Study on D-UPFC in the Clustered PV System with Grid

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Abstract: Reverse power flow from a clustered PV system causes over-voltage problem in the distribution system. This paper proposes D-UPFC (Distribution-Unified Power Flow Controller) to solve the over-voltage condition when the clustered PV system is injected to the distribution system. D-UPFC simply controls distribution voltage level because PV systems almost produce active power. This system simply consists of AC-AC buck converter, a shunt transformer and an injection transformer. Simulation results show that D-UPFC controls distribution line voltage.
Key Words: Clustered PV system, D-UPFC, AC-AC buck converter.

1 Introduction

Reverse power flow from the grid-connected photovoltaic (PV) systems increases the voltage of power distribution line. In the case that large numbers of residential PV systems are connected to the power grid within a small area, this situation called "clustered", amount of delta-voltage will be higher than the stand-alone PV systems [1]. So, the over-voltage effect, which is normally happened in the grid-connected PV system, is the one of power quality problems in the distribution system.

Many kinds of methods are suggested to solve power quality problems. Among the most common are tap-changing transformers, which are the types of voltage regulators used in today's power distribution systems. However, these methods have significant shortcomings. For instance, the tap-changing transformer requires a large number of thyristors, which results in highly complex operation for fast response. Furthermore, it has very poor transient voltage rejection, and only has an average response time [2].

UPFC is basically used in the transmission line. It controls voltage level, impedance and phase angle simultaneously. However, D-UPFC, the author suggested, is not the same topology with normal UPFC. It consists of a shunt transformer, ac-ac buck converter and an injection (series) transformer. Also, it simply controls voltage level in the distribution line.

This paper is divided into two major parts. Part 2 provides details of the design and description of the D-UPFC model. Part 3 contains simulation results and their analysis. The paper ends with future scope and conclusion.

2 D-UPFC Model

To solve the over-voltage problem, the analysis of simple D-UPFC model is suggested. Fig.1 shows the simple D-UPFC model between a grid source and a clustered PV system.

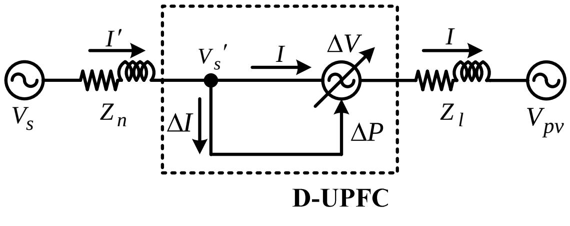

Fig.1 Simple D-UPFC model

When the distribution line voltage increases, ΔV is

$$\Delta P = \Delta V \cdot I \quad (1)$$

$$\Delta I = \frac{\Delta P}{V_s'} = \frac{\Delta V}{V_s'} \cdot I \quad (2)$$

$$I' = I + \Delta I = (1 + \frac{\Delta V}{V_s'}) I \quad (3)$$

$$V_s' = V_s - Z_n I' = V_s - Z_n I (1 + \frac{\Delta V}{V_s'}) \quad (4)$$

In the equation (4), distribution line V_s' decreases due to controlling D-UPFC.

Fig.2 shows the schematic of D-UPFC system. D-UPFC system is based on an ac-ac buck converter ($V_{out} \le V_{in}$) configuration, with a shunt transformer used at its input and a step-down injection transformer used at its output [2]. Under the over-voltage with reverse power flow from the PV systems, D-UPFC injects a required voltage in series to regulate the load voltage at a desired value (100V, rms). D-UPFC has four IGBT switches. The switches S_{w1} and S_{w4} form one pair and are turned on/off simultaneously. Similarly, switches S_{w2} and S_{w3} form another pair and are turned on/off simultaneously. The duty cycle of switches varies from 0.05 to 0.95 depending upon over-voltages from the clustered PV system [3]. Also, D-UPFC controls only voltage levels. Fig.3 shows voltage control of D-UPFC.

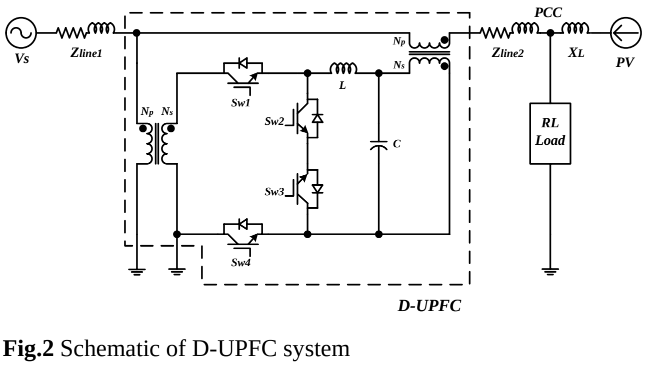

Fig.2 Schematic of D-UPFC system

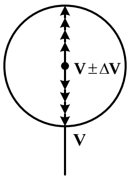

Fig.3 Voltage control of D-UPFC

3 Simulation Results and Analysis

Fig.2 was simulated in the PSIM. Tab.1 shows simulation parameters for D-UPFC.

Tab.1 Parameters of D-UPFC system

Vs	100[V],rms
Shunt & series transformer	1:1
Switching frequency	10[kHz]
LC filter	3[mH], 20[uF]
RL Load	10[Ω], 0.1[mH]
Line impedance(R+jL)	0.025+j0.00001[Ω]
PV output reactance(X_L)	1[mH]

Fig.4 shows the normal condition of distribution line and reverse power flow. Generally speaking, load voltage (Vload) is less than voltage source (Vs) in the distribution line because of line impedance. However, reverse power from the PV system flows from 0.6[s] and then line's over-voltage situation happens.

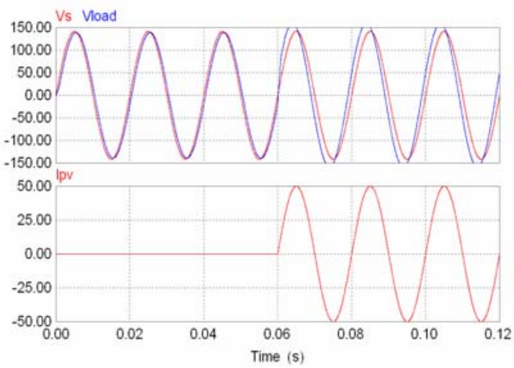

Fig.4 Normal condition and reverse power flow

Fig.5 shows the result of D-UPFC control. Although output power of PV is 50[A] at 0.6[s], Vload is the same as Vs.

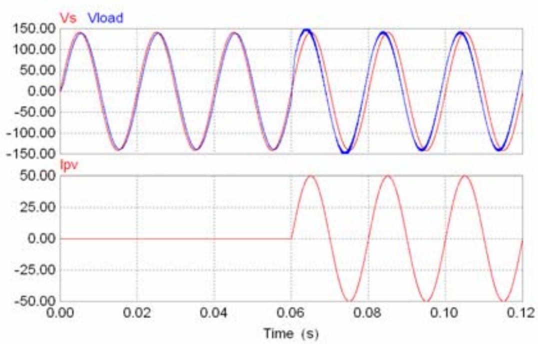

Fig.5 Voltage control with 50[A] of PV output current

Fig.6 represents over-voltage situation as well as voltage control from D-UPFC. Even though 60[A] of reverse power flow situation happens, D-UPFC controls distribution line voltage.

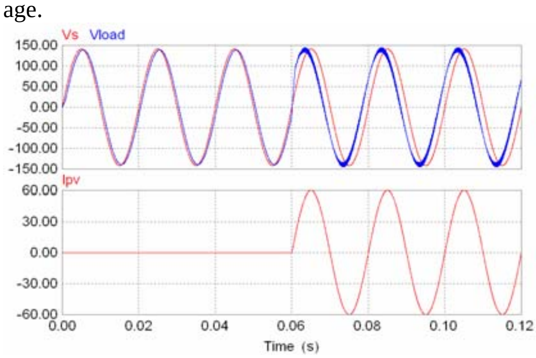

Fig.6 oltage control with 60[A] of PV output current

Through the simulation results, D-UPFC controls distribution line voltage when PV output current was 50[A] and 60[A].

4 Future Scope

D-UPFC simply controls over-voltage condition in the distribution line. However, it is important to control distribution line voltage optimally when the reverse power flow happens. Also, it needs to research why line voltage angle leads source voltage angle when the reactive power flows.

5 Conclusions

To solve the over-voltage condition due to the clustered PV systems connected with distribution line, D-UPFC was suggested and carried out the voltage regulation in this paper. It has been found that D-UPFC effectively compensates over-voltage condition in the distribution line. D-UPFC is modified from the normal UPFC, which has two converters and a dc link capacitor and two transformers in the transmission system. However, D-UPFC has an ac-ac buck converter and two transformers. Simulation results were shown that D-UPFC controls over-voltage condition in the distribution system. Future study will include to control more effectively the distribution line's voltage.

Acknowledgements

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