Energy Flows in Electrical Grids

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PROJECT DESCRIPTIONS

- DistFlow ODEs are used to develop a model showing power and voltage distribution along an electrical line to understand how energy flows in electrical grids. The equations are then used to identify the relationship between voltage and position along a feeder line
- Using MATLAB, the DistFlow ODEs are utilized by adding stochasticity to modify power consumption and the results were analysed for the effect on power and voltage

SCIENTIFIC IMPACTS

- Real life power usage is difficult to accurately model. Incorrect modeling may lead to an undesirable scenario in which the system experiences a power failure
- Varying real and reactive power consumption along a feeder line can be modeled and tested in order to increase grid reliability and efficiency.

POTENTIAL APPLICATIONS

- More accurate modeling to prevent power outages
- Better integration of renewable energy sources without causing instability in the electrical grid
- Optimize power flows and support variable power supplies from wind and solar energy

GLOSSARY OF TECHNICAL TERMS

- Real Power: Real component of complex power that is consumed
- Reactive Power: Imaginary component of complex power which is stored and returned to the system

ACKNOWLEDGMENTS

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REFERENCES

1.D. Wang, K Turitsyn and M Chertkov, “DistFlow ODE: Modeling, Analyzing and Controlling Long Distribution Feeder”, Proceedings of, the 51st IEEE Conference on Decision and Control (2012)
2.S. Islam, D Johnson, H. Shayan, J Utegaard, “Power Distribution in Electrical Grids. May 7, 2013 The University of Arizona

MODEL FORMULATION

Electrical feed, one directional line, combined the real, reactive and voltage can be modeled by the following system of ordinary differential equations with desirable boundary conditions:

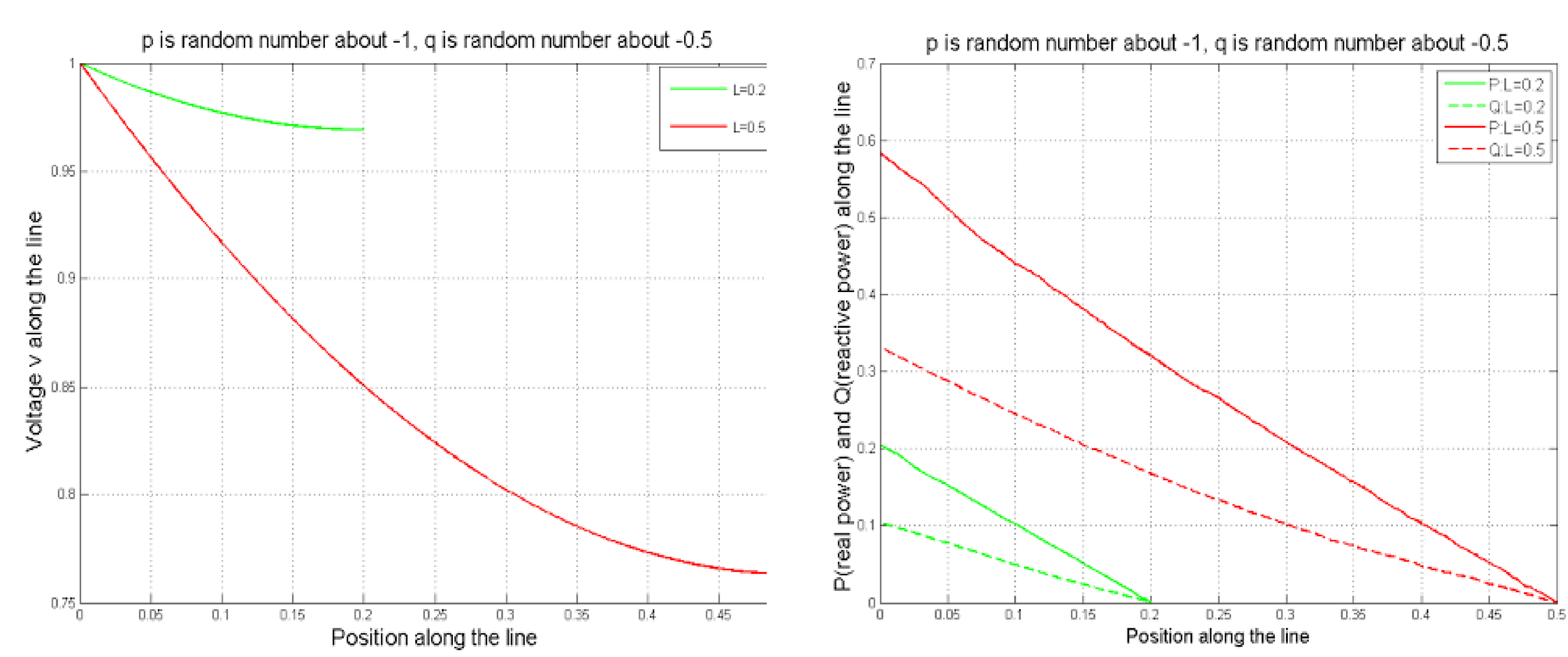
$$\frac{d}{dz}\begin{pmatrix} P \\ Q \\ v \end{pmatrix} = \begin{pmatrix} p - s\frac{P^2+Q^2}{v^2} \\ q - x\frac{P^2+Q^2}{v^2} \\ -\frac{rP+xQ}{v} \end{pmatrix}$$

$$v_0 = 1, P(L) = Q(L) = 0$$

Where:
Z is the position along the line
p and q represent the real and reactive power consumptions along the line
r and x represent the resistance and reactance of the line
P and Q represent the real and reactive power flows
v is the voltage

RESULTS

Boundary Value Problem



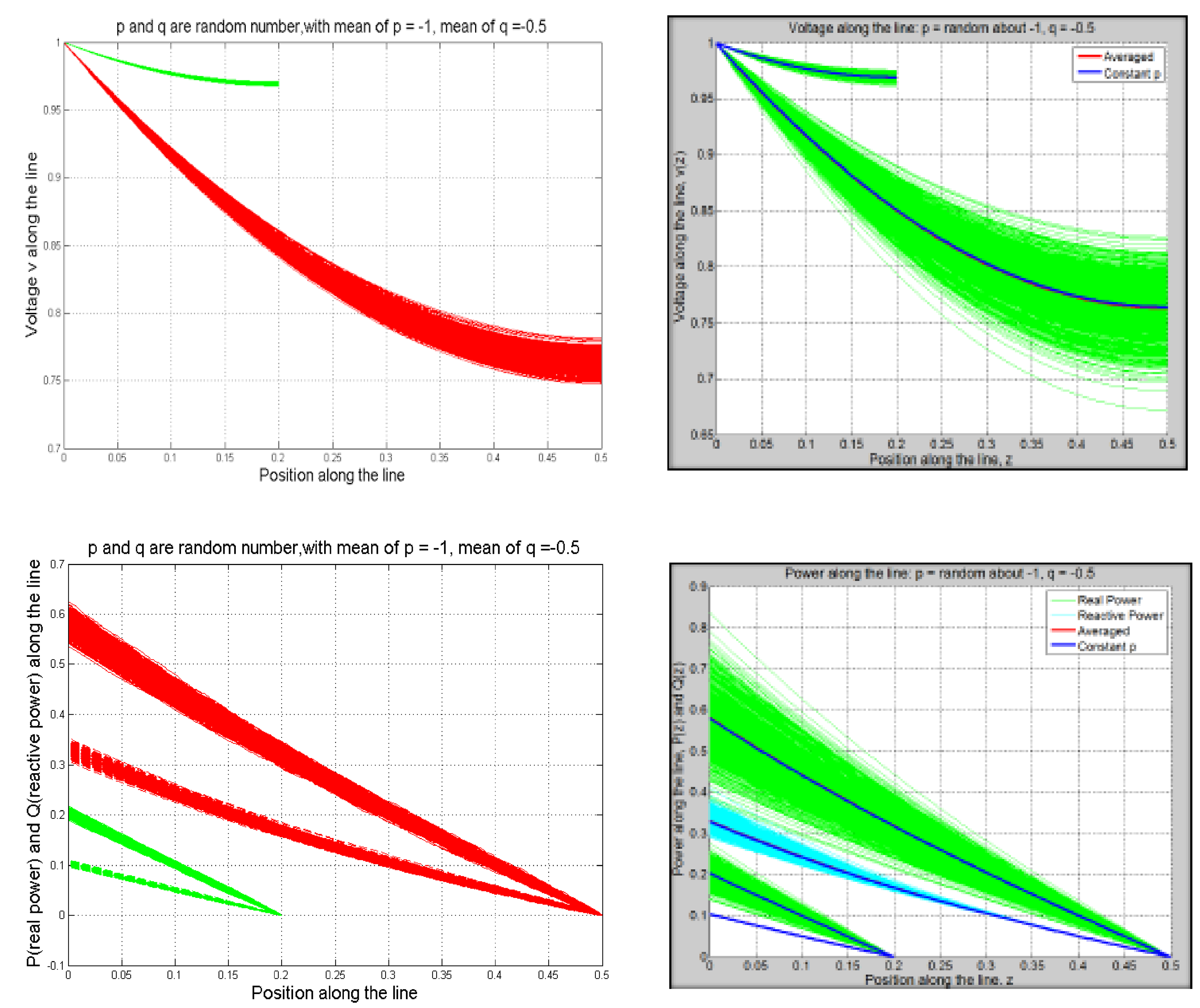
Voltage and position along a feeder line:

- A negative p leads to power consumption (decreasing curve)
- All boundary conditions are met $(v_0 = 1, P(0) = Q(0) = 0)$

ADDING STOCHASTICITY

- Previous project, “Energy Flows in Electrical Grids”, a Wiener Process was added to the power consumption, p, in the boundary value problem, making a discretely defined function of a line
- In this project, an Identical Independently Distributed noise (IID) was added to the power consumption and p & q are perturbed independently in the boundary value problem. Making the power consumption rate of each house independent of other houses.
- The boundary value problem solver was then run with the new power consumption profile p(z) and q(z), independently, and the process was repeated 1000 times

STOCHASTIC RESULTS V.S PREVIOUS RESULTS



- Because of real life variability, the final results of each run, of the model, will vary. This is to be expected.
- From the simulation, the power consumption along a power line varies based on varying power usage for each consumer. Therefore randomized power consumption across the line is a valid conclusion.
- In the previous results, variances within the electrical grid results in uncertainty in the voltage measurement. Making the voltage more challenging to read.
- The variance of n voltage were higher than the power consumption profile.
- Previous results only relay on random p and constant q values. These results are less ideal than what was found this year.