Modeling of Nonlinear Energy Harvesting

Project Description

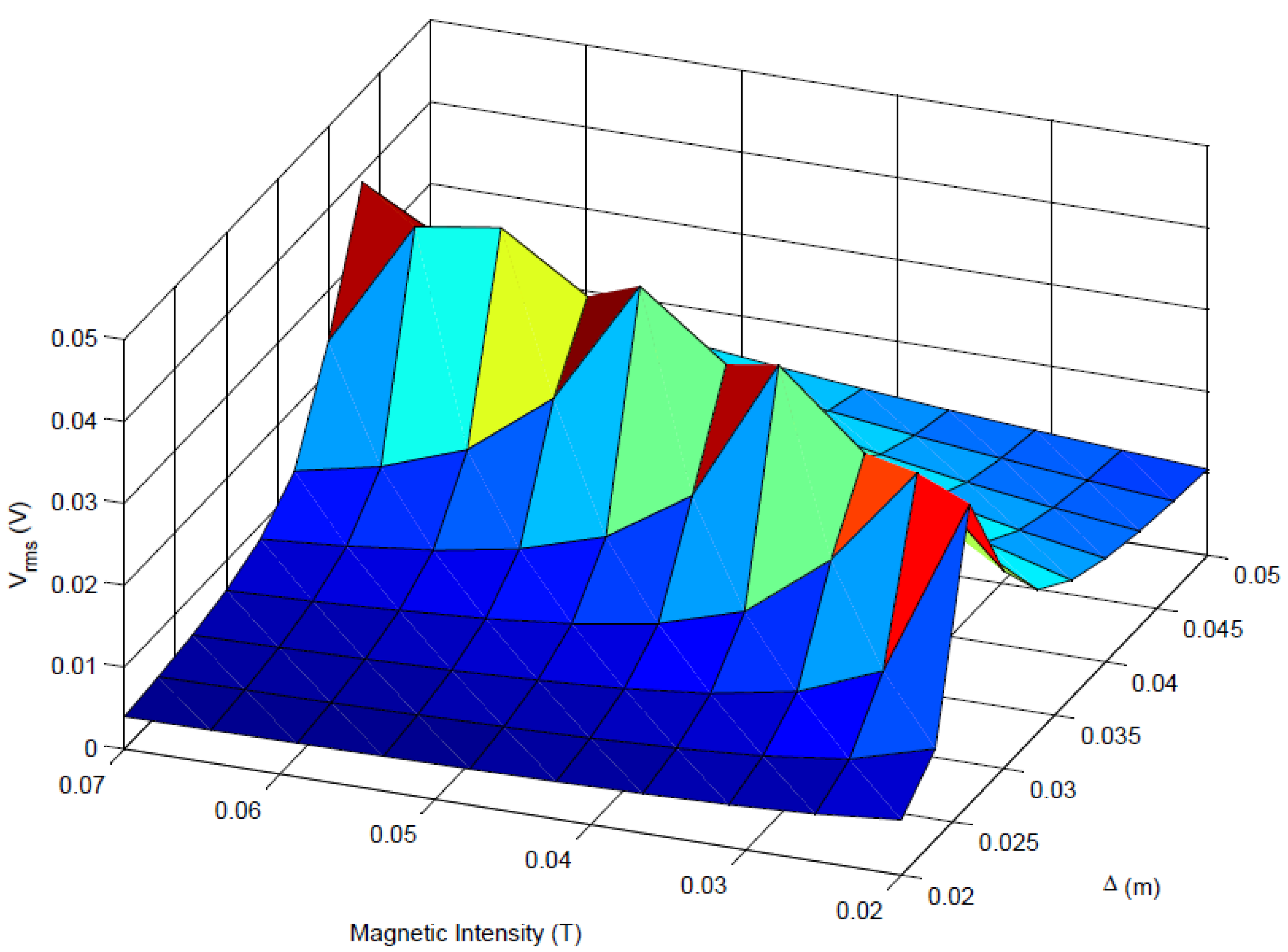
- Energy is transferred to the environment in the form of vibrations
- Inverted oscillators can be used to capture these vibrations and reclaim the energy
- Nonlinear oscillators are found to harness more energy than linear [1]
- A defined model allows for the voltage generated to be known cheaply
- The goal of the model is to find the optimum physical parameters for energy harvesting

Scientific Challenges

- The exact behavior of the oscillator varies from trial to trial due to the stochastic force applied
- The ideal parameters of the inverted oscillator vary with the magnitude and frequency of the applied force

Potential Applications

- The vibrations of bus riders can power ticket gates [2]
- Sensors can be powered by the energy generated, removing the cost of replacing batteries [3]



Root mean squared voltage for delta (meters) and magnetic intensity (Tesla) made using the program MATLAB [4]
Δ: Distance between the magnets
Magnetic Intensity: The charge associated with each magnet, squared

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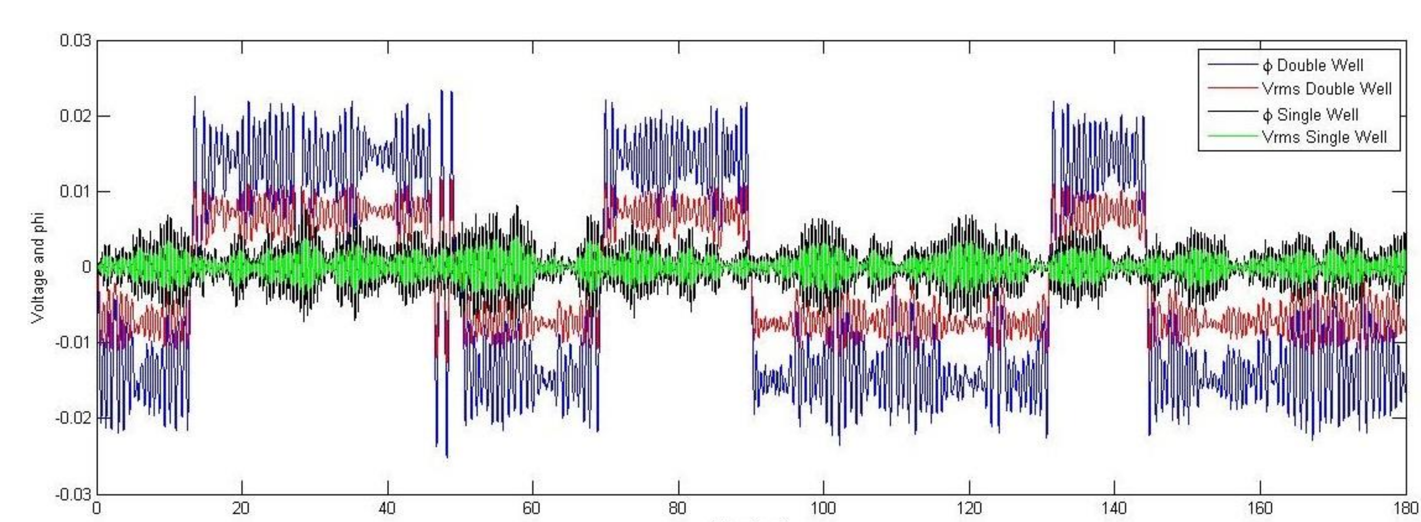
Methodology

1. The potential energy of the system must be derived by analyzing the forces acting on the oscillator
2. Position graphs were generated to analyze jumps between potential wells of the oscillator and then how they affected voltage output
3. Numerical simulations were run to find whether the system self averages or randomly averages over time
4. The root mean square voltage (V_{rms}) was graphed as a function of the physical distance between the magnets and their strength

Results

1. The system was found to be self averaging
2. The double well potential for the oscillator was shown to have a greater V_{rms} than the single well potential
3. The model showed the V_{rms} was greatest along a curve of delta and Magnetic Intensity values, decreasing as the magnets no longer had an effect on the potential or trapped the oscillator in on of the two energy wells



The angle of phi (radians) and V_{rms} value of single and double well oscillators over time. Δ=.005m for both oscillators. Magnetic Intensity = .0002 T for the double well oscillator

Glossary of Technical Terms

Self Averaging: A disordered system that can be described by averaging over a large number of samples
Random Averaging: A system that does not consistently average, regardless of sample size
Root mean square voltage: The average voltage produced over large periods of time

Future Work

- Explore how the V_{rms} changes by increasing the number of magnets in the system
- Determine the effect of the inverted oscillator's dimensions on the value of V_{rms}
- Improve the stochastic force generated in the model to represent the vibrations produced by wind, cars, and people
- Derive an equation for the ideal Magnetic Intensity as a function of delta and the dimensions of the inverted oscillator

References

1. Cottone, F. , Vocca, H. , Gammaitoni, L. , *Nonlinear Energy Harvesting* Physical Review Letters **102** (2009) 1-4
2. Report by the East Japan Railway Company on the efficiency of piezoelectric flooring powered by vibrations (http://www.jreast.co.jp/e/development/press/20080111.pdf)
3. Sazonov, E. , Li, H. , Curry, D. , Pillay, P. ,*Self-Powered Sensors for Monitoring of Highway Bridges* IEEE Sensors Journal **9** 11 (2009) 1422-1429
4. MATLAB was developed by the company MathWorks

Acknowledgments

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