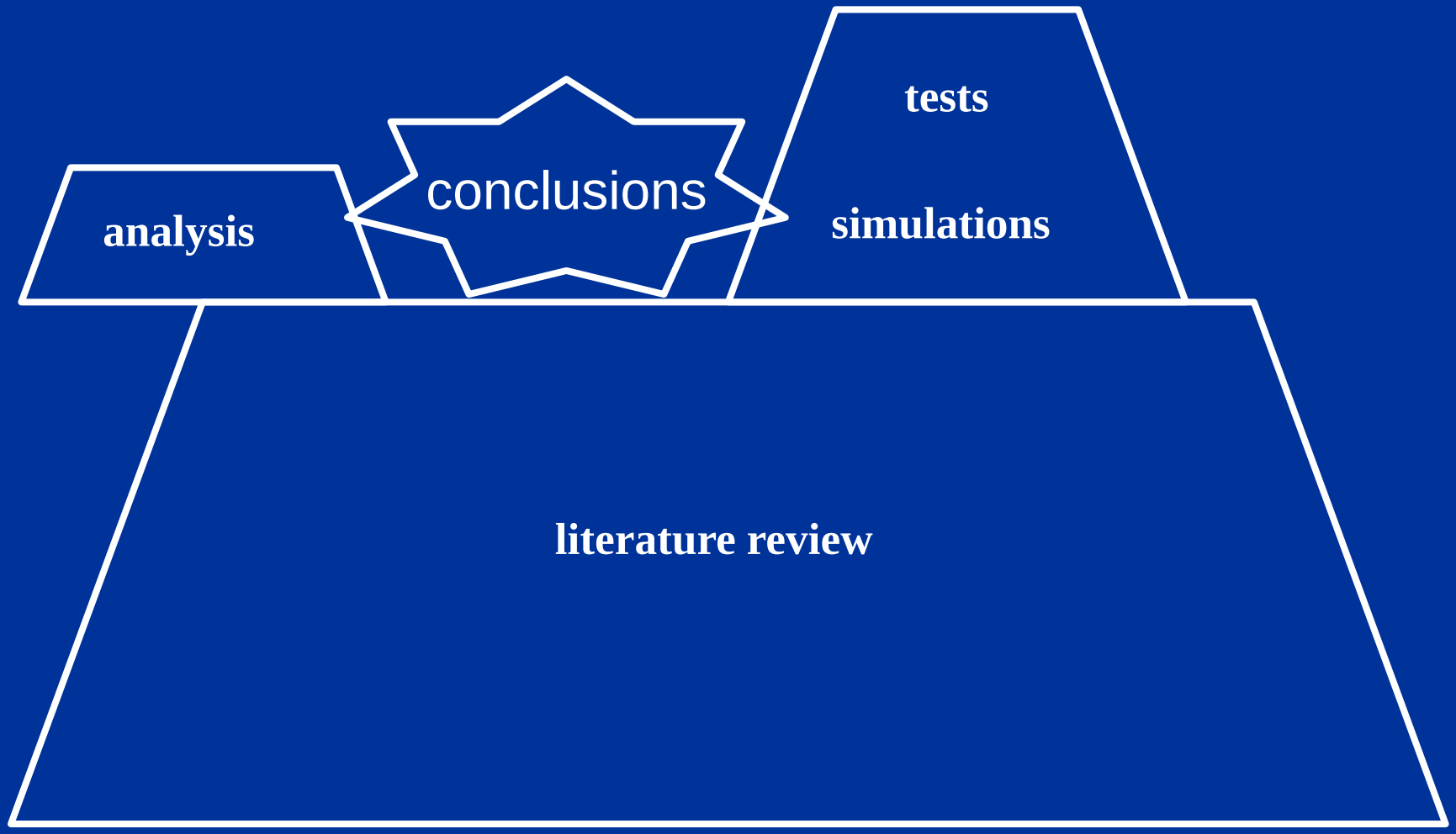
the content of a paper is there to support the conclusions

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



5.2. “Bad” 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 …

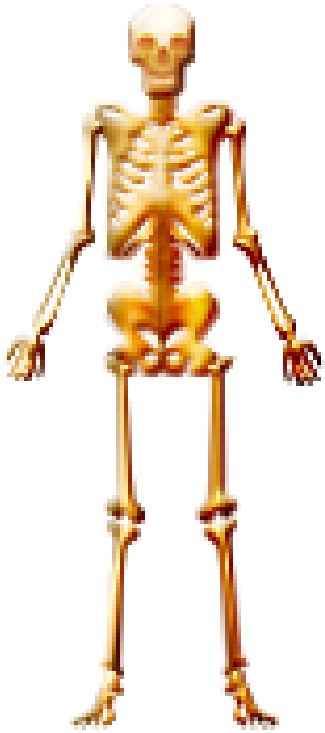
– analytical derivation of power reduction …

– numerical simulation of power reduction …

Importance/Applications

– allow rapid estimation of output power reduction …

– understanding the relationship between …



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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. Seek Insight by Analysis
7. Understand Literature Reviews
8. Utilise Parallel Processing
9. Effective Management
10. Balance and Sustainability

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Key #6. Seek Insight by Analysis

seek understanding and insight

- Start from first principles
  - begin with simplest models and build up
- Have curiosity, seek insight and understanding

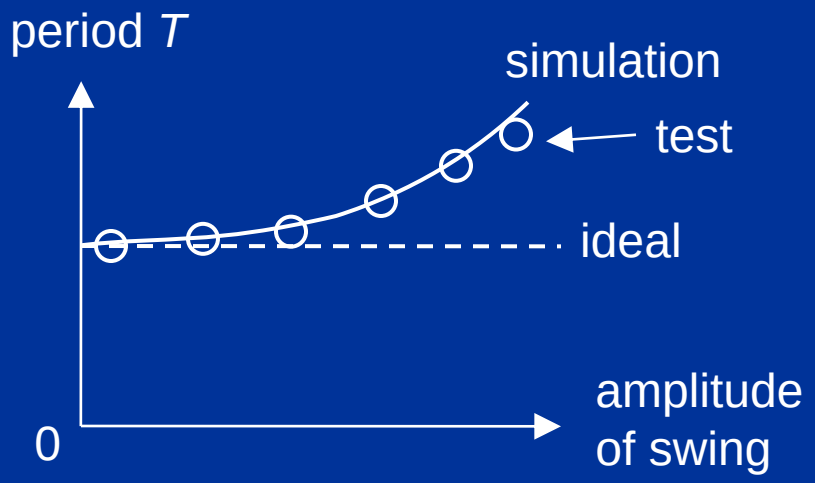
- Investigate parametric modelling
  - powerful technique for certain applications

6.1. Analyse, Simulate and Test

Example : simple pendulum

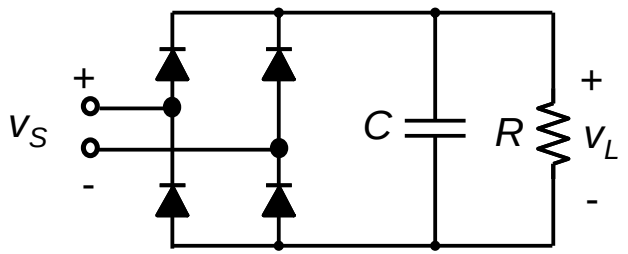
- Analysis : equation of motion
- Simulation
  - E.g. numerical
- Experiments
  - test pendulum

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



6.2. Parametric Analysis

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



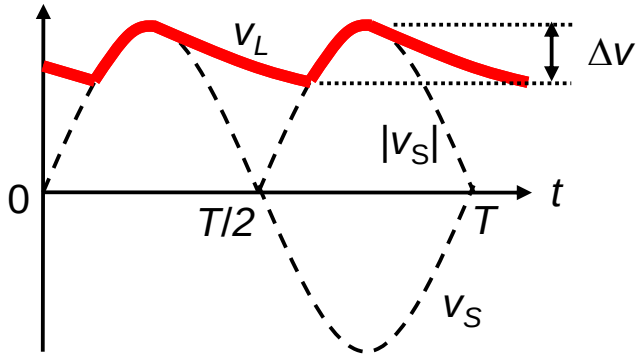
Example : consider a full-wave diode rectifier with a 1ph AC voltage input

a) 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



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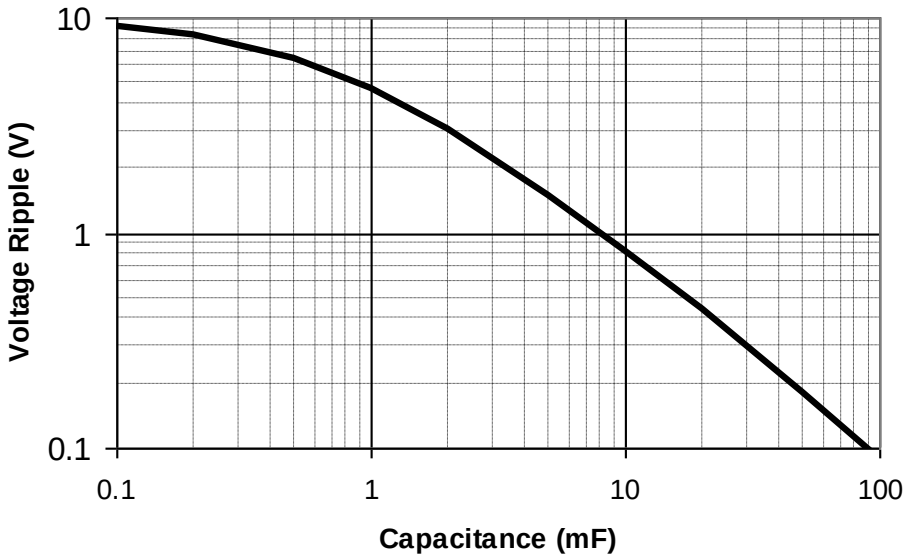
6.2.1. Parametric Analysis

1) particular 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



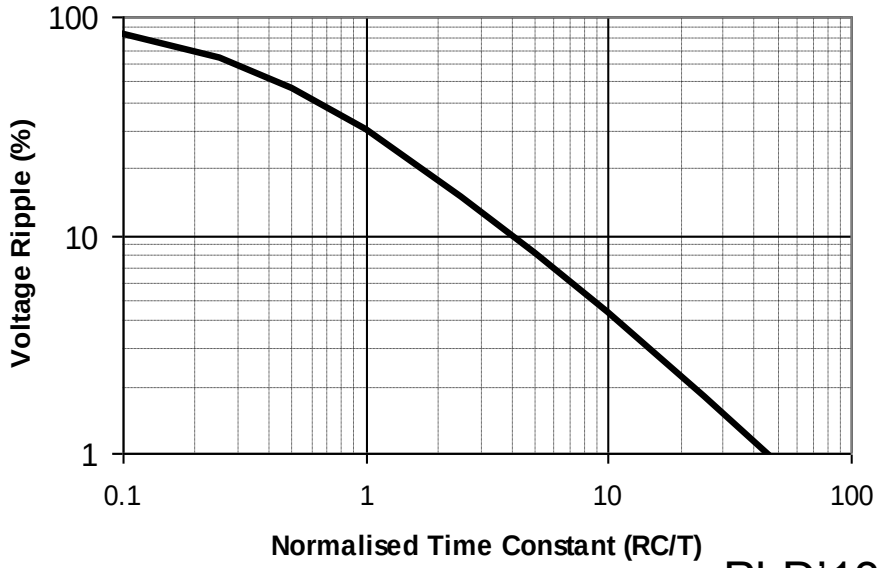
2) general case

use physical understanding of system 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



6.2.2. Extending Results

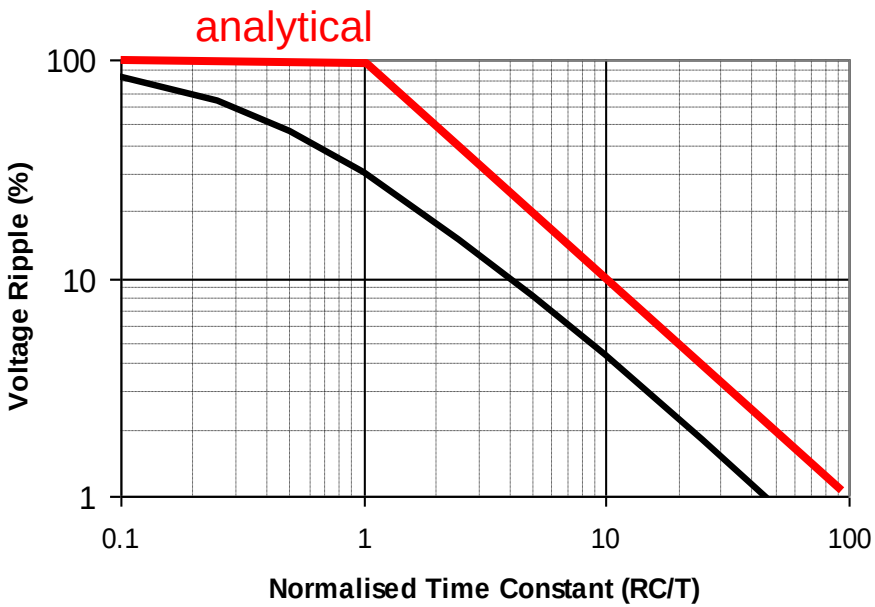
1) Analytical Result

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



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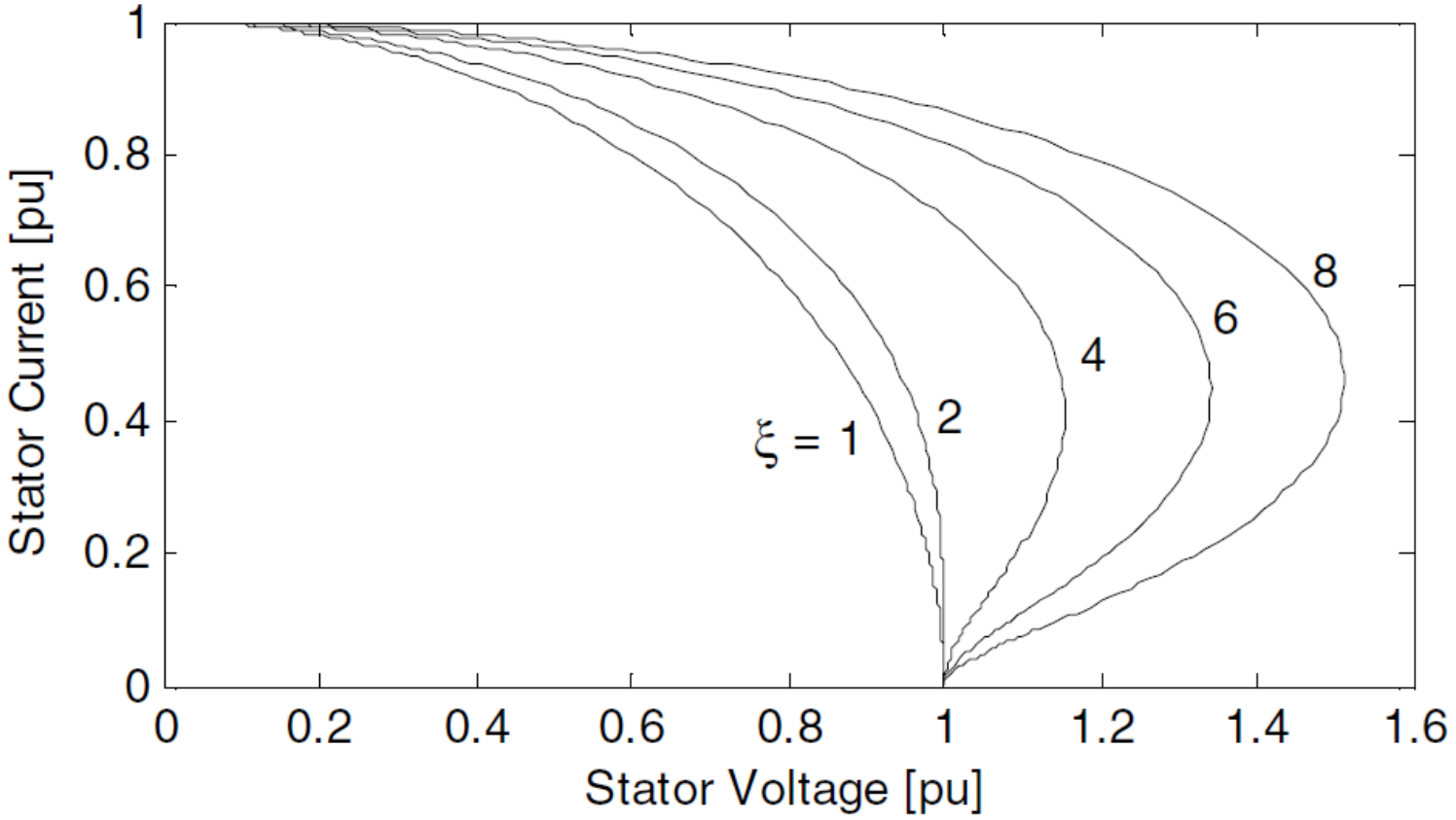
6.3. Parametric Example #1

normalised parameters used to generalise result to all parameter values – x-y plot



[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.

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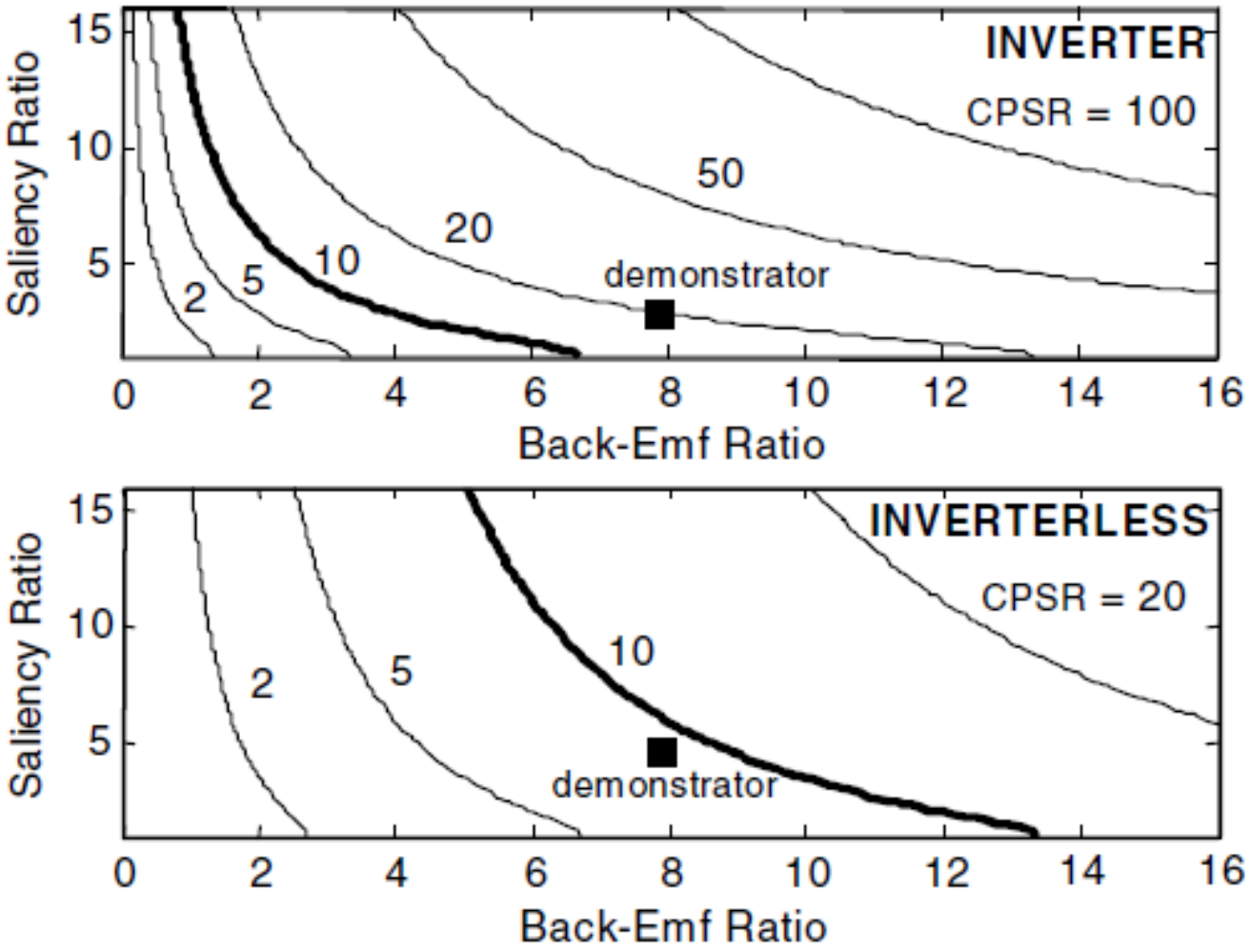
6.4. Parametric Example #2

contour plots using normalised parameters



[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.

6.5. Parametric Example #3

study maximum torque per ampere control of interior PM machines

three parameters : Ψ_m, L_d, L_q

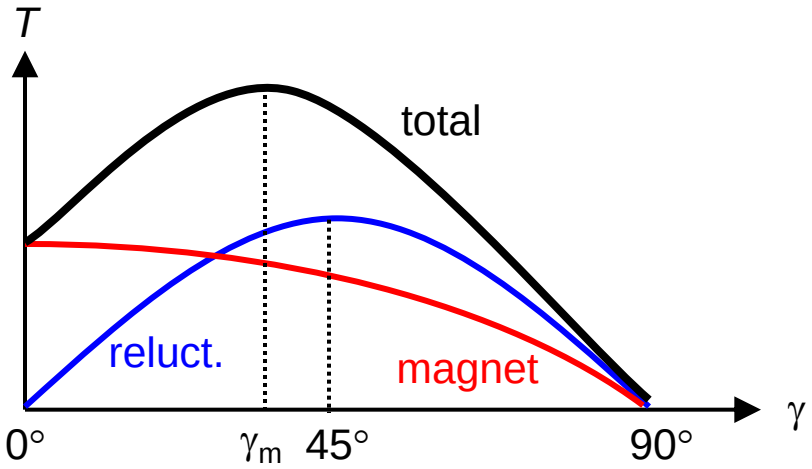
with constant current I, torque varies with current angle

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

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



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

6.5.1. Parametric Example #3

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

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

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

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

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Key #7. Understand Literature Reviews

purpose: show you understand background and can demonstrate innovation

- Classify the existing literature
  - identify relevant categories
  - classify previous work by category
- Clarify original contribution with respect to most relevant work

7.1. Literature Review

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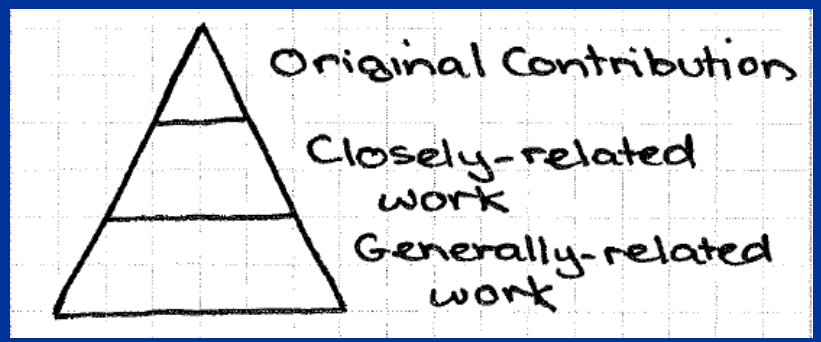
- Classification of existing work
  - identify factors which can be used to classify existing work
  - how does your work fits in?
- Clarification of contribution
  - identify relevant work in the field
  - discuss their contributions
  - highlight short-comings
  - identify research opportunities
  - explain your contribution

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



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Key #8. Utilise Parallel Processing

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

- "classic sequential" approach : first literature, then analysis, then simulations, then tests
- "parallel" approach : while doing reading and analysis, also learn
  - simulation tools
  - experimental skills

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Key #9. Effective Management

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

- Manage yourself
  - efficiently organise & back-up paper/electronic files and email
  - forward planning (e.g. 3 year, next month), be pro-active
- Manage your supervisors
  - meeting management

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9.1. 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

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Key #10. Balance and Sustainability

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
- improve your research skills along the way
  - communication, reasoning, analysis etc.
- seek to learn something new everyday
- find things to enjoy in the journey!

Keys to Success in a PhD

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- 1. Continuous Writing
- 2. Build Your Thesis Step by Step
- 3. Know the Big Picture
- 4. Outstanding Figures
- 5. Write Great Papers
- 6. Seek Insight by Analysis
- 7. Understand Literature Reviews
- 8. Utilise Parallel Processing
- 9. Effective Management
- 10. Balance and Sustainability

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Keys to Success as an Engineer

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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!
  - questions, seminars, books, courses …
- Keep passing it on - document what you learn
  - clarify understanding
  - reference for yourself and others

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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, reports, presentations, emails, calls, meetings

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

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3 Keys to Success : #3 Environment

success as an engineer is more than solving technical issues

- understand the big picture
  - global, industry, company, your management and customers
  - how things work in company – mentoring can help
- know the aim of company
  - satisfy customers needs and make a profit
- consider further training – management, finance etc.

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Summary

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

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Power Engineering Briefing Notes

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

- pebn013 PhD research three keys to success
- pebn012 writing a good journal paper
- pebn011 parametric analysis in power engineering
- 12R021 great graphs make excellent papers
- 12R014 literature reviews
- 12R021 how to do research
- thesis writing hints

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Keys to Success in PhD Research

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