Synchronization in Electrical Power Networks

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Project Description

- Develop a model to understand the stability between generators and consumers.
- Despite oversight, power plants are still prone to failure due to phase de-synchronization [1].
- A model aids in simplifying dynamics between generator nodes and phase stability.
- Goal: To find the ideal conditions for generator stability.

Scientific Challenges

- Many power outages are caused by de-synchronization of the power generators. [1]

Potential Applications

- Autonomous power plants and self-stabilizing power networks.
  - More reliable power networks (less power outages)
  - More efficient power networks (lower cost)

Governing Equations

$$\frac{2H_i}{\omega_R}\frac{d^2\delta_i}{dt^2} = P_{mi} - P_{ei}$$

- Equation of motion derived from the conservation of angular momentum
- The linearization of the motion equation can be reduced to a set of decoupled first-order equations:

$$\frac{2H_i}{\omega_R}\frac{d^2\delta_i'}{dt^2} = \frac{\partial P_{mi}}{\partial \omega_i}\omega_i' - \frac{\partial P_{ei}}{\partial \omega_i}\omega_i' - \sum_{j=1}^{n}\frac{\partial P_{ei}}{\partial \delta_j}\delta_j'$$

$$\dot{\mathbf{X}}_1 = \dot{\boldsymbol{X}}_2; \qquad \dot{\mathbf{X}}_2 = -P\mathbf{X}_1 - B\mathbf{X}_2$$

- Matrix form of above equation adding a first order perturbation and grouping of terms
- X_1 denotes the vectorization of all Delta values
- X_2 denotes the vectorization of all Delta Dot values

Glossary of Technical Terms

Delta: Phase offset from optimal phase of generators.
Delta Dot: Frequency offset from optimal frequency of generators.
Alpha: Combination of all intrinsic properties of each generator
Beta: The system-wide control parameter

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Methodology

1. To begin, we developed a numerical simulation of a set of generators in MATLAB based on equations from the paper.
2. We created variation in the dynamics by drawing each node's alpha from a normal distribution
3. This randomly altered parameter alpha is then run through an ODE45 solver.
4. The dynamics are solved for each of the N nodes for several values of beta
5. These O.D.E solutions are then plotted and the optimal value of beta can then be seen by integration

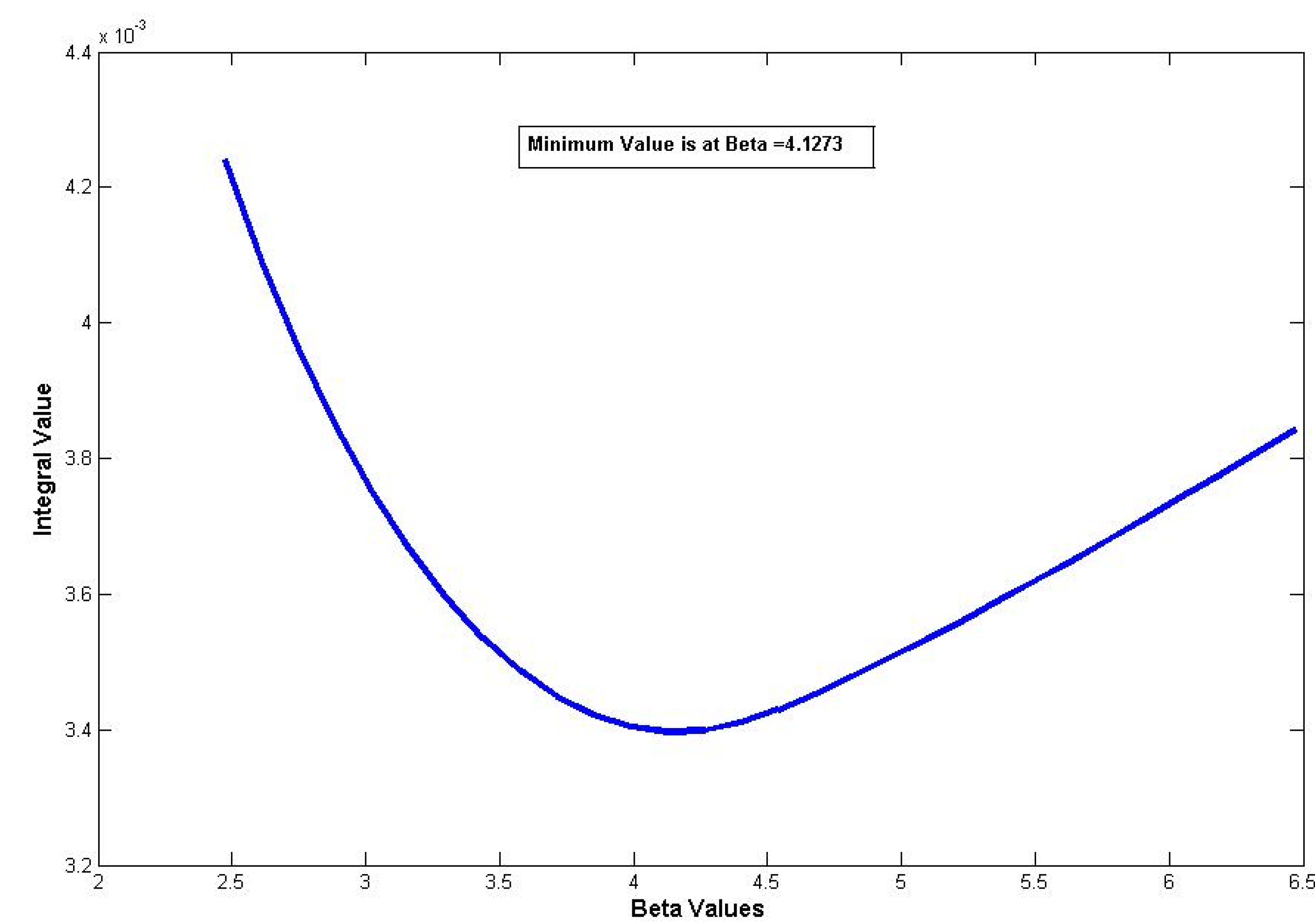

Figure 1
Delta, for varying beta values (example: Figure 2) was integrated over time to determine the optimal beta. The results are plotted above.

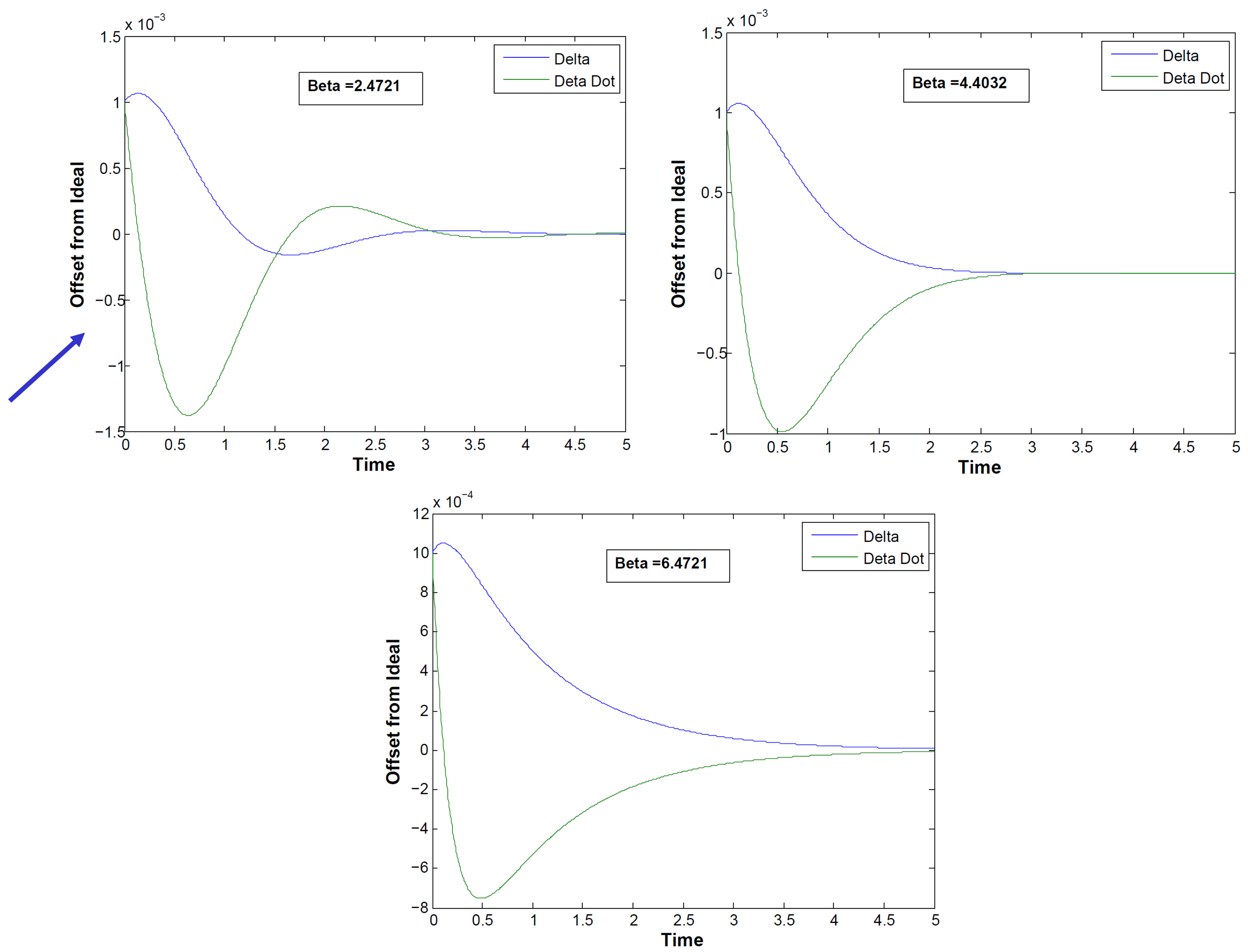

Figure 2
Different values for beta and the effects it causes on both delta (phase) and delta dot (frequency). It can be seen here that the optimal value for beta of this system must be near 4.4.

Results

1. Our results support those of the literature
2. The ideal beta for stability is the value of $2\sqrt{\alpha_2}$ determined by the governing equation of the system
3. It was found that the actual ideal beta varied slightly (~10%) from the value above due to randomness added in the system

References

Adilsom E. Motter, Seth A. Myers, Marian Anghel and Takashi Nishikawa, Spontaneous synchrony in power-grid networks, NATURE PHYSICS VOL 9, MARCH 2013, www.nature.com/naturephysics

Acknowledgments

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