Analysis & Visualization of Frequency in Power Systems

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INTRODUCTION

In order for the power grid to function properly, a relatively constant frequency must be maintained. Increased penetration of renewable energy into the grid can lead to less stable frequency within the system due to relative reduction of inertia. Fast-acting energy storage systems (FESS) offer a solution as they can provide energy at a faster rate when demanded. The distribution of inertia will determine the dynamic performance of the system and will depend greatly on the penetration of renewables into the grid. The distribution of inertia in the system is analyzed through a visualization tool which helps to identify the center of inertia and other points useful in determining the location for the deployment of FESS with the increased utilization of renewable energy.

36 BUS TEST SYSTEM

METHODS

Mathematical model consists of the DC Load Flow equations and the swing equations of all four generators. Generators were assumed to have a strong AVR so that the internal voltages were constant.

Assumptions made:
- **Bus angles are approximately equal to one another**
- **Resistance is significantly less than reactance**
- **Voltage of each bus is 1 p.u.**

The model begins under steady-state conditions and a change is applied to the initial conditions of the angle and angular frequency of the generator. The simulation is then run and the frequency values at each bus are plotted in the dynamic plot from times *t = 0 s* to *t = 10 s*. The visualization displays a new plot approximately every 0.075 s within the simulation.

The system in the 36 Bus Test System includes four synchronous generators located at the corners of a rectangular grid system. Each line along the horizontal (Fig. 1), or x-, axis has a reactance of 0.2 p.u. and each line along the vertical (Fig. 1), or y-, axis has a reactance of 0.4 p.u.. Generators located at Buses A1, A6, and F1 have inertia values of 4 s and that located at F6 has an inertia value of 12 s.

CONCLUSION

For a vast majority of the trials, the center of inertia was found to be located at Bus E5 (Fig. 3, 4, 6). This was expected as Bus E5 is located within close proximity to the generator at F6 that has a large inertia value of 12 s. The least variance in frequency occurs at this point. The FESS will ideally be located at a point farthest from this.

Changes made to the angular velocity of the generators represented larger disruptions to the grid than the equivalent changes made to the angle of the generators, as small changes applied to the angle cause small changes in the electrical power output which does not reflect significantly in the frequency. Conversely, when the perturbations are applied to the speed of the generator, the changes in electrical power output are large. This manifests in large deviations in the frequency of the system.

FIGURES

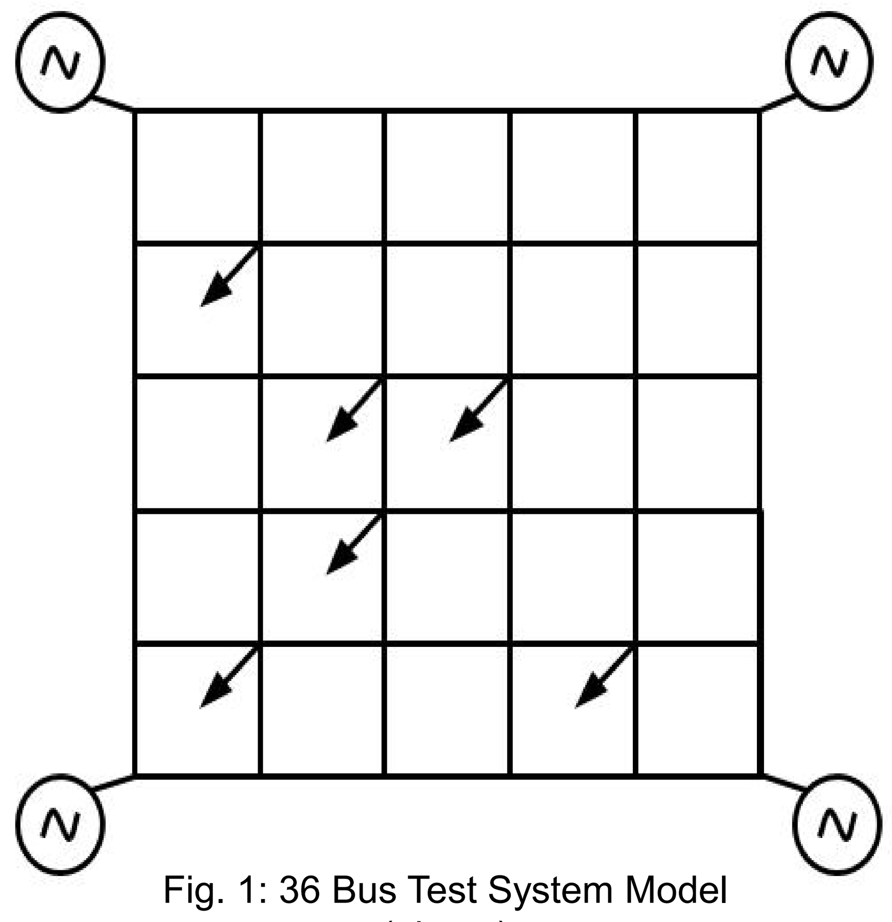

Fig. 1: 36 Bus Test System Model (above)

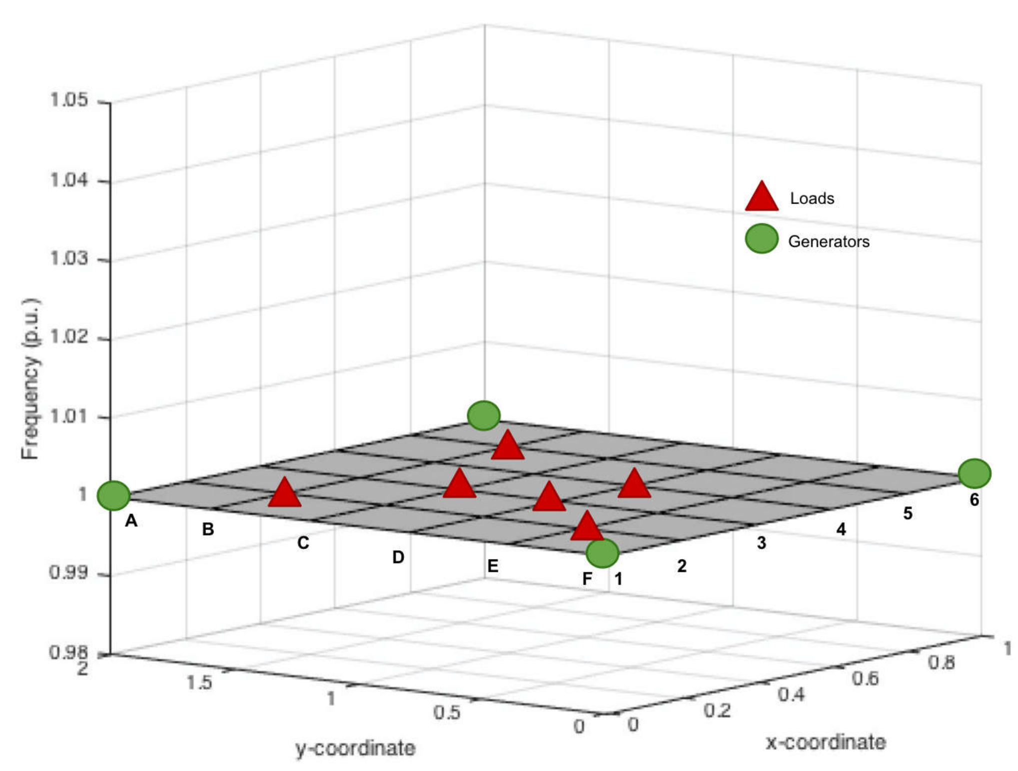

Fig. 2: 36 Bus Test System, alphanumeric coordinates (above)

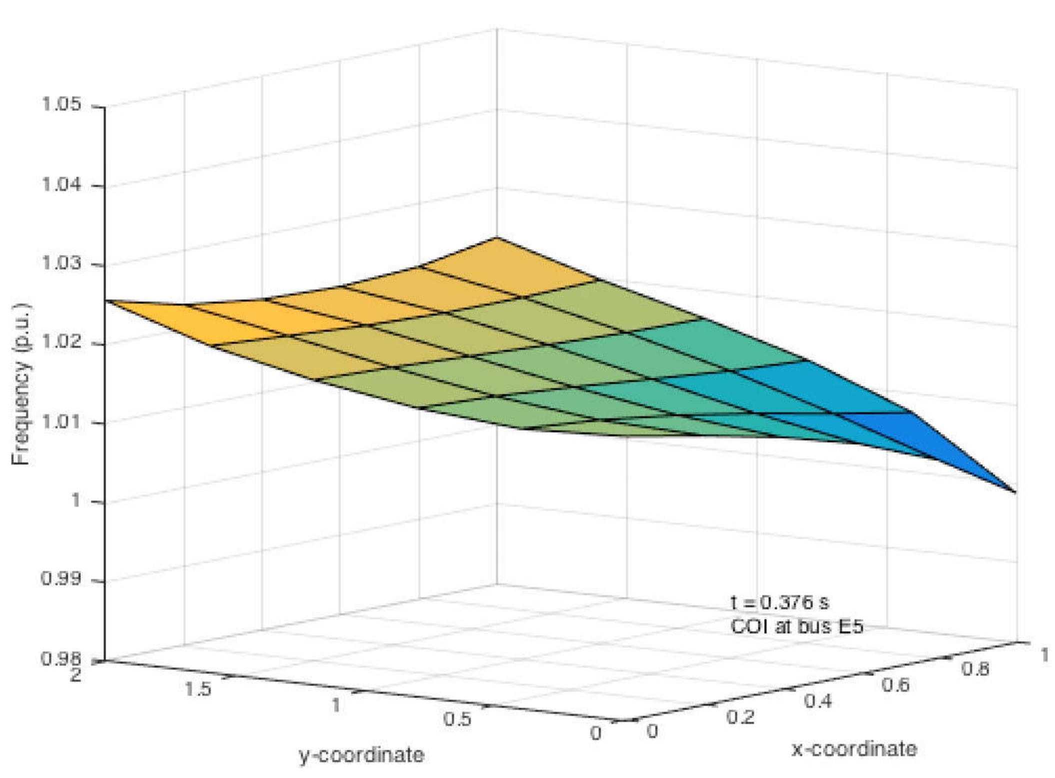

Fig. 3: delx0 = [0; 0.03; 0; 0; 0; 0; 0; 0.01;] (above)

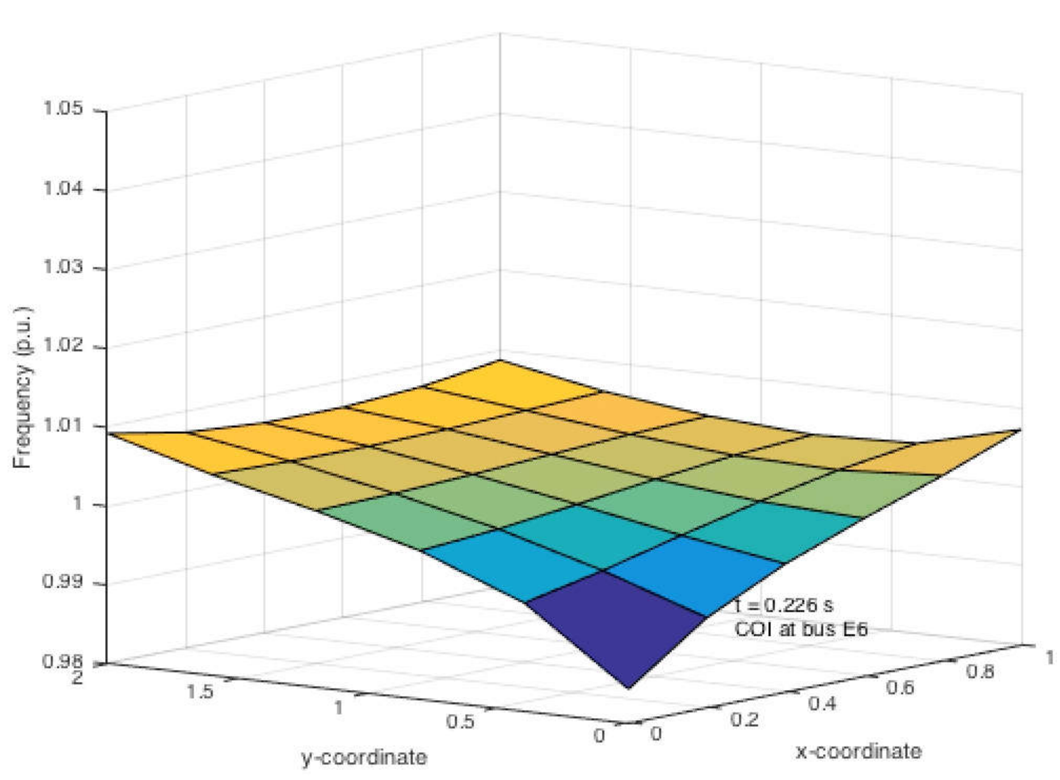

Fig. 5: delx0 = [0.03; 0; 0; 0; 0; 0; 0; 0.01;]

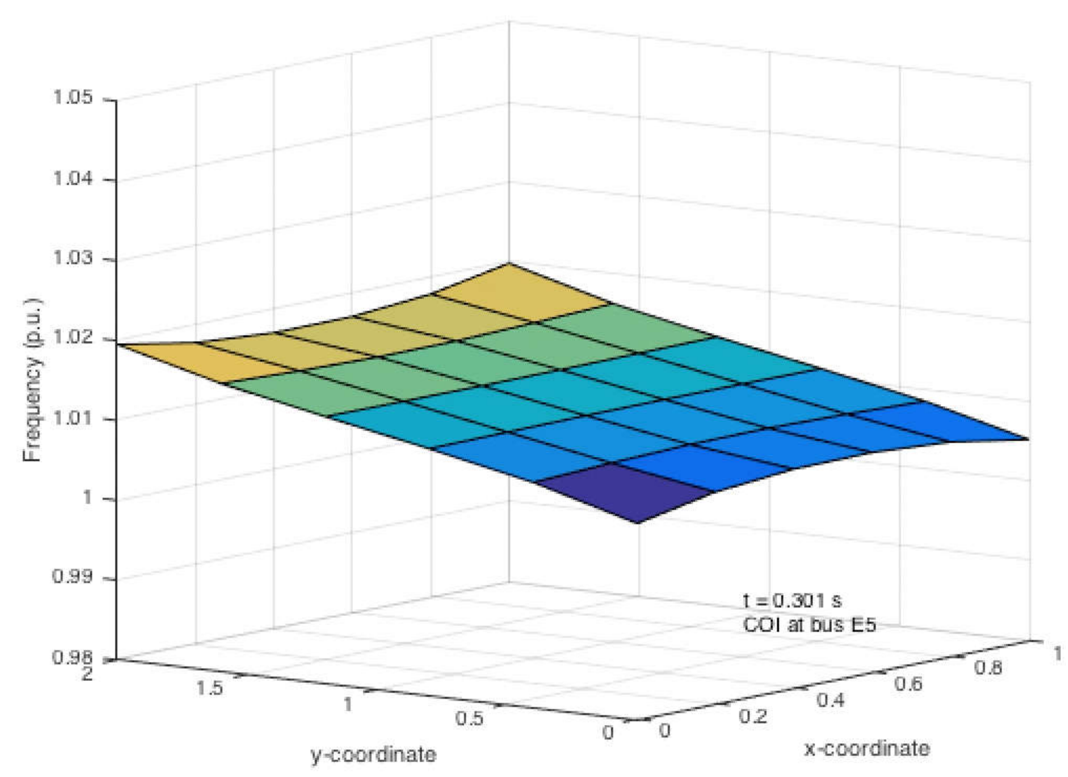

Fig. 4: delx0 = [0.02; 0.02; 0; 0; 0; 0; 0; 0;]

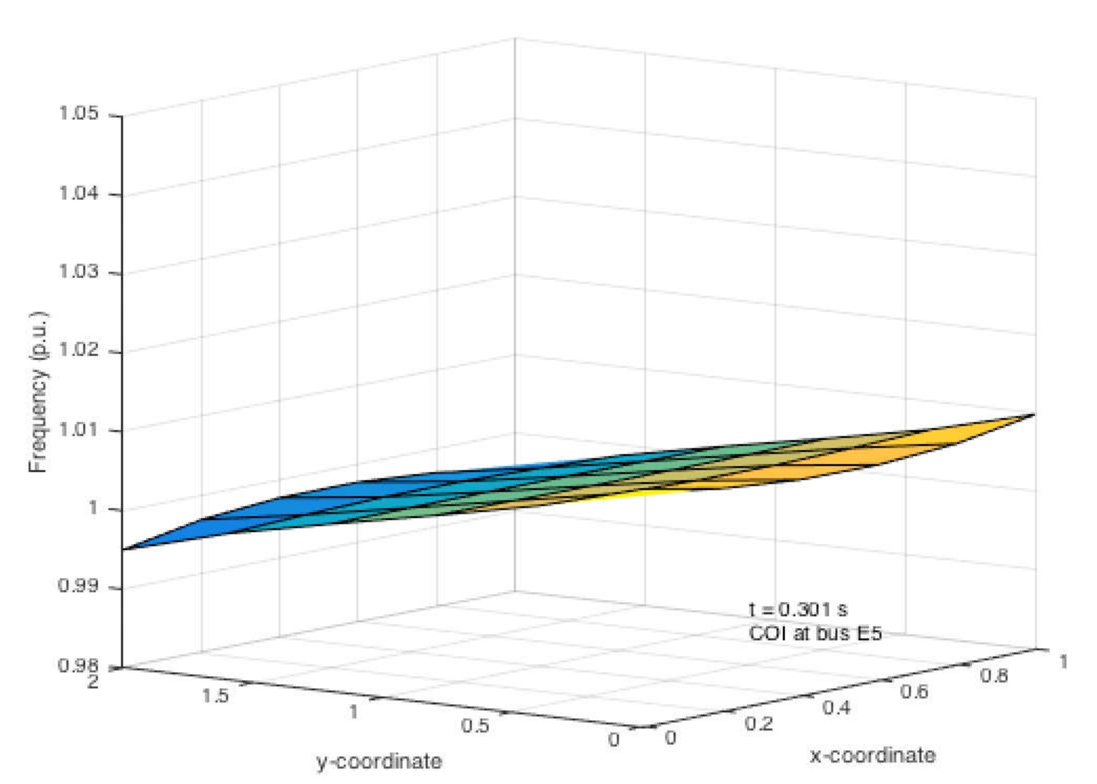

Fig. 6: delx0 = [0; 0; 0.02; 0.02; 0; 0; 0; 0.02;]

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