Summary Report

Project Title: Design of Novel Variable DC Link Capacitor for Solar Photovoltaic System.

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Summary: This research was conducted as an undergraduate design project, where four undergraduate students registered for the senior design course (EECE 4280) in the Fall 2021 semester at the University of Memphis. The goal of the project was to design and operate a solar photovoltaic (PV) system by considering an intelligent controller based variable DC-link capacitor. The proposed DC-link capacitor will enable the grid to be used for secondary frequency or voltage response during night-time or in the daytime intermittent cloud conditions. The proposed approach features a controllable variable capacitor to be used instead of the typical fixed DC-link capacitor. The conventional DC-link capacitor with a small capacitance value (micro or milli) provides a smooth DC voltage and maintains the balance between the DC and AC side while the proposed variable capacitance can operate both as a typical DC-link capacitor with a small capacitance or as a supercapacitor with a large capacitance value (several Farads).

The variable capacitor is made up of a small capacitor and a supercapacitor wired in series, with a parallel switch. Under normal operating conditions, the switch will remain open, which allows the series combination of the supercapacitor and the small capacitor to remain at a low capacitance value. During night conditions or cloudy weather, the switch will be closed, removing the small capacitor from the circuit, and leaving the supercapacitor connected to the DC-link point. This will allow the charged large capacitor along with the smart PV inverter to function equivalently as a typical supercapacitor energy storage (SES) system.

It is important to note that the new configuration of the PV system can be implemented for high-power, low-energy absorption/generation which will provide significant operational benefits to the connected power grid system. The dynamic performance improvements include power fluctuation minimization, transient stabilization, power quality improvements, power oscillation damping, and power transmission capacity increase of the connected network with other distributed energy resources. Moreover, during daytime when there is sufficient solar irradiance, the PV panel will be disconnected through a switch for a very short time following any disturbances, such as a fault in the power grid, and the large capacitor and smart PV inverter together will control the active power and reactive power of the grid, providing both voltage and

frequency support to the grid. Once power grid stability is maintained, the PV panel will be connected to the system and operate normally.

Results: For this project, the circuit simulation was completed by using a template grid connected PV system (Fig. 1) in Simulink which is available through the MatLab application. This circuit was then changed to include the variable DC-link capacitor in place of the standard DC-link capacitor. For simulation purposes, the capacitance of the variable DC-Link capacitor was adjusted for a 100kW system, with a nominal DC-link voltage of 500V DC. The program used a 10% voltage ripple, so this was also included in the calculations for the simulation. This changed the series DC-Link capacitance to 5.3mF. Fig. 2 shows the hardware prototype of the proposed variable DC link capacitor circuit.

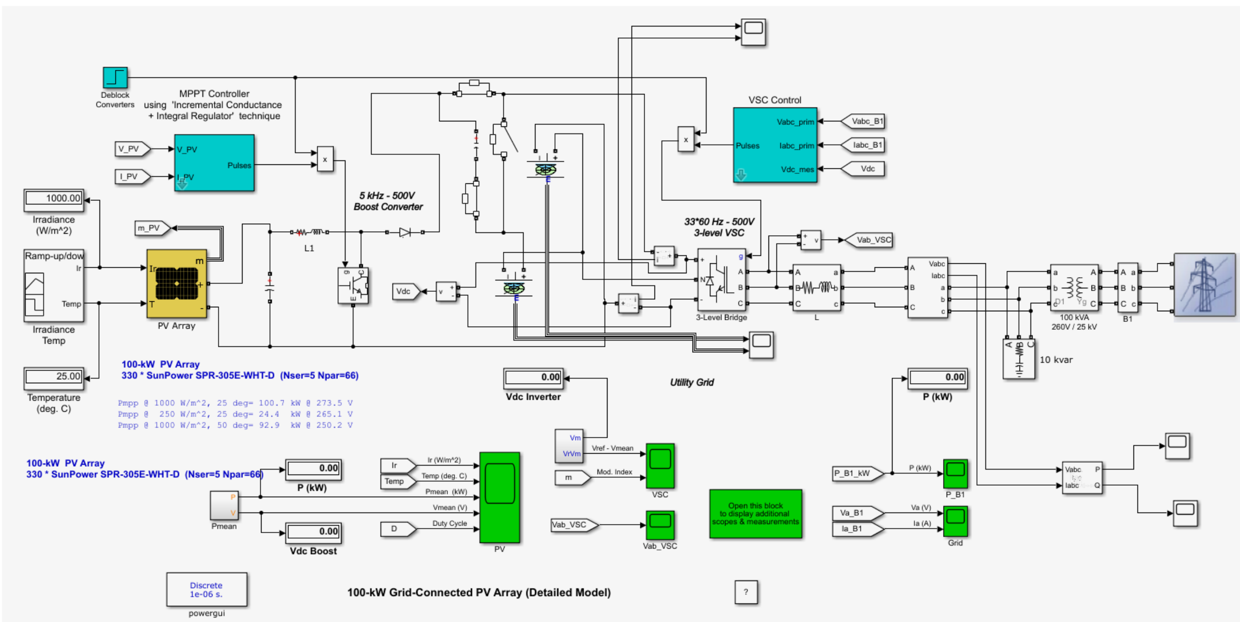

Fig. 1. Grid Connected PV with variable dc-link capacitor circuit simulation.

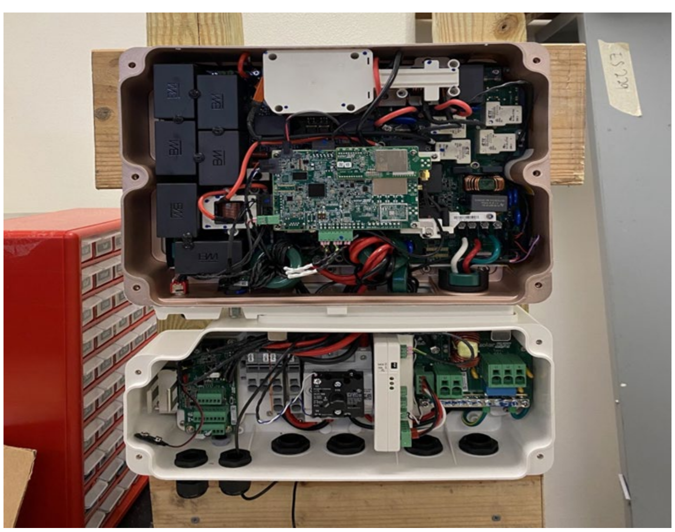

Fig. 2. Prototype of the variable dc-link capacitor circuit.

Fig. 3 shows the DC-link initial overshoot and voltage ripple. Fig. 4 shows the supercapacitor inserted temporarily for grid stability at t = 1s to t = 1.2s. Fig. 5 shows the supercapacitor inserted as back up energy source at t = 2s to t = 7.5s. From the simulation, we can expect the DC-link voltage to overshoot 300V DC by less than the max threshold voltage of 321V DC. We also expect the steady-state voltage ripple to be far less than the 7% limit we imposed with our DC-link capacitor. The switching transients of the supercapacitor also appears to be negligible provided the breakers are operated in the correct order. When the system is operating in backup mode, the supercapacitor bank should easily maintain the 300V DC required.

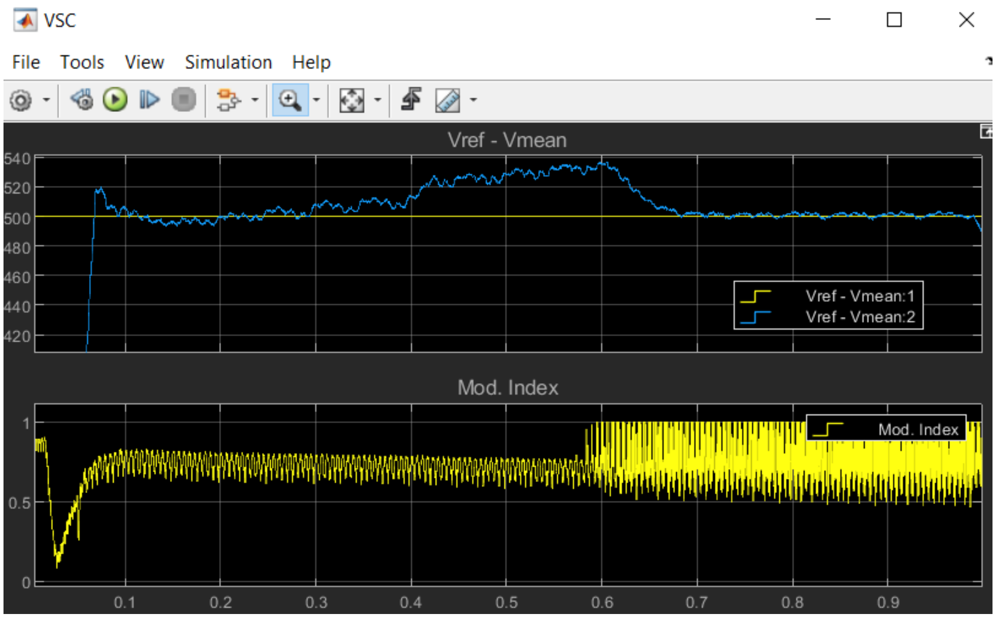

Fig. 3. DC-link initial overshoot and voltage ripple.

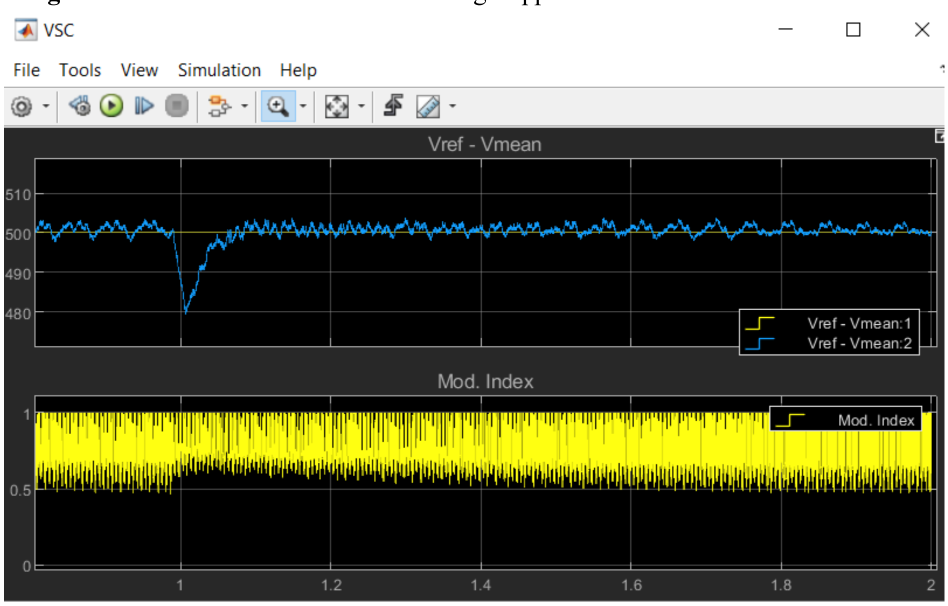

Fig. 4. Supercapacitor inserted temporarily for grid stability: t = 1s to t = 1.2s.

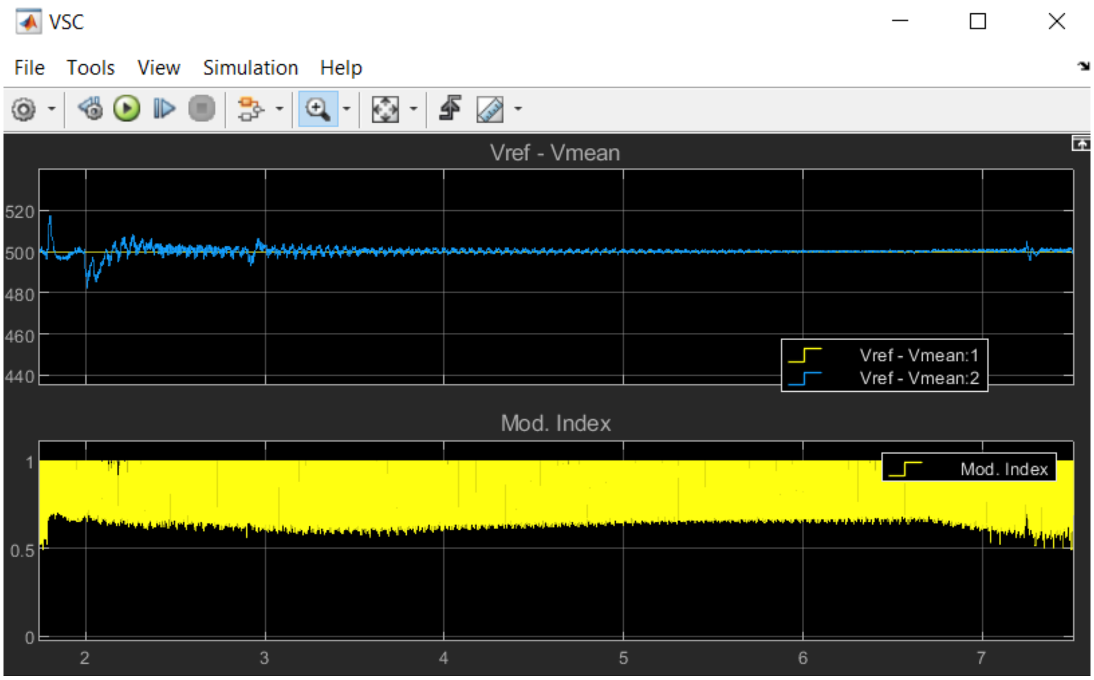

Fig. 5. Supercapacitor inserted as back up energy source: t = 2s to t = 7.5s.

Conclusion: The proposed variable DC-link capacitor was successfully implemented in the project. The variable DC-link capacitor can work as a standard DC-link capacitor and as a backup energy source for the inverter system. The proposed project has potential impact on the relevant field and application. Renewable energy resources, in particular PV systems, are gradually being connected to the electric power grid in various places all over the USA. The proposed solution is expected to benefit electric power utilities and PV system manufacturing companies as primary new technology adopters. Thus, the proposed solution has a great commercial potential in the field.

References

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