M.Sc Thesis Topic

R & D Area: Electronics and Data Analytics

Design of a Vienna Rectifier

Abstract

The Vienna Rectifier is useful wherever six-switch converters are used to achieve sinusoidal mains current and controlled output voltage, when no energy feedback from the load into the mains is available. In practice, use of the Vienna Rectifier is advantageous when space is premium, EMI requirements are strict, and regulatory needs on power factor are stringent

Previous Knowledge

- A strong working knowledge of power electronics,
- PCB design and experience with relevant software,
- Experience using MATLAB/Simulink.

Outcomes

A physical interpretation of the rectifier will be built. During its development practical experience will be attained from working with sofware and in design of power electronic circuits. Such as: Simulation, Heating analysis, Choosing of correct parts, PCB design and circuit construction.

The constructed work will be used in demonstrations and in lectures as pedagogic tool.

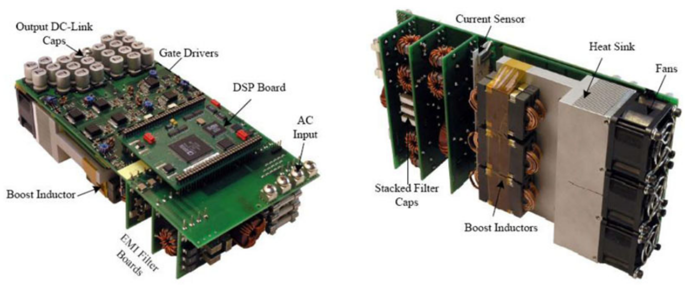
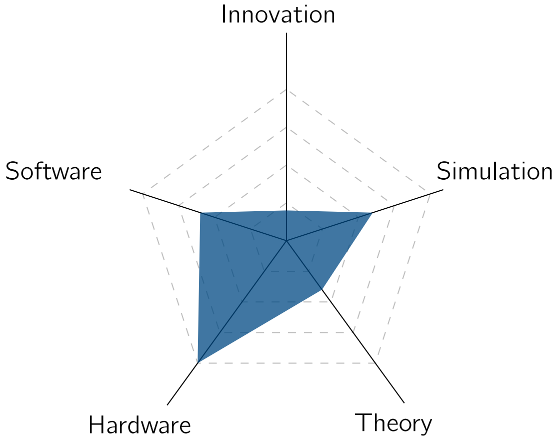


Figure 1: Top and bottom view of an air-cooled 10kW-Vienna rectifier (400kHz PWM). This is an example of a build rectifier by the researcher who devised the topology. The requirements and the hardware will be discussed by the interested student.



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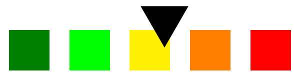

For Enquiry

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Scientific Interests

- Power Systems,
- Superconductive Physics,
- Open-Source Software,
- Electromagnetic Waves,
- Electrical Machine Design,
- Communication Methods,
- Mathematical Physics

R & D Area: Electronics and Data Analytics

Design of a Vienna Rectifier

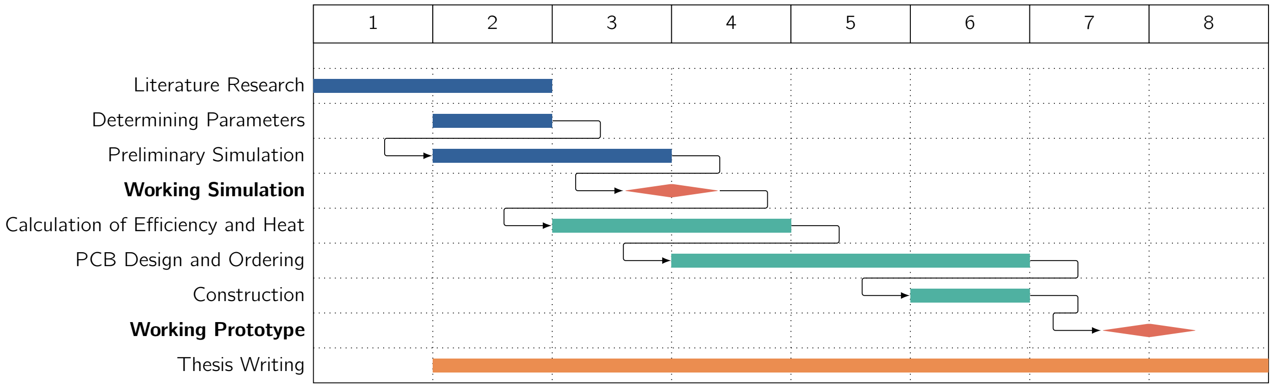


Figure 2: A template on how the project should be structured.

Topic Introduction

Limitation of the high harmonic contents in the currents and improvement of the input power factor of the loads supplied by the power electronic converters is one of the most important problems of power electronics. This is especially true when there are regulatory limitations imposed by the power companies or a device which needs to be protected from transient effects.

A standard diode (full, or half) and thyristor rectifiers are sources of the high harmonic current components drawn out from the electric power utility (THD $\approx$ 30%), while the regulations usually demand the total harmonic distortion factor (THD $\approx$ 5%), These constraints require the design of a different topology which the Vienna rectifier delivers.

The primary advantages of this construction are: three phase, three level input voltage generation, controlling only three electronic switches, less voltage stress of the electronic switches than in the case of the standard PWM converter.

It is worth underlining that this configuration is death time problem free. However, the Vienna rectifier is unidirectional system. It can convey the electrical energy only from AC circuit to the DC circuit.

There are numerous methods of controlling Vienna rectifier which the interested student is encouraged to look at. The controlling Vienna rectifier by the voltage space vector method and its limitations is the subject of this paper. The Vienna rectifier belongs to the class of AC/DC converters with current source input and voltage source output. The primary sides of input magnetic coils are supplied by phase voltages. The controlling this kind of the converter relies on the generation of three phase voltages at the secondary side of the input magnetic coils. This generation must go in the manner that the voltages at the input magnetic coil impedance have low high harmonic contents, the phase angle and amplitude of the first harmonic voltage oriented to obtain the desired current values near sinusoidal and usually in phase with input phase voltages

M.Sc Thesis Topic

R & D Area: Electronics and Data Analytics

Simulation of a Synchronous Reluctance Machine

Abstract

A synchronous reluctance motor (synRM) is a type of electric motor which operates based on the principle of magnetic reluctance. Unlike traditional motors, which rely on electromagnets or permanent magnets, synRMs generate torque through the rotor's reluctance to the magnetic field generated by the stator. This results in a highly efficient motor with a simpler construction.

Previous Knowledge

- A good understanding of electric machine design,
- A strong background in C/C++ programming,
- Good knowledge of electrodynamics is preferred.

Outcomes

A FEM simulation of a synchronous reluctance machine will be conducted. The student is required to design his/her/their own geometry/mesh using gmsh/CAD and do the necessary simulation using open-source software such as OpenFOAM, GetDP, or oneLAB to get a performance analysis. After a successful work, the student will gain significant understanding of modelling electrical machines, understanding meshes for use in simulations and possibly working with industry standard software (i.e., CERN, Audi, Porsche, . . .)
This work will be used heavily in lectures as showcase for how a machine can be designed and analysed.

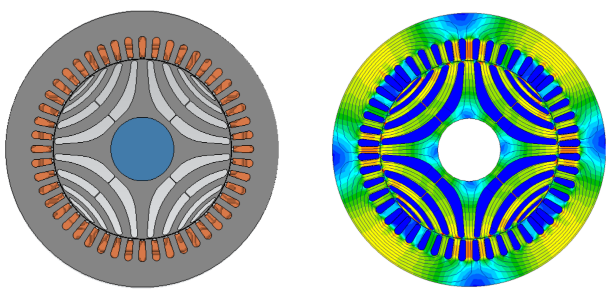
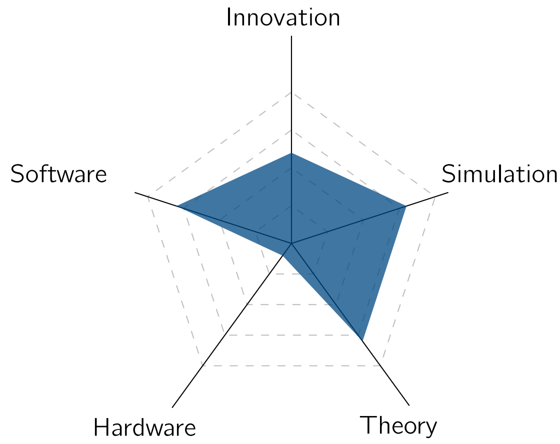


Figure 3: Cross-section of the SynRel FEA model (left) and an example of flux density map (right). The above figures are part of what is expected of this work.



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R & D Area: Electronics and Data Analytics

Simulation of a Synchronous Reluctance Machine

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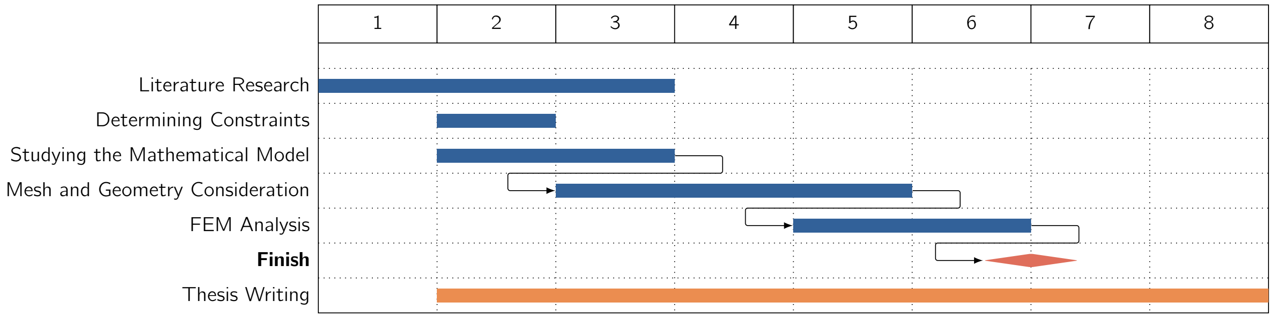


Topic Introduction

The mature IM is recognized as a well-established and widely available structure on account of its rigid mechanical construction and low cost and maintenance requirements. However, the implementation of the bars on the rotor leads to many drawbacks in this motor. The inherent warm rotor operation due to the currents in the bars can lead to rotor losses, which consist of around 20% of all losses in IM. As a consequence of high substantial losses, the high temperature of the rotor can lead to more probable faults in bearings, which have the biggest share in IMs faults.

Today, PMSMs are the dominant technologies for many applications. High efficiency, high torque density, and desirable wide speed range performance of these motors have made the technology popular among manufacturers. PM materials are the most important elements of PMSMs. Two common applicable PM materials for PMSMs are neodymium-iron-boron (Nd-Fe-B) and samarium-cobalt (Sm-Co), both of which contain the rare-earth elements. The dramatic rise and fall of the price of the rare-earth magnets, especially Nd-Fe-B magnets, have directed the research towards rare-earth-free machines to replace high-performance PMSMs. The reliability issues in PMSM due to possible faults of the magnets are also disputable. The rotor design of SynRM distinguishes it from its IM and PMSM counterparts. In comparison with those conventional motors, SynRM attains higher reliability and easier maintenance (due to the very low winding and bearing temperature, and they also lack cage or PMs in rotor structure), lower cost (due to the lack of PMs in comparison with PMSM), faster dynamic response (due to smaller size in the same power range and lower moment of inertia), higher speed range (due to the wide constant-power operation in comparison with IM) and higher efficiency in the same power range with the same frame size (due to the cold rotor operation in comparison with IM), and higher power density and higher torque per ampere (in comparison with IM). In this sense, SynRM offers the high performance of PMSM, while it can be as cheap, simple, and service- friendly as IM. Therefore, the attention paid for these motors in high-speed applications has experienced continuous growth in the literature, which has convinced the electric vehicles (EVs) and hybrid electric vehicles (HEVs) manufacturers to apply SynRMs as an alternative for PMSM. Having said this, the possibility of the drive with the same VSDs for IM and PMSM in various recently designed VSDs has provided a viable development base for SynRM. All in all, the high efficiency of SynRMs against IM has attracted attention for applications such as pumps and fans. Also, the high performance and especially wide speed operation capability with the consideration of lack of rare-earth PMs compared to the PMSM has attracted the researchers to study these motors for traction application.

M.Sc Thesis Topic

R & D Area: Electronics and Data Analytics

Minimising Space Harmonics of an Induction Motor

Abstract

Spatial harmonics are the cumulative name given to the distortions happening on the MMF waveform of a motor and one of the major interests is its effect on the induction motor. These harmonics are often produced by dead times in pulse width modulation (PWM), supply voltage unbalance, magnetic circuit saturation, non-sinusoidal winding distribution, lamination slotting and some other non-linearities and asymmetries. As induction motors are still a relevant choice for electric vehicles, its optimisation is still a big interest among many companies.

Previous Knowledge

- A good understanding of machine design/FEM methods,
- Practical skills on C/C++, or Python
- Understanding of Electrodynamics and electric machines.

Outcomes

The student who finishes the project will gain significant knowledge on motor construction and design along with a good understanding with working FEM and writing their own code for diminishing the space harmonic problem. The student will also gain a working knowledge on how meshes work, how are solvers written and attain a deeper appreciation to crafting machines. The outcome of this work will be used in Drive lectures as a pedagogic tool, in addition, based on the progress of this work, there is a possibility of publication.

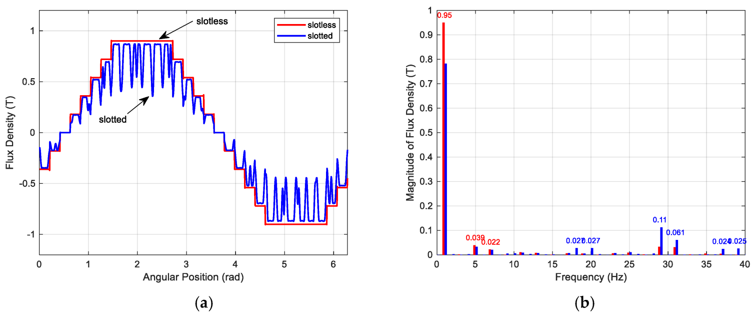
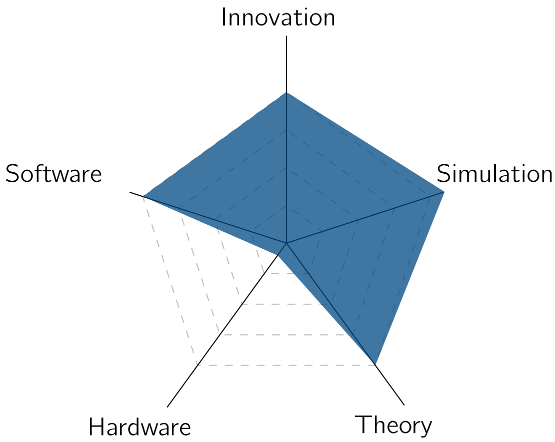


Figure 4: Two plots explaining the effects of the spatial harmonics effect on the MMF waveform. The act of having a slot is a necessity and causes harmonics. Clever methods are needed to avoid or at least diminish its effects.



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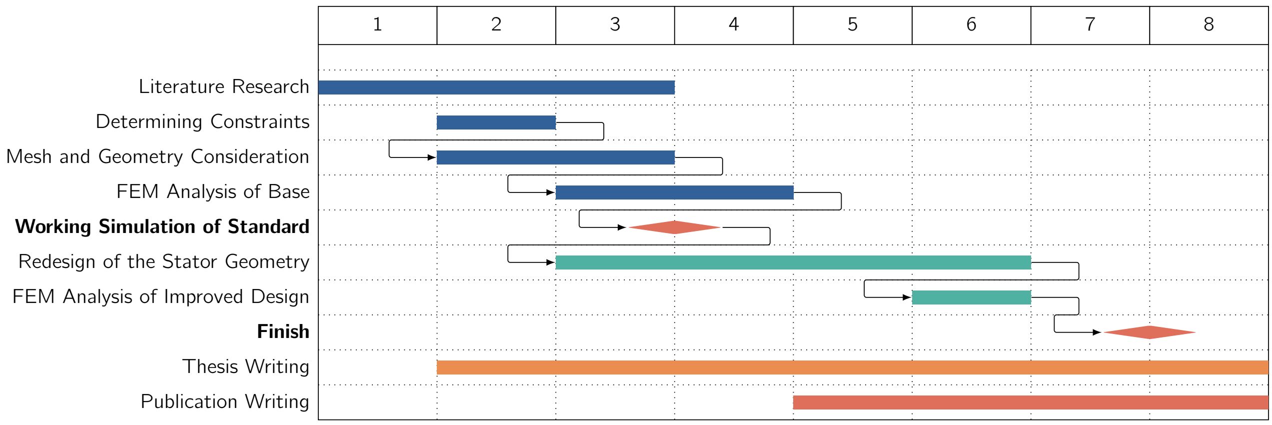
R & D Area: Electronics and Data Analytics

Minimising Space Harmonics of an Induction Motor



Topic Introduction

Space harmonics are mainly considered by motor design engineers. When the power supply to the induction motor is sinusoidal, the harmonics in the magetomotive force (MMF) of the air-gap are what is called, space harmonics. This type of harmonics will affect motor starting and cause magnetic noise and vibration. Space harmonics can not be avoided because they are generated by the magnetic interaction of the different phase windings in order to produce the rotating magnetic field, but they can be reduced by optimizing the machine design.

This work would require of the student to start working with first generating the physical construction of the machine using a meshing program as this work relies heavily on using FEM. Then the generated mesh must be studied using a FEM software. Once the structure has been analysed, then the configuration of the stator needs to be changed to minimise some of the harmonics caused by the MMF.

Depending on the outcome of the work, there is a possibility of a publication or a proceeding.

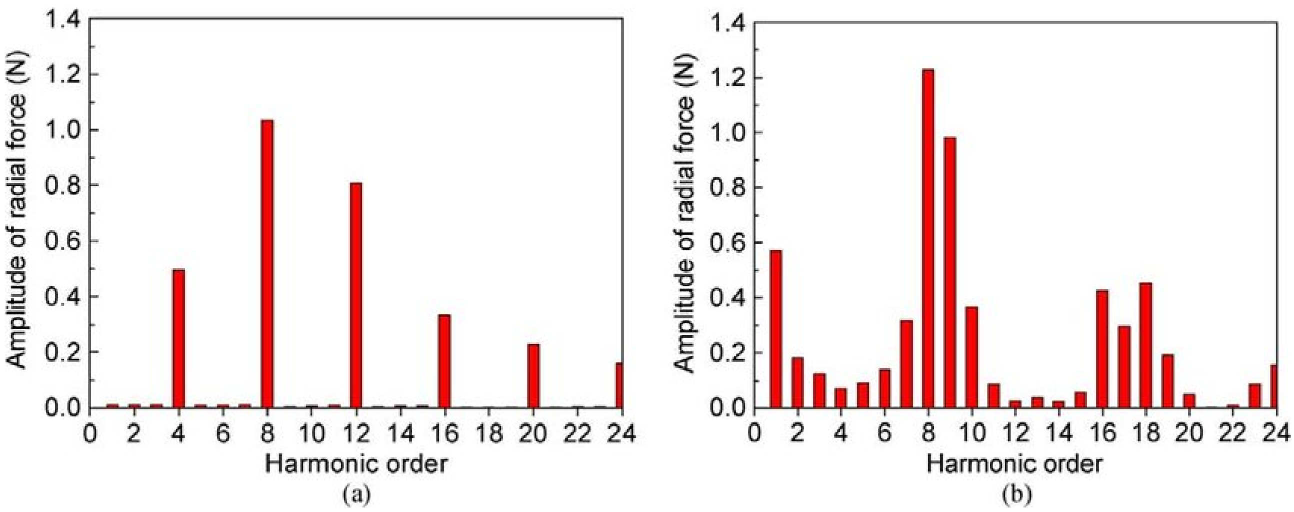


Figure 5: While most topics and optimisations occur of AC motors, BLDC and PMSM can also experience these effects.

M.Sc Thesis Topic

R & D Area: Electronics and Data Analytics

Analog Computer for Solving ODEs

Abstract

Analog computer, any of a class of devices in which continuously variable physical quantities, (i.e., electrical potential) are represented in a way analogous to the corresponding quantities in the problem to be solved. The analog system is set up according to initial conditions and then allowed to change freely. Answers to the problem are obtained by measuring the variables in the analog model and are seeing a resurgence as a good alternative to digital computers.

Project design/test/construct an electrical circuit which should be able to solve and ODEs given to the circuit as input. As an example, the circuit will get waveform as inputs and based on its user adjustable configuration produce a waveform which is the solution of the ODE in question.

Previous Knowledge

The student is required to have a working knowledge of:

- Working understanding with PCBs,
- Circuit design and soldering.
- Understanding ODEs are a plus.

Outcomes

The outcome a working example of an analog computer constructed from electrical circuit components. The student will also gain a strong understanding with circuit design.

The outcome of this work will be used extensively in Mathematics Lectures to showcase ODE solving and will be used in demonstrations.

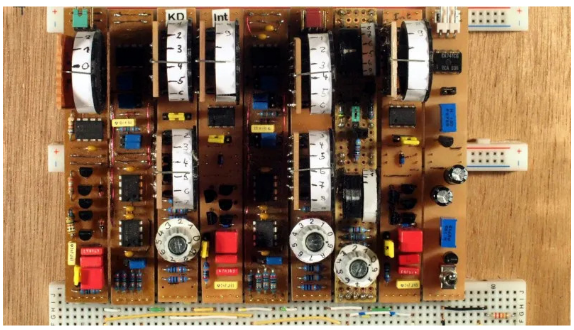
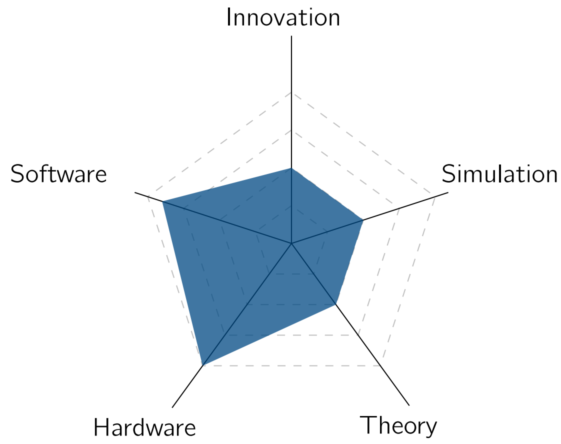


Figure 6: A modular analog computer.



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R & D Area: Electronics and Data Analytics

Analog Computer for Solving ODEs

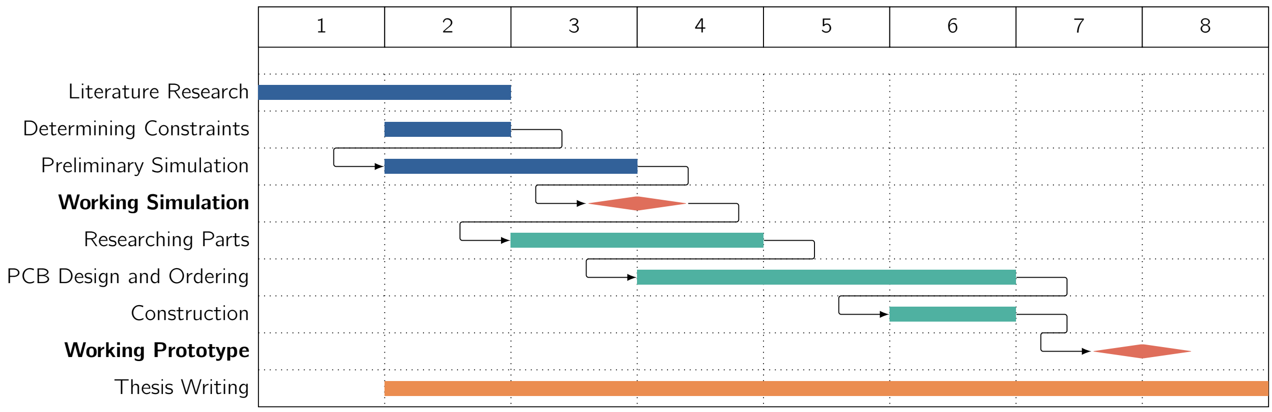


Figure 7: A template on how the project should be structured.

Topic Introduction

When it comes to differential equations, things can become complex relatively fast or at least that's what it looks like at a first glance. When I studied mathematics, lectures on differential equations were considered to be amongst the hardest and most abstract of all (which is what I teach in Higher Mathematics I ...). However, their importance should not be underestimated as it is one of the essential ways we can model natural or engineering phenomena such as circuit dynamics, object motion or population dynamics.

When asked about solving differential equations, most people tend to think of a plethora of complex numerical techniques, such as Euler's algorithm, Runge-Kutta or Heun's method, but few people think of using physical phenomena to tackle them, representing the equation to be solved by interconnecting various mechanical or electrical components in the right way. This work shall be used extensively in lectures and showcasing the engineering approach to solving differential equations.

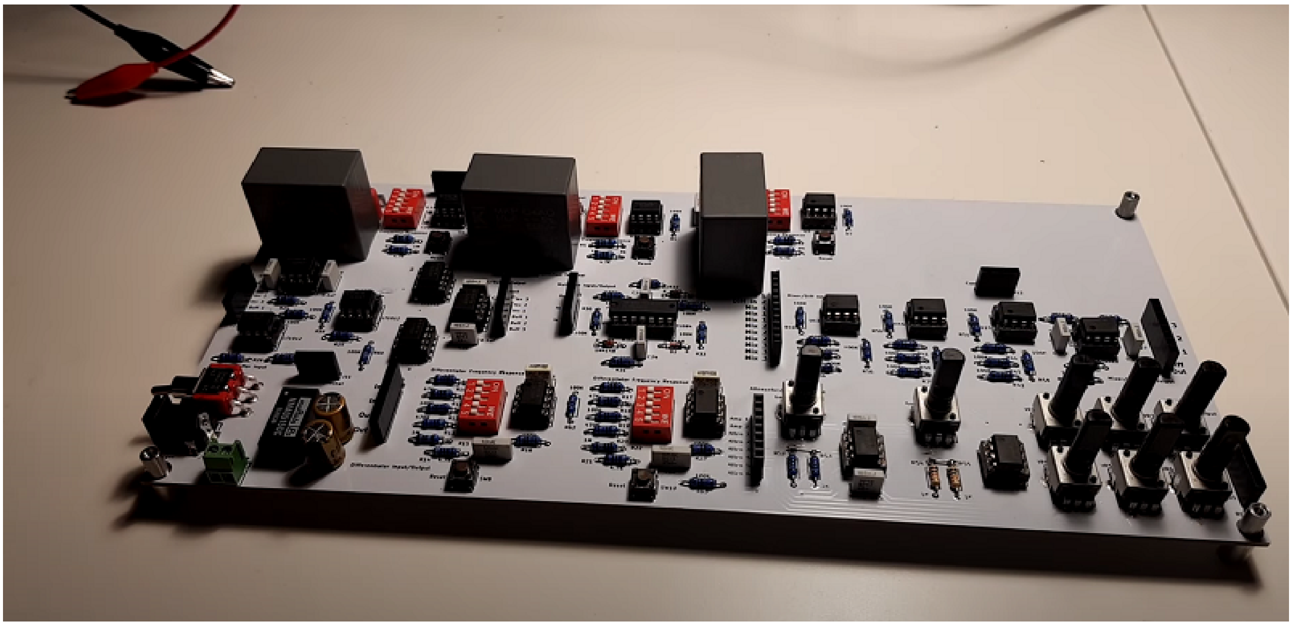


Figure 8: A possible outcome of what the circuit could look like

M.Sc Thesis Topic

R & D Area: Electronics and Data Analytics

Design, Construction and Testing of an Eddy Current Brake

Abstract

Unlike mechanical brakes, which are based on friction and kinetic energy, eddy current brakes rely on electromagnetism to stop objects from moving.
Eddy currents are created when a conductor passes through a magnetic field, which creates opposing forces that spin inside the conductor. According to Lenz law, an eddy current produces a magnetic field that is in opposition to the magnetic field that produced it, and therefore eddy currents are an inverse response to the source magnetic field. This reaction between electromagnetic forces happens to be ideal for clean deceleration.

Previous Knowledge

The student is required to have a working knowledge of:

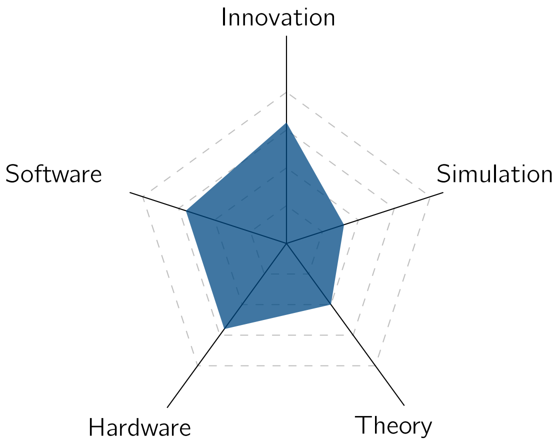
- A good understanding of electric machine design,
- A strong background in C/C++ programming,
- Good knowledge of electrodynamics is preferred.

Outcomes

The outcome is a functioning prototype which will play a vital role in shaping the new lab resources for the electric machine labs in addition to getting hands-on experience working and designing electrical machines.

This work shall be used extensively as a pedagogic toll for three lectures where electromagnetism is taught as a primary concept.

Figure 9: All-SiC JFET IMC prototype power circuit without input filter. Base area dimensions: 220 mm x 80 mm.



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R & D Area: Electronics and Data Analytics

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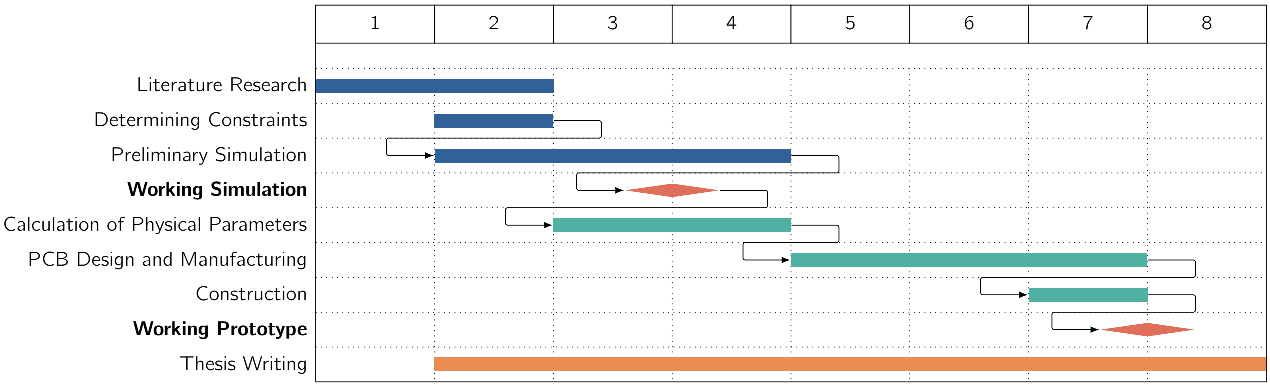
M.Sc Thesis Topic



Topic Introduction

Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor, due to Faradays law of induction. By Lenzs Law, the direction of induced eddy currents is such that the magnetic field generated due to it, opposes the source of induction. Thus, this phenomenon inspires its application in the field of braking and is known as eddy current braking system. In this type of braking, deceleration is achieved by eddy currents produced by the relative motion between the magnet and the metal, which induces a reverse magnetic field. The magnetic field may be created by a permanent magnet or an electromagnet, so the braking force may be varied by adjusting the electric current in the electromagnets windings. The motive of modelling eddy current brakes is to investigate the performance of non-ferrous rotating disc and estimate the braking torque. Contactless eddy current brakes have scope in a wide range of applications such as automobiles, locomotives, roller coasters, aeronautical industries, hydraulic and turbomachinery, emergency shut-off systems, machine tools, robots, elevators, etc. They can be used either as a replacement for mechanical brakes or as an auxiliary braking system.