Management of Renewable Sources in Power System

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Project Description

- This project is designed to control the fluctuation of voltage for improved performance along the feeder line.
- Our model is based on the distribution flow ODE in terms of real power, reactive power, and voltage [1].
- Adding Dirac's delta function into the ODE will allow us to compute the change of voltage throughout the line for the sake of a specific value that will keep voltage constant within range.
- Mathematica was used to solve the ODE and determine that adding real and reactive power through a renewable source is a viable way of controlling voltage.

Scientific Challenges

- For those renewable resources that are generated far from the loads, there will be voltage loss during the long-distance transmission process. This constitutes another complex voltage-loss problem that our model needs to solve.
- When the renewable energy is injected into the feeder line, the voltage will fluctuate. If the peak value of voltage is too high, it will damage the transmission equipment.

Potential Applications

- Within-city: For cities that can collect renewable resources, such as Tucson, this model can be used to achieve the constant high-voltage transmission from the energy generator to loads.
- One energy generator can support more than one city due to its constant voltage and limited energy loss during the transmission process.

Glossary of Technical Terms

- Real power: The power that can be used to do work, which has the net transfer of energy in one direction
- Reactive power: Imaginary power consumption averaging between power generator and loads

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Model and Formulas

- The electrical feeding on one-direction line is modeled by the following **Distribution ODE** of real power, reactive power, and voltage [1][2]:

$$P'[z] = p - r\frac{P[z]^2+Q[z]^2}{v[z]^2}, Q'[z] = q - x\frac{P[z]^2+Q[z]^2}{v[z]^2}, v'[z] = -\frac{r*P[z]+x*Q[z]}{v[z]}$$

where v = 1.05, P(L) = 0, Q(L) = 0

- **Nose Curve** [3]:
  - Catch the second branch to realize that there will be a bad performance of containing too low voltage.

- **The Approximation of Dirac's delta function**:
  - $g(z) = -1 + \frac{\beta}{\varepsilon\sqrt{\pi}} Exp\left(\left(-\frac{z-0.5L}{\varepsilon}\right)^2\right)$

  where ε = 0.015, L = 0.5, z = [0, 0.5].

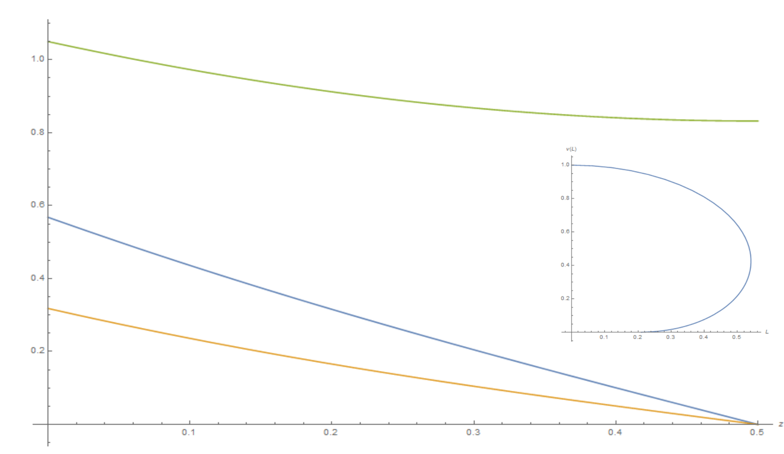

Figure 1: ODE function and nose curve

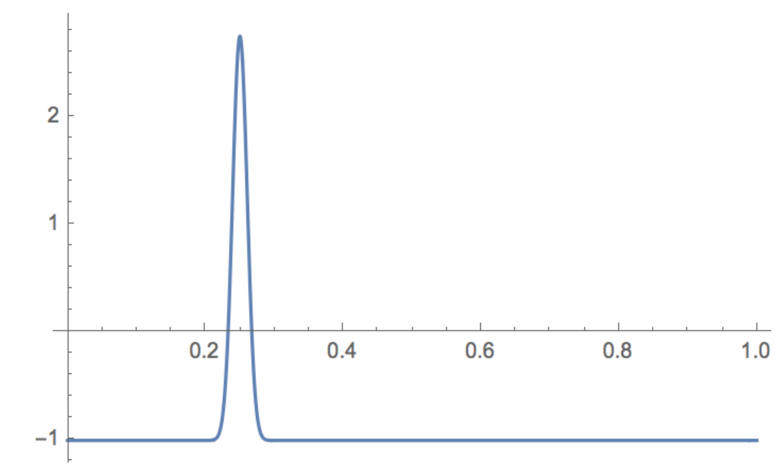

Figure 2: the Approximation of Dirac's delta function

- The idea of our model is to add renewable energy sources into the feeder line to control the voltage fluctuation.

Figure 3: Model: Adding renewable energy into the feeder line

Results

- Adding the renewable energy injection power into the feeder line can make a better voltage by controlling its fluctuations
- After adding the renewable energy, we need to control and adjust the renewable energy power to keep the voltage at the end point to be within the margin.
- When β = 0.2 as minimum value, the voltage reaches the engineering voltage margin.

Methodology

- **Method 1:**
  - When voltage drops in the normal situation, we add it into real power to see the result:

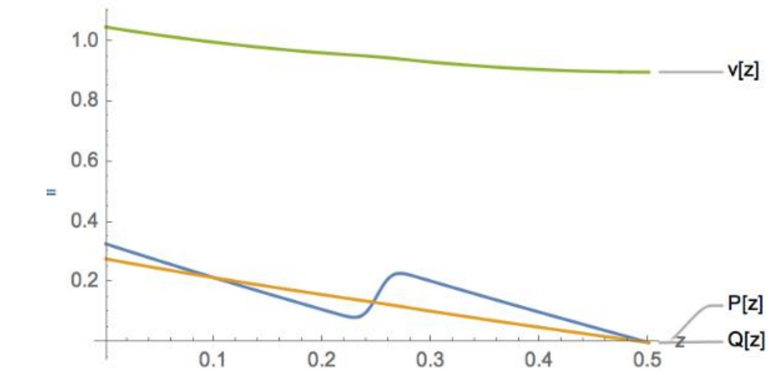

Figure 4: add renewable energy into real power

- **Method 2:**
  - After adding renewable energy into real power, voltage still drops dramatically.
  - We add renewable energy into both real and reactive power:

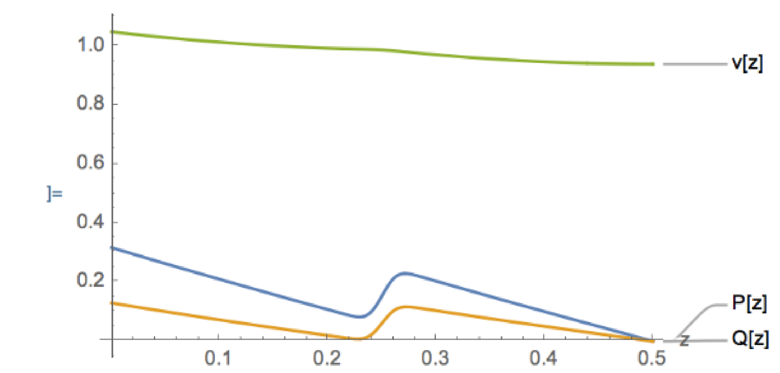

Figure 5: add renewable energy into real and reactive power

- Voltage stays within the Engineering margin: [0.9, 1.05] at the end point [4].

References

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4. K. Turitsyn *et al*, "Options for Control of Reactive Power by Distributed Photovoltaic Generators," *Proceedings of the IEEE,* vol. 99, *(6),* pp. 1063-1073, 2011;2010;.