Literature Review of the Recent Research on Power Photovoltaic Injection into the Power Grid

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1. Background

As the future approaches, concerns for renewable energy resources has been growing from small scale to large scale distributed energy generators. Improper conditioning of generated current that is fed back into the grid with unwanted harmonics or is out of phase can cause a fault and temporarily a power outage. DC current flowing with AC current can saturate the core of the transformer or rotating electrical machines. This saturation of the core can lead to uneven torque, overheating, and vibrations.

2. Objective

I will be conducting a literature review to summarize some proposed methods to possibly be used as reference in the future.

3. Materials & Methods

I will be reviewing transaction papers from the Institute of Electrical and Electronics Engineers Xplore Digital Library, excluding conference papers. Ten papers were analyzed with five being large utility scale grids and five being the smaller DC microgrids. Papers are examined by summarizing, explaining the significance, and concluding each method. For the purpose of this poster, I will only be presenting the methods with the most promising outcome. One will be on the utility grid and one on the DC microgrid.

4. Results & Discussion

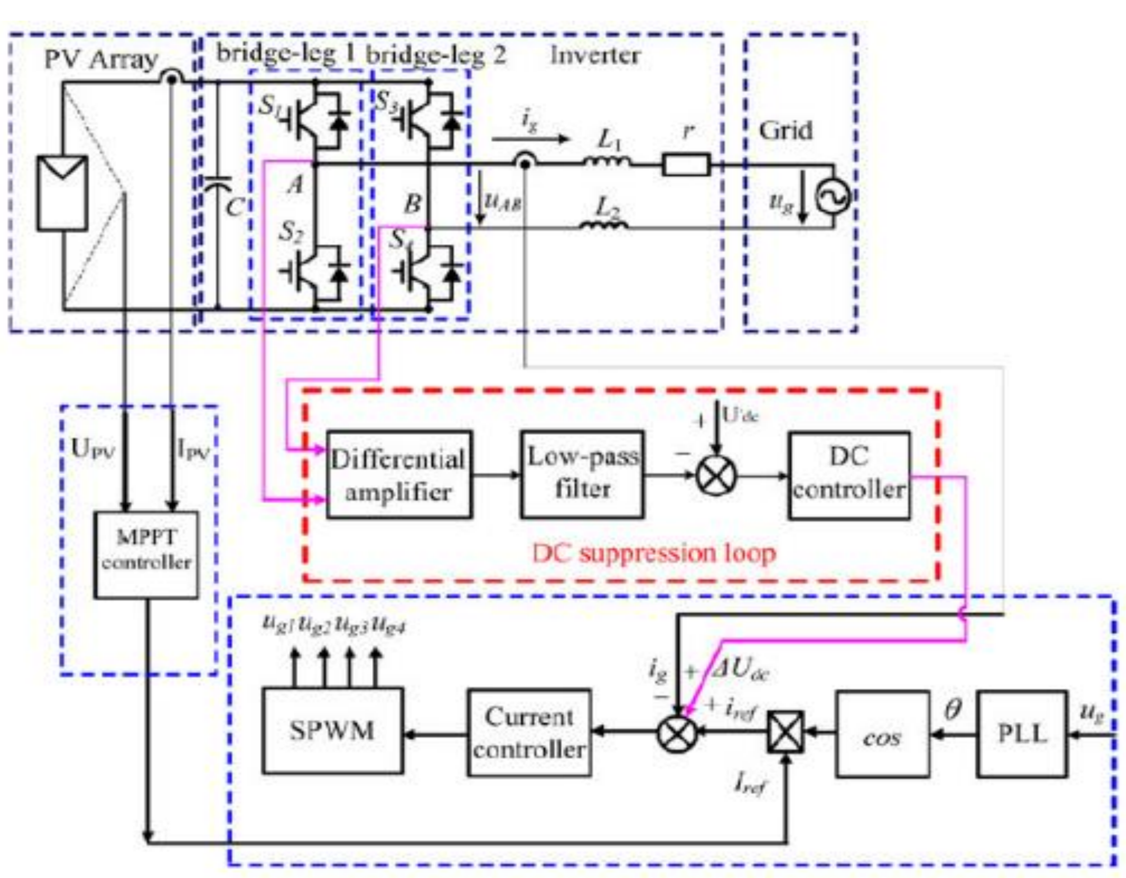

Figure 1. Topography of the DC Suppression Loop. A simple addition to the original transformerless inverter topography (from Guofeng He, 2015).

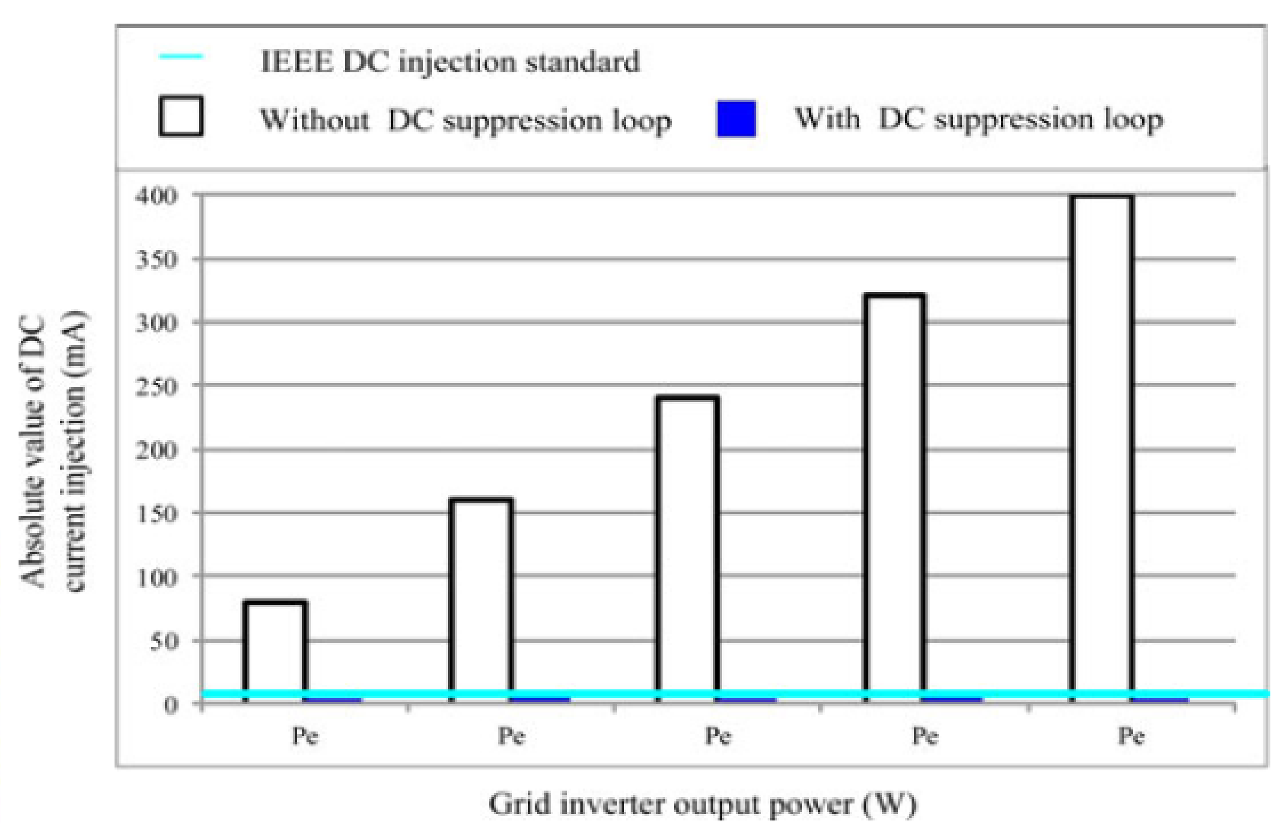

Figure 2. Comparison of Injected Current Disturbance. The system was operating at same rated power while injected with varying DC current (from Guofeng He, 2015).

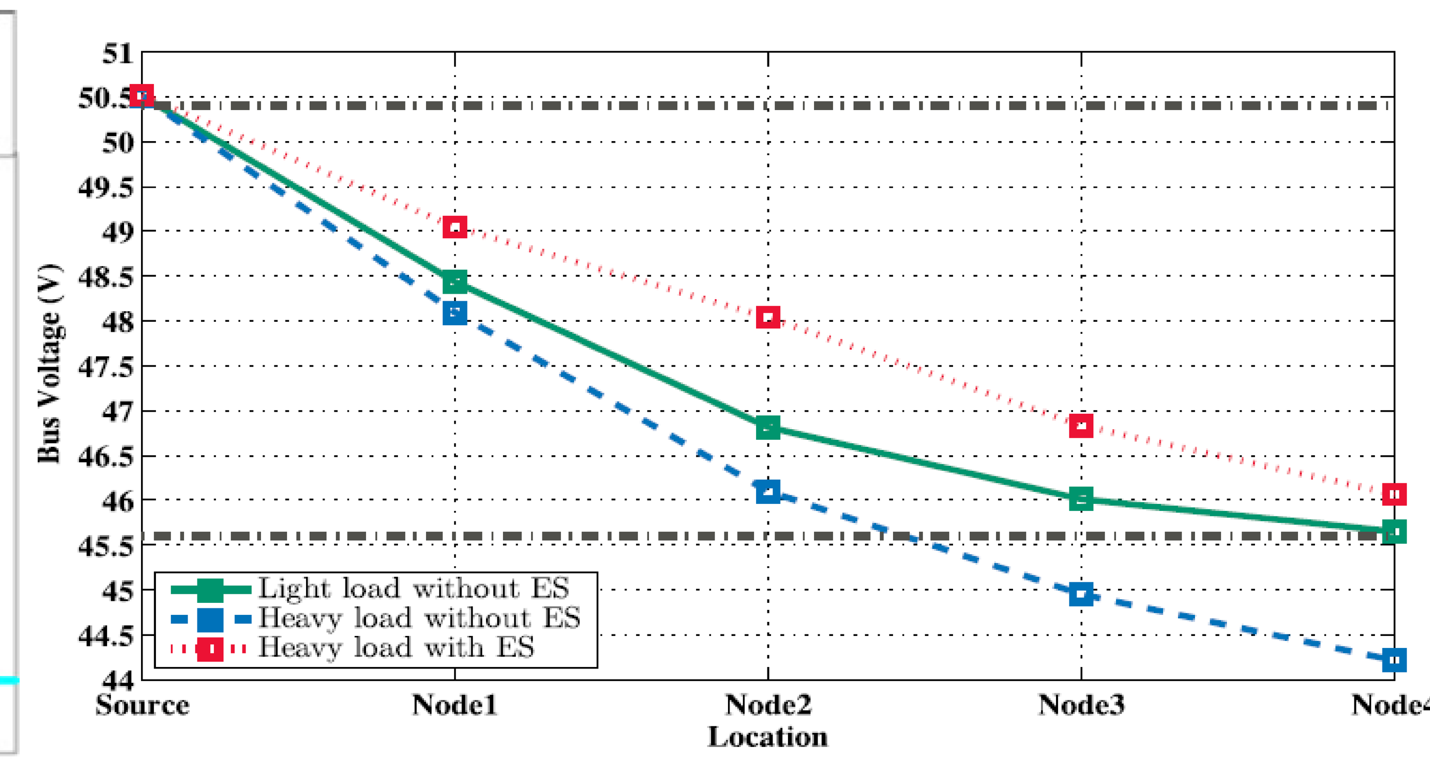

Figure 3. Comparison of Voltage Drops Across Nodes. The voltage measured along the bus at different locations with and without the Electric Spring (from Kwan-Tat Mok, 2017).

Figure 1 is the control scheme for the DC suppression loop that was designed to be implemented with the original control scheme. It is an additional PI controller that accurately calculates the DC offset between the neutral legs of the inverter and feeds that information back into the loop to fix that offset. The experimental criteria that Guofeng and his partners established was to test the inverter DC offset output at different rated power levels and to inject different disturbances when operating at rated power, with and without the DC suppression loop. Figure 2 is the experiment when the researchers operated at rated power output while injecting different DC offset disturbances. Without the suppression loop, the absolute DC injection to the grid ranged from 80 mA to 400 mA. When the DC suppression loop was applied in the second case, results showed great improvement to lowering the inject current to below 5 mA for all cases. It can be noted that the DC suppression loop can successfully measure current offset errors and eliminate them. The main significance of the DC suppression loop is that it eliminates the need for an isolation transformer. Isolation transformers are ideal because they do not transfer DC current, but they are expensive to maintain. The DC suppression loop design is a low cost and effective method as an addition to the original PV grid-tied inverter. The method is successful in eliminating DC current injection to below 5 mA which meets the standards for inverter design. It is necessary to minimize the injected DC current because it can lead to complications with the grid. Figure 3 demonstrates their experimental tests, they considered line impedances, different loading conditions of the electric spring, and the system fault protection. The electric spring can operate as a constant resistive non-critical load or constant power non-critical load. The prototype consisted of a half-bridge rectifier with a low cost commercial controller. Their experiment validated their calculations for adjusting the operating voltage of the electric spring and results were satisfactory. Without using the electric spring the bus voltage varied a little by ±.2 V, but activating it can regulate the voltage at all times. Their experiment also validated their claim that this can help voltage droops distributed along the microgrid by boosting the bus voltage. The proposed location of the electric spring is on the demand side that operates with or without a non-critical load, such as a thermal heater unit. The use of the electric spring improves voltage regulation, suppresses oscillations, and improving voltage droops or sags.

5. Conclusion

All these papers show some method of suppressing DC current injection into AC waves, or suppressing oscillations in the common voltage bus due to harmonics. DC microgrids offer a big advantage because it allows distributed energy resources to be connected and share their load without needing to synchronize the phase or losing power from converting DC to AC. For the utility scale grid, one promising method was the DC suppression loop because of its cost effective design and ability to operate well under the standard IEEE limit. For the DC microgrid, one promising method was the electric spring because of its flexibility to increase or shed the load throughout the system.

6. Future

For future work, I would like to conduct a literature review on more transaction papers. I would like to further characterize and compare the different proposed methods.

7. References

[1] G. He, D. Xu and M. Chen, "A Novel Control Strategy of Suppressing DC Current Injection to the Grid for Single-Phase PV Inverter," in IEEE Transactions on Power Electronics, vol. 30, no. 3, pp. 1266-1274, March 2015.

[2] K. T. Mok, M. H. Wang, S. C. Tan and S. Y. R. Hui, "DC Electric Springs—A Technology for Stabilizing DC Power Distribution Systems," in IEEE Transactions on Power Electronics, vol. 32, no. 2, Feb. 2017.