Loss Minimization Through Local Volt-Var Control

B. McCornack, Dr. H. Ren, Dr. S. Pannala, Dr. N. Schulz, *Washington State University*

Abstract

In recent years, the drive for renewable energy has increased substantially. By nature, these renewable energy sources are widely distributed, creating new and unique challenges. This poster will propose a scalable solution for Volt-Var control. The goal of this controller is to optimize through loss minimization. The scalability of this solution comes from the locality of the controller. A local controller does not need to communicate its decisions or be informed of other's decisions. This inherently removes the need for a power system model as well, greatly reducing the time and effort needed to design and build the control as well as reduced risk of human error.

Introduction

While traditional controls and power generation are centralized and are highly regulated and dispatched by organizations such as the Federal Energy Regulator Commission (FERC), renewable sources are spread over large areas and can be deployed as large power plants or privately on homes reducing the ability to regulate and control the power production for system power quality.

Creating controls and regulations that utilize and manage the distributed and privately owned photo voltaic (PV), Battery Energy Storage System (BESS), or any other renewable source is much more challenging than designing for a centralized source. Even if larger entities like utility companies choose to offer programs to install renewables in homes so that they maintain ownership and control, they still face the problem that centralized control requires tremendous amounts of data and computational effort to maintain stability and optimize the system. This increases the number of individually contributing sources which increases the computational burden significantly and is not a scalable solution over large areas.

Methods

1. The **extremum seeking** algorithm was used to minimize power losses by monitoring line currents and adjusting the downstream bus voltage to reduce the line current.

2. **Static State Error** algorithm was used to adjust the base VAR (Q) setpoint of the voltage droop controller, increasing the voltage stability by eliminating the chance for the feedback control to oscillate while simultaneously providing the same functionality of droop control.

Test System

The total test system is comprised of 14 loads, 18 buses, 11 PV units, and one utility connection.

This figure is representative for part of the system to present the two PV units shown in the results section.

This test system is a feeder model taken from a partner utility, where the load profile and PV output profile was created from a live data poll from the field.

The simulations were done using OpenDSS as the simulation calculation, and the controller has been built using MATLAB. The OpenDSS com interface was used to allow MATLAB access to the simulation.
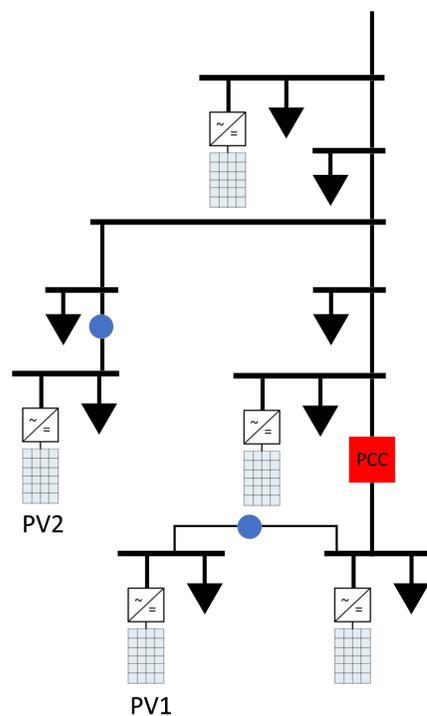

Figure 1: Representative single line diagram
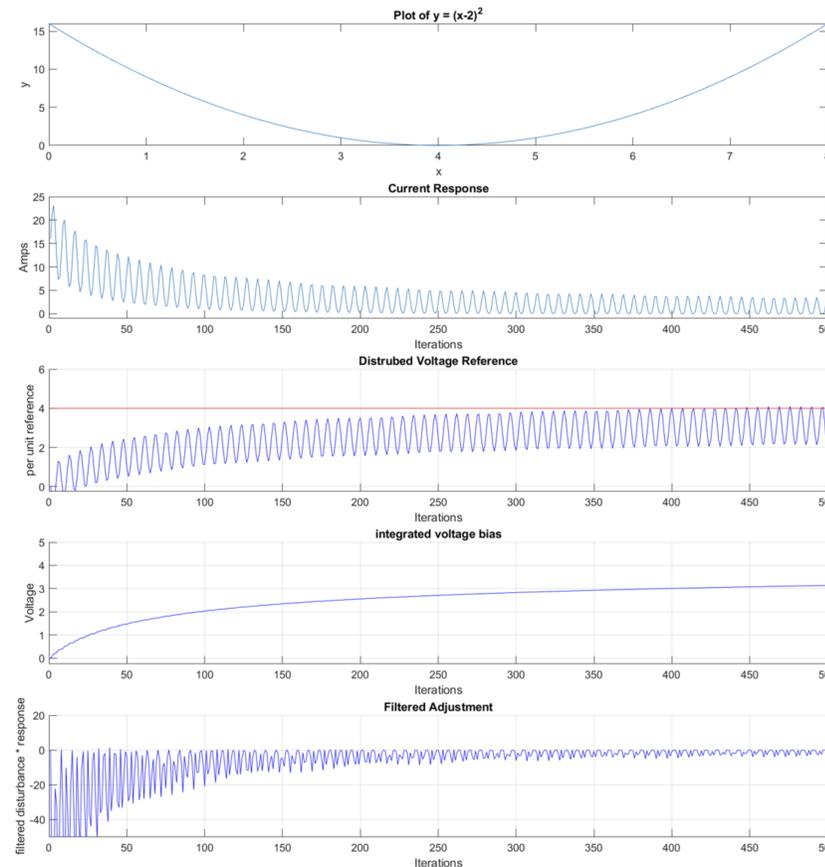
Extremum Seeking

Figure 2: Demonstration of how the extremum seeking perturb and observe method works to find the minimum of the objective function.

Results

Figure 4: Depiction of the performance of 2 representative PV units out of 10 units

System Losses:
- No Control   398.1 kWH
- With Control   360.7 kWH
- Savings: (398.1 − 360.7)/398.1
->0.0939 ~ 9% savings

Line Current Reduction:
- PV1 - 29.4%
- PV2 - 42.8%

Voltage Stability

The static state error algoritm alters the shape of the droop curve calculation used in the extremum seeking algorithm.

The Qmax and Qmin limits are set based on the measured P of the inverter.

Vmin and Vmax are tunable parameters.

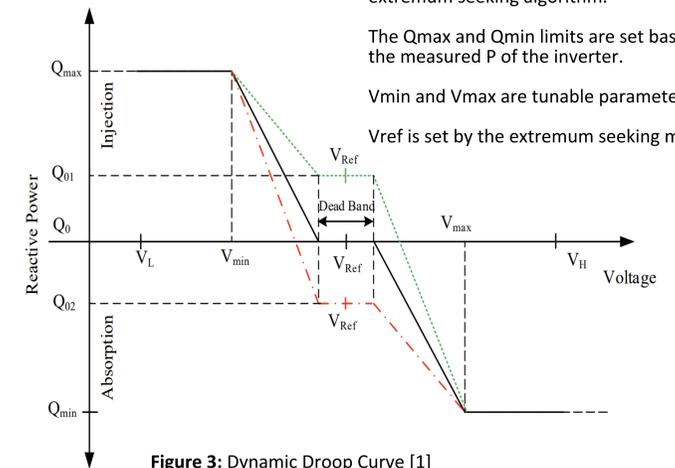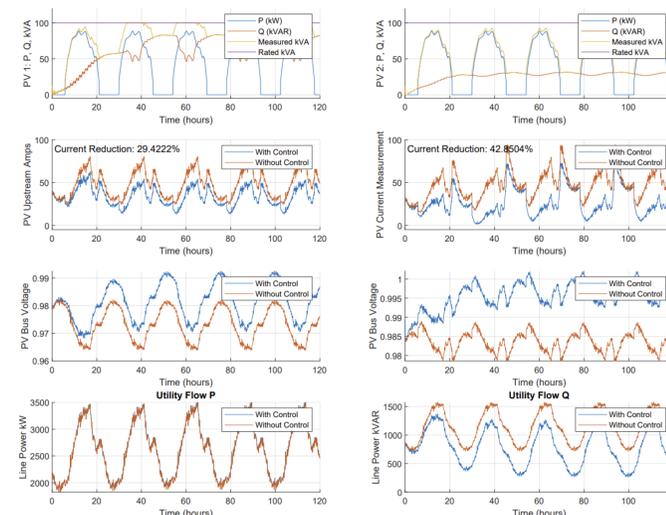Vref is set by the extremum seeking method

Figure 3: Dynamic Droop Curve [1]

Discussion

One main objective of the local VVC was to reduce system losses. The results strongly demonstrate the saving potential of the local VVC system. Showing ~9% kWH savings across the whole system, and over 30% reduction in line current on the two representative PVs chosen.

During regular load flow in this simulation and without the controller active, PV1 and PV2 buses are consistently under voltage. PV1 runs between 0.965 and 0.98 per unit voltage. Using the same load flow and with the controller active, this range moves up to 0.97 to 0.99. Showing through the static state error method in combination with the extremum seeking method that the voltage of the bus has improved while also minimizing the current flowing to/through the bus.

These two PV were chosen not because they have the best performance, but to demonstrate different responses based on the measured line currents, load, topology, etc.

Observing the results of [1], it is shown that a centralized controller does perform slightly better than the local VVC. However, the advantage to the local VVC is not about achieving the best optimum value. The advantage comes from the minimal design and installation hours/requirements for similar results.

The local VVC can be programmed into a PLC and placed within the smart inverter enclosure. No communication network, system model design, and validation are needed to achieve results similar to the centralized controller.

The local VVC is highly dependent on the % penetration of renewable resources as well as the location of the renewable insertions. However, the % penetration is continually on the rise due to individuals purchasing their own renewable sources. If this local VVC was installed on new smart inverters then, with no coordination, no integration, the grid would theoretically see reductions in line losses, as well as an increase to voltage stability (not shown in these results, but demonstrated in [1]).

References

[1] H. Ren, R. R. Jha, A. Dubey and N. N. Schulz, "Extremum-Seeking Adaptive-Droop for Model-Free and Localized Volt-VAR Optimization," in IEEE Transactions on Power Systems, vol. 37, no. 1, pp. 179-190, Jan. 2022, doi: 10.1109/TPWRS.2021.3093831.

Acknowledgement