# Virtual Inertia-Based PV Systems

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ECG 743 Project

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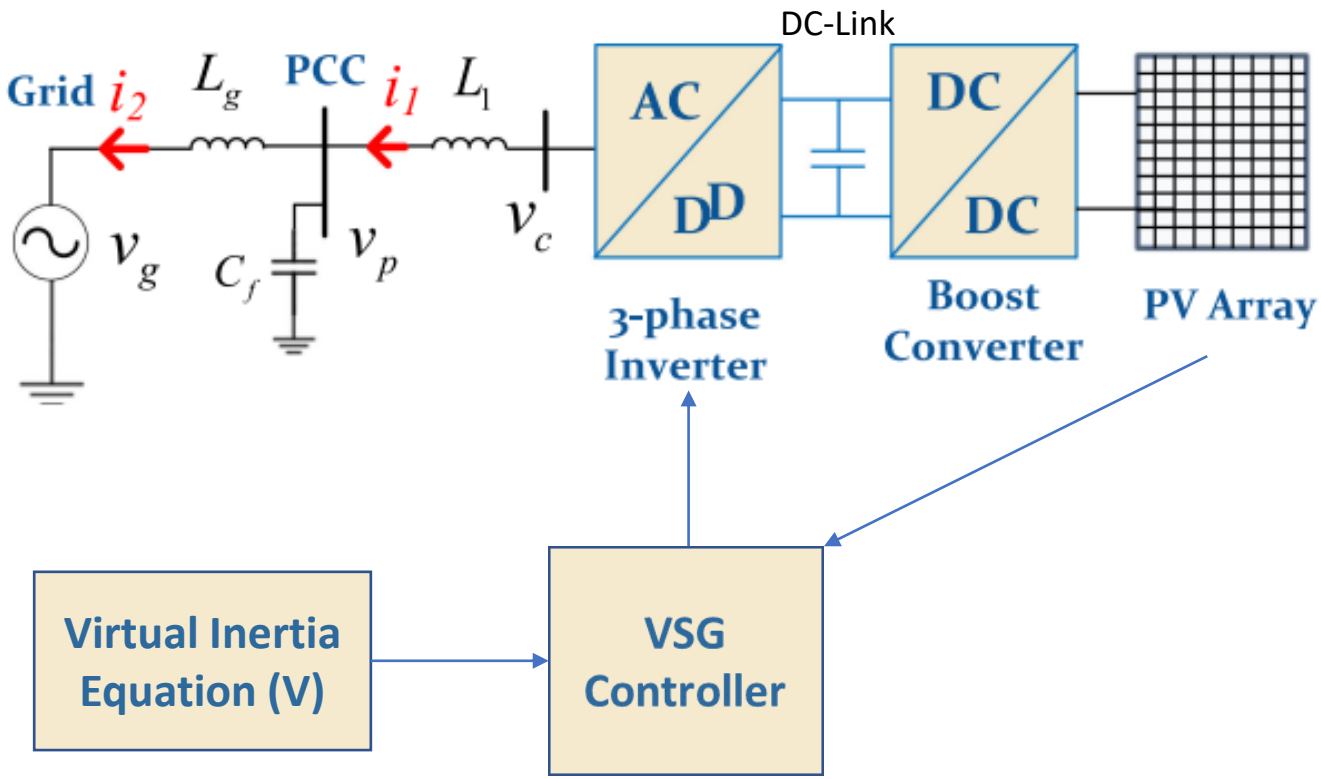
# Introduction

- Solar renewable energy resources stereotypically provide low inertia
- The addition of photovoltaic sources into the power grid has negative affects on the overall moment of inertia and damping [4]
  - Decreases the overall system efficiency
  - Makes system more susceptible to noise and oscillation
- To combat the issue, methods to create “virtual” inertia are being studied
  - Since solar PVs usually lack a rotational component (such as what is seen with energy sources like wind turbines), the kinetic energy must be supplied some other way [1]

# Overview of the System

Two-stage PV system [4]



# Virtual Inertia Equation

$$V_{dc*} = \frac{2H_{VSC}S_{VSC}}{f_o * C_{dc}V_{dc0}}(f - f_0) + V_{dc0} \quad [4]$$

$$V_{dc*} = \frac{2 * W_E}{f_o * C_{dc}V_{dc0}}(f - f_0) + V_{dc0}$$

$$V_{dc*} = \frac{2 * \frac{1}{2} * F * V^2}{Hz * F * V} * \mathrm{Hz} + \mathrm{V}$$

$$V_{dc*} = \frac{V}{Hz} * \mathrm{Hz} + \mathrm{V}$$

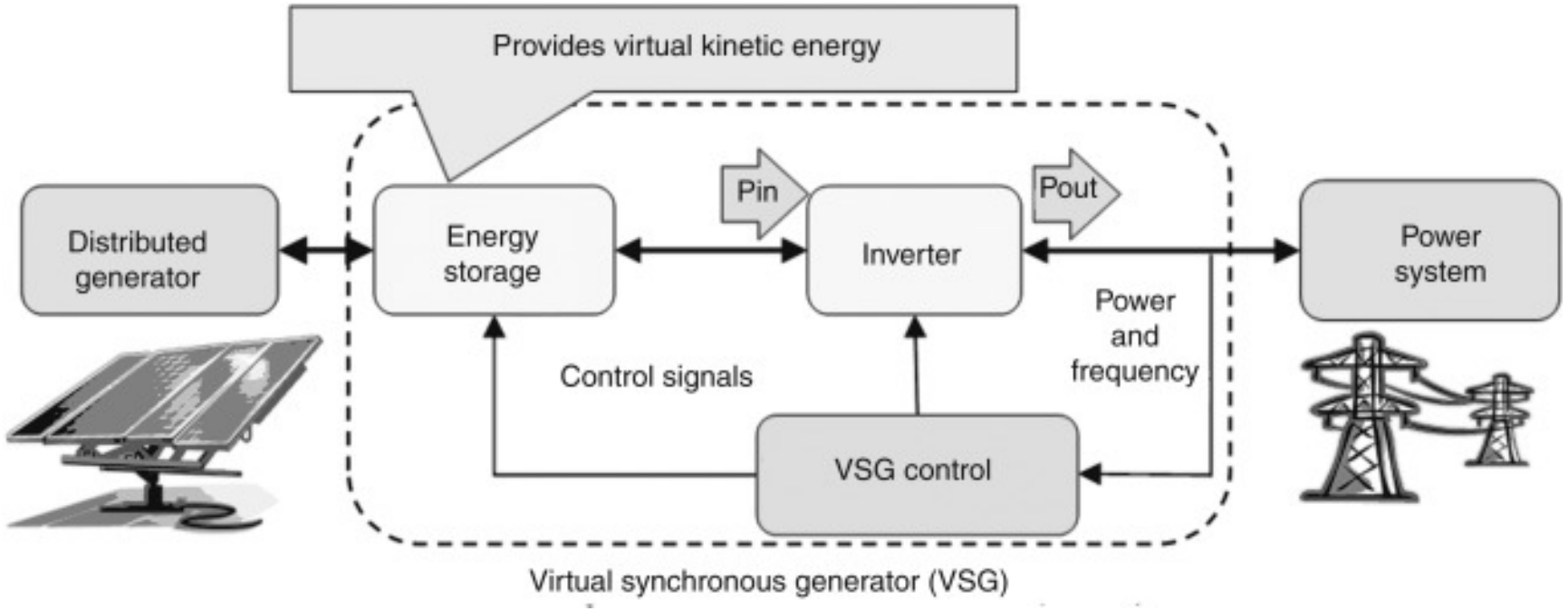
$$V_{dc*} = A\ unit\ of\ voltage\ based\ on\ circumstaces$$

Where:

- $H_{VSC}$ is the virtual inertia coefficient (or the stored kinetic energy, WE, divided by the rated power of the PV generator, SVSC)
- f is the measured frequency of the model, and $f_o$ is the nominal frequency of the system
- $C_{dc}$ is the DC-Link capacitance
- $V_{dc0}$ is the nominal DC-Link voltage

- The result of this equation (a voltage) is sent through proportional integral (PI) controllers and a pulse width modulator, among other circuitry, which is then fed into the 3-phase inverter to control the system inertia

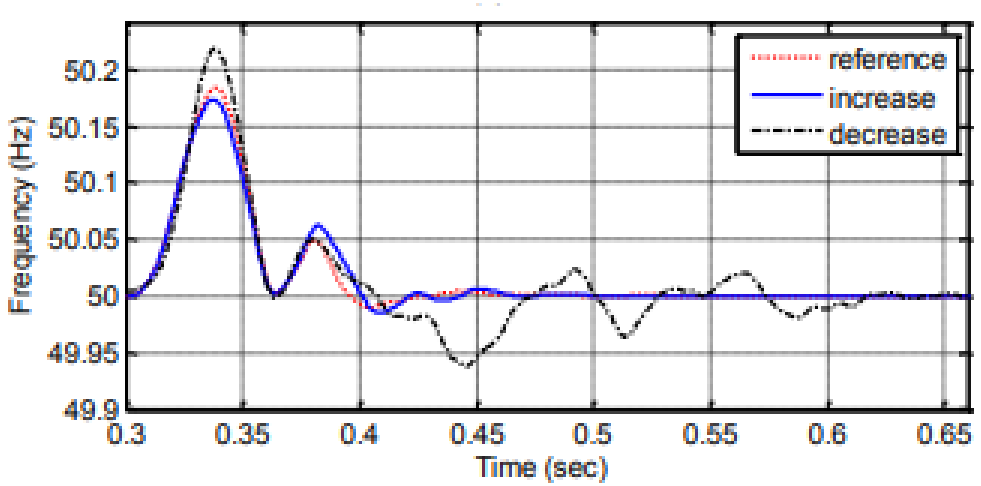
# Virtual Synchronous Generator (VSG)




Reference: [5]

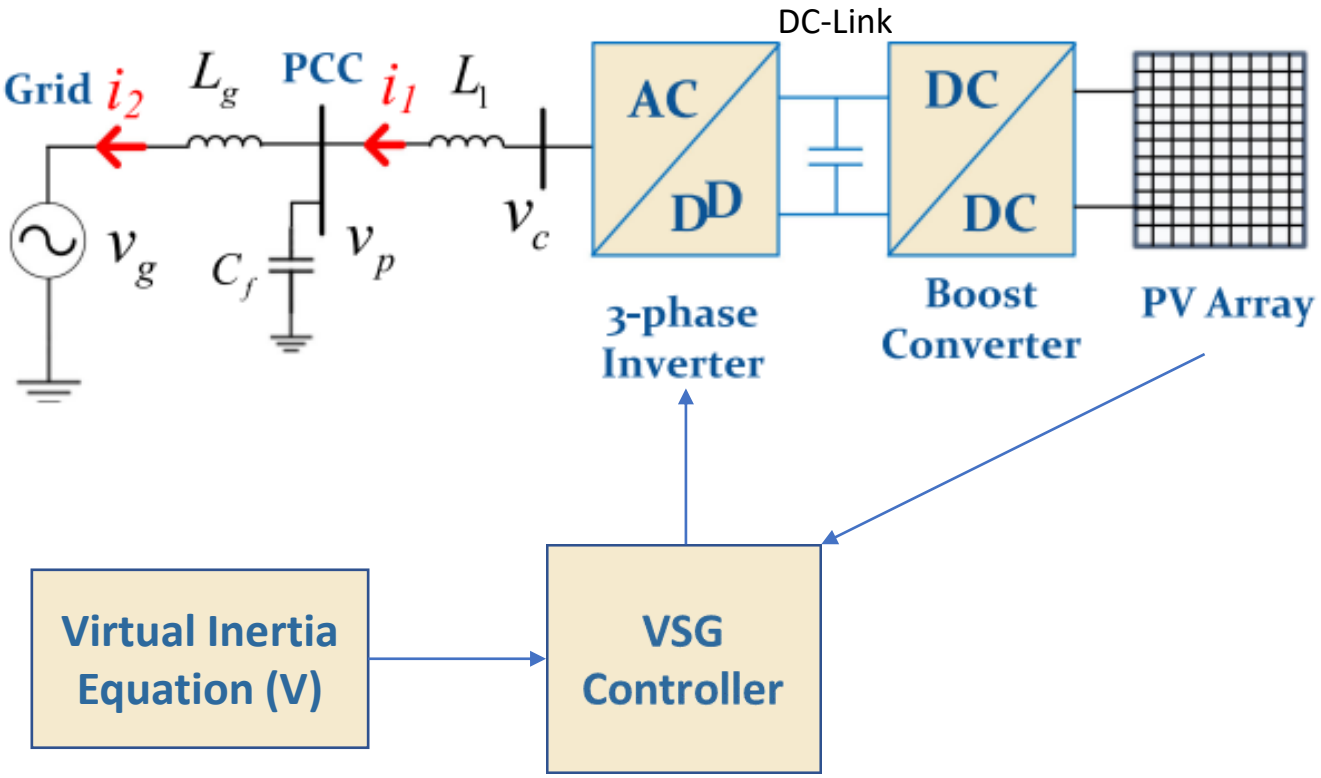
# Modifying DC–Link Capacitance

- The DC-Link capacitance, as shown in previous slide, can be modified to change the voltage value that is sent to the VSG controller
- Example: increasing the value of DC-Link capacitance from a tested value of 4mF to 7mF could significantly decrease the system settling time; the tradeoff associated with this is a small increase in overshoot [1]
- Decreasing the capacitance to a value less than 1mF would result in a significant increase in both overshoot and settling time [1]



# Modifying AC Filter Parameters

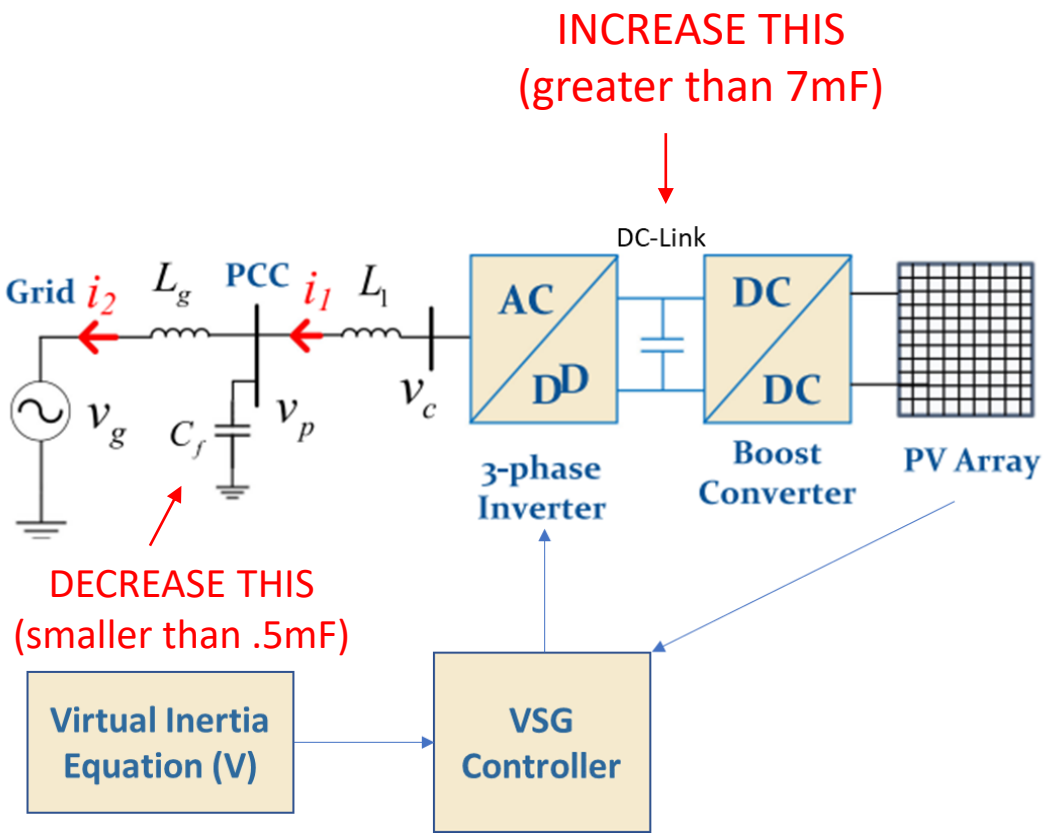
- Changing the AC filter parameters of the PV model was also tested with the addition of a VSG controller
- Relatively small AC-side inductor and capacitor (in comparison to normal PV systems) improved system performance [4]




| *Parameter* | *Appropriate change* | *Effect on performance* |
|---|---|---|
| DC-link inductor | Decrease | Decrease over shoot |
| DC-link capacitor | Increase | Decrease settling time |
| Moment of inertia | Decrease | Small decrease in over shoot |
| AC- side inductor | Decrease | High decrease in over shoot |
| AC-side capacitor | Decrease | Decrease in over shoot |

# My Thoughts/Ideas

- Based on two different studies conducted by IEEE ([1] and [4]), the size of the DC-link capacitor has a large effect on the system
  - Having a very large capacitor here (greater than seven millifarads) could be tested to decrease settling time even further
  - Since this is associated with a small increase in overshoot, the AC-side capacitor could be modified (smaller) to combat this tradeoff since doing so proved to decrease the overshoot
    - Tradeoff: small added oscillation – but would this occur if the DC-link capacitor was also changed?



# Conclusion

- As renewable energy becomes more and more used, it needs to optimize itself to stay stable & effective
  - Can be achieved with the addition of inertia to solar PV systems
    - Can be achieved with the addition of a VSG
- Virtual inertia-based PV systems are still a fairly new topic (almost all articles were written within the past 5 years)
- Expected to be researched even further because of the growth of PV into the grid

# References


[1] A. Nazih, D. S. M. Osheba and A. S. Mansour, "Virtual inertia impact on the performance of photovoltaic system," 2019 IEEE Conference on Power Electronics and Renewable Energy (CPERE), 2019, pp. 7-11, doi: 10.1109/CPERE45374.2019.8980133

[2] cetonline.org, "Advantages and disadvantages of photovoltaics," *Advantages and disadvantages of PV*

[3] J. Driesen and K. Visscher, "Virtual synchronous generators," 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, 2008, pp. 1-3, doi: 10.1109/PES.2008.4596800

[4] J. Khazaei, Z. Tu and W. Liu, "Small-Signal Modeling and Analysis of Virtual Inertia-Based PV Systems," in IEEE Transactions on Energy Conversion, vol. 35, no. 2, pp. 1129-1138, June 2020, doi: 10.1109/TEC.2020.2973102

[5] O. O. Mohammed, A. O. Otuoze, S. Salisu, O. Ibrahim, N. A. Rufa'i, "Virtual Synchronous Generator: An Overview," *Nigerian Journal of Technology (NIJOTECH)*, Jan. 2019.

[6] W. Im, C. Wang, W. Liu, L. Liu and J. Kim, "Distributed virtual inertia based control of multiple photovoltaic systems in autonomous microgrid," in IEEE/CAA Journal of Automatica Sinica, vol. 4, no. 3, pp. 512-519, 2017, doi: 10.1109/JAS.2016.7510031