Research Proposal

School of Mechanical Engineering

Project Title: Optimisation of magnetic bistable energy harvesting devices
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1.0 Project Summary

The outcome of this project is to apply knowledge of negative effective stiffness in the design of energy collection systems. Two possible applications include an ocean wave energy harvester and ambient vibration energy collection to provide energy for low-power microelectromechanical devices. Optimisation of energy collection for such systems is the primary purpose of the project, alongside experimental evidence to verify the theoretical results. The Ultimate outcome of the project will be to create a prototype to validate the new dynamic models developed in the research.

2.0 Project Details

2.1 Introductory Background

Energy collection using bistable magnetic systems an area of ongoing research with many applications. Two such applications are ocean wave energy harvester and energy collection of ambient vibration to provide energy for low-power microelectromechanical devices. The applications differ enormously in magnitude of vibration, but in principle, optimisation of either involves similar concepts. Recent advancements in understanding the effect of negative effective stiffness show that energy collection of systems involving a simple spring can be significantly improved. Frequencies corresponding to maximising the energy collection of a system may be even be targeted through controlling certain parameters. Synonymous to a system with negative stiffness provided by mechanical springs, is a system by which the negative stiffness and non-linear properties is achieved through various magnetic set ups [1]. Such designs can be called bistable as typically there exist 3 equilibrium points, 2 of which are stable.

The ocean wave energy harvesting portion of the project relates to research currently being undertaken at the University of Adelaide. This application is of a large scale and involves energy collection from low frequency motion. The concept of using a repulsive magnetic scavenger (a bistable system using magnetic repulsion) for ocean wave energy harvesting has been the topic of recent research [2], but the tuning or optimisation procedure, as well as the implementation of the design has not yet been investigated by the authors.

Providing energy for low-power microelectromechanical devices through ambient vibration is again a topic that has been the subject of various research papers [3]. However, much of the research has been focused on energy harvesting using a piezoelectric system, whereas this project proposes using a magnetic setup for the ability to target optimal frequencies in such a device. This application is very much on a smaller physical scale than the ocean wave energy harvesting application, but would be hugely significant in powering sensors in hazardous or hard to access environments. The typical frequencies of vibrations these smaller devices would be required to target may be much higher than the frequencies of ocean waves. Accordingly, the optimisation through targeting certain desirable frequencies is an important factor in determining if a repulsive magnetic set up is suitable.

2.2 Research Questions

This research aims to address several important questions;

1.) How can the tuning/targeting of optimum frequencies be achieved in bistable magnetic energy harvesting systems?

2.) How can bistable magnetic energy collection be implemented into the design of an ocean wave energy harvester?

3.) Is a bistable magnetic energy harvesting mechanism suitable for the small scale powering of low-powered microelectromechanical devices?

2.3 Objective of the Project

These questions will initially be addressed through a review of current literature relevant to each topic. Based on this literature, a finite element computer model of the bistable magnetic system will be constructed. The targeting of optimum frequencies will be addressed through the development of a control system and implemented in a computational simulation to determine how the system may be controlled appropriately. The bistable magnetic energy collection implementation into the ocean wave energy will be accomplished through designing a scaled prototype based on previous work and in consultation with other project stakeholders. This prototype will then be tested experimentally to verify theoretical results.

The modelled and simulated systems could be analysed for the suitability to the different application of providing small amounts of energy for low-powered microelectromechanical devices. Additionally, due to the small nature the application, another prototype could be made and experimental results used to determine feasibility of such an application. To aid in the design of a prototype, certain criteria and requirements has been the subject of a paper focusing on the optimisation of the geometry of an electromagnetic actuator [4].

2.4 Significance and Contribution to the Discipline

May studies have been based on these bistable energy systems, including mechanical bistability, magnetic attraction bistability and magnetic repulsion bistability. It was found that generally, there exists many advantages of bistable energy harvesting systems [5]. Such collection systems have been shown theoretically and experimentally to be superior to linear counterparts in energy output (e.g. 50% greater voltage [6]) and in the harvesting frequency bandwidth [7]. However, the application of such bistable systems to stochastic excitation has not been conclusively explored. Additionally the reliable prediction of high-energy bistable dynamics has only recently begun to be explored. Hence a robust platform for energy collection using bistable systems remains a gap in current understand. Therefore creation of a control system with a method of targeting various frequencies would have significant useful impact.

The specific application of ocean wave energy harvesting system involving repulsive magnetic scavenging has been theoretically and experimentally investigated [2]. Application of such a device to ocean wave energy devices has not yet been performed, neither has a system to target specific frequencies. The effect of negative stiffness has been explored for the context of wave energy [1], and has been shown to significantly increase the energies collected. Also, a mechanism to control the negative stiffness was also suggested for a mechanical spring system allowing the system to target specific frequencies to optimise energy output. It has been suggested that to capture wave energy though magnetic means, the design requires a low frequency resonance [2]. By extension, an ability to target specific frequencies would improve the versatility of the design. One particular gap noticed was that the derived model used viscous damping. To improve the accuracy of the modelled vibrations, a coulomb damping model could be used or a lubrication system should be designed into the experimental device to improve the emf output voltage for lower frequencies [2].

2.5 Theoretical Framework and Methods

Creation of a computational model involves an in-depth understanding of magnetic systems and finite element analysis theory. Additionally, construction of a control system requires a comprehensive working knowledge of control systems, and analytical representation of the system dynamics. Investigation of current control strategies used in similar contexts will aid in gaining the required knowledge. Skills related to finite element analysis and electromagnetic aspects will be developed through undertaking relevant courses or through textbooks and practical learning. Understandings of system dynamics and control methods will be acquired through review of literature, independent practice and consultation with relevant experts within the School of Mechanical Engineering. Furthermore collaboration with other researches involved with relevant projects will contribute to an understanding of the design requirements of such a system.

3.0 Research Plan and of Thesis

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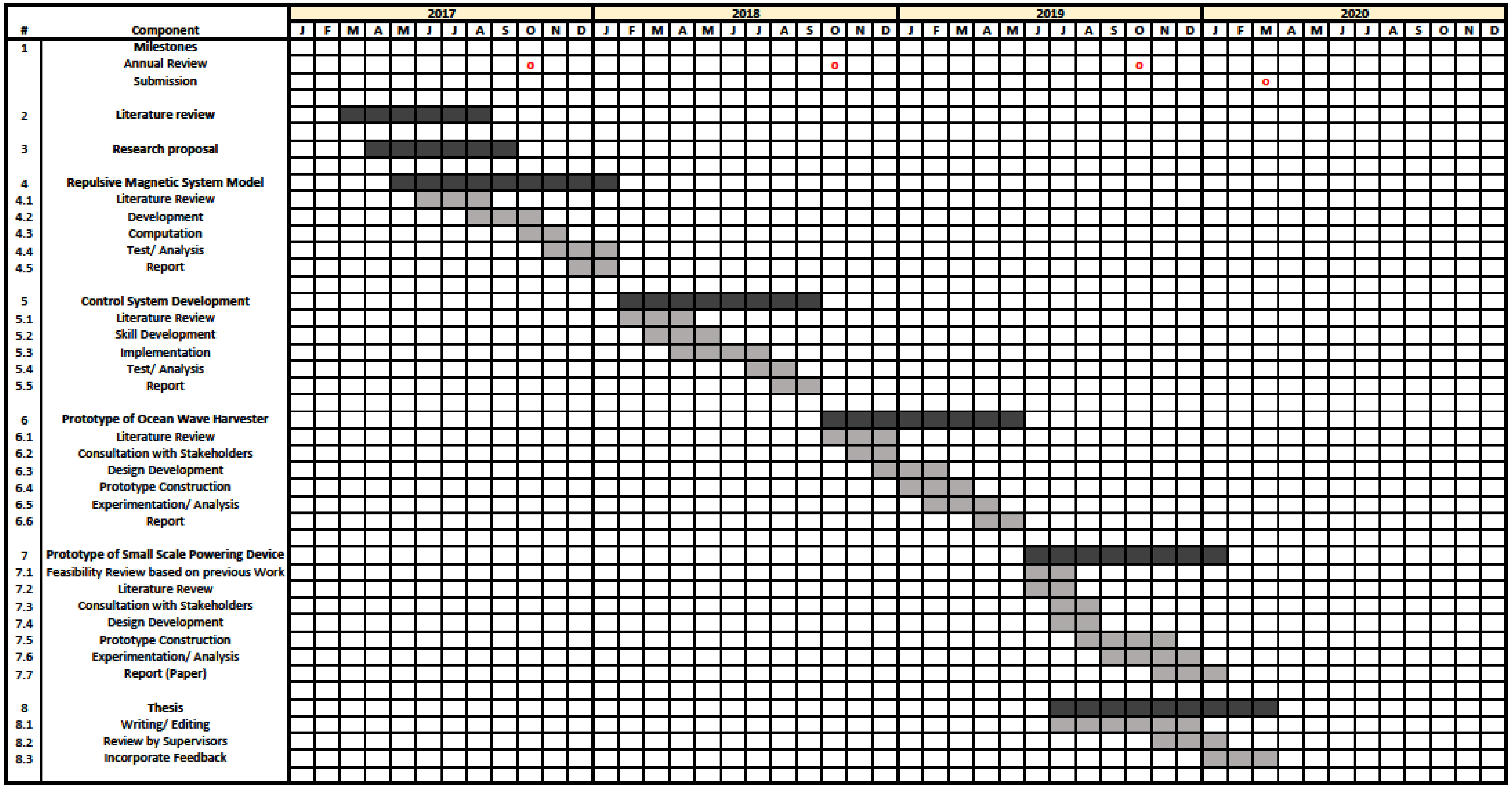
Proposed Thesis Title	Application of repulsive magnetism in designing optimised energy harvesting devices



4.0 References

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