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# ADVANCED VAR PLANNING WITH TUNING OF UPFC IN A DISTRIBUTION GENERATION INTEGRATED INDUSTRIAL SYSTEM

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## ABSTRACT

This project " AdvanceVAR Planning With Tuning of UPFC in a DG Integrated Industrial System" is composed of an Wide-scale penetration of distributed-generation (DG) units into a weakly meshed distribution system is one of the major concerns for power system engineers in recent years. As grid standards limit voltage control operation of small DG units, a lack of sufficient reactive power support brings the problem of slow voltage recovery and this leads to the usage of expensive flexible ac transmission system (FACTS) devices, such as a Unified power flow compensator (UPFC). In this project, a systematicmethodology has been developed for fast voltage recovery at the DG bus. This methodology reduces the number as well as the rating of UPFCs through the tuning of control parameters. The UPFC rating at selected locations has been tested and verified to be adequate at various dispatch levels of DG units. Additional benefits of UPFC tuning on the damping of weak modes have also been studied.

## 1. INTRODUCTION

In recent years, environmental and commercial concerns have led to worldwide large-scale distributed-generation (DG) integration. DG units can bring a number of advantages, for example, reduced losses as well as improved grid security and reliability. However, the penetration of DG units into the existing grid poses challenges to the utilities due to two-way power-flow and different characteristics compared to the conventionalgenerators. Therefore, grid standards are proposing a set of regulations to allow flawless integration of renewable as well as nonrenewable-based DG in the main grid. Most of the grid operators do not allow small-scale DG units to operate in a voltage-control mode and those units also lack low-voltage ridethrough (LVRT) capability. LVRT capability is a demand of network operators from large-scale DG units. The American Wind Energy Association (AWEA) and the Western Electricity Coordinating Council (WECC) proposed LVRT requirements for all new generators greater than 20 MW and no distinctions were made between conventional synchronous and inverter-based variable-speed generators. Similar sets of LVRT requirements have been issued by FERC orders no. 661 and 661-A for wind generators greater than 20 MW. Since the small DG units are not facilitated with LVRT capability, strict grid standards make these units more prone to frequent tripping.

A number of studies have shown that FACTS devices, such as static VAR (Volt-ampere-reactive) compensator (SVC) and UPFC, can assist grid integration of DG units by supplying dynamic VAR under post fault conditions. However, in terms of providing dynamic VAR, STATCOM is superior to SVC as it can maintain reactive current output at its nominal value over a wide range of bus voltages. By placing UPFC at the point of common coupling (PCC) voltage under abnormal and continuous conditions can be improved, ultimately allowing DG units to remain connected to the grid. In a recent study, a sensitivity index-based methodology was developed to place UPFC on a bus other than the DG unit bus to ensure faster recovery of the voltage at the PCC.With this approach, the number of UPFCs can be reduced in a distribution system with multiple DG units. Cost can be further reduced by reducing the rating of UPFC along with an appropriate combination of capacitors.

In order to achieve fast voltage recovery, the rating of UPFC is chosen based on available mechanically switched capacitors, network connection strength, generator rating, and the voltage recovery time frame. In addition, the control strategy, consisting of a proportional-integral (PI) controller, plays a significant role in determining the final rating of UPFC. Under normal operating conditions, the rating of UPFC as well as other FACTS devices is chosen based on the power factor and voltage requirements at the PCC. For example, when UPFC is placed at the PCC with a DG unit, the rating of UPFC varies between 30% and 100% of the DG unit rating. However, determining the minimum rating under faulty or abnormal condition requires detailed time-domain simulations. Since dynamic FACTS devices, such as UPFC, are always an expensive option for reactive power planning, there is always an urge to minimize the number and rating of UPFC units in the system with multiple DG units. Although a number of studies have been proposed in the literature for the determination of optimum UPFC size, a systematic complete methodology of VAR planning with UPFC to facilitate grid integration of DG units has not yet been presented.

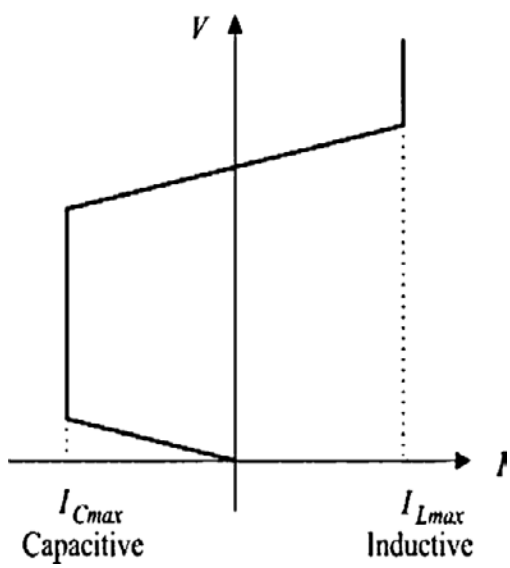


**Fig. 1.V-I characteristics of UPFC.**

## 2. UPFC FEATURES AND DYNAMIC MODEL

UPFC is a voltage and current source converter (V&I SC)-based flexible ac transmission system (FACTS) device. Its prime function is to exchange dynamic reactive power with the host ac system. In distribution systems, UPFC applications have been found in voltage regulation and stabilization, power factor control, voltage flicker compensation, and power-quality improvement. Fig. 1 shows V-I characteristics of UPFC.

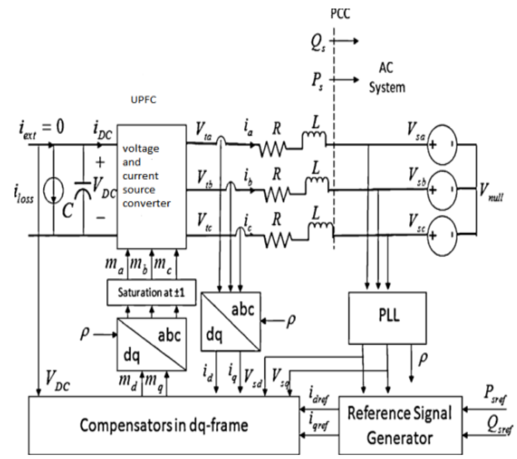


**Fig. 2. Dynamic model of a UPFC connected to the ac system.**

The basic dynamic model of STATCOM connected to an ac system has been shown in Fig. 2. Each phase of the VSC is connected to the ac system via series*RL* branch representing coupling transformer leakage impedance. The ac system is modeled by an ideal three-phase voltage source. The current-mode control is performed in -frame as illustrated in Fig. 2. Both the feedback and feed forward signals are first transformed to the -frame and then processed by compensators to generate the control signals in the -frame. The compensators in the -frame include four proportional-integral (PI) controllers: the -axis current regulator, the -axis current regulator, the dc voltage regulator, and the ac voltage regulator. Finally, the control signals are transformed back to the abc-frame and fed to the Voltage and current Source Converter.

With large penetration of small distributed-generation units, there is a desire for the extensive use of dynamic reactive power sources to facilitate fast voltage recovery. In this project, a step-by-step methodology has been proposed for effective VAR planning with UPFC. Initially, with the use of an index , this methodology reduces the number of UPFC controllers required in a system with multiple DG units. The UPFC controller parameter is selected fortuning after a detailed analysis of the dynamic model. Tuning subsequently reduces the rating of UPFC. The influence of varying dispatch levels of DG units on the rating and recovery performance of UPFC is also studied. Simulation results prove the effectiveness of the proposed VAR planning with UPFC for a DG-based industrial system.

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