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RELIABILITY EVALUATION OF BULK POWER INCORPORATING UPFC

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Abstract:

Unified power flow controller (UPFC) is one of the most advanced flexible AC transmission system (FACTS) devices that can simultaneously and independently control both the real and reactive power flow in a transmission line. The utilization of UPFC can result in significant reliability benefits in modern power systems. This paper proposes a novel reliability network model for a UPFC, which incorporates the logical structure and the distinct operating modes of a UPFC. Two-state or three-state models have been used for UPFC by previous researchers. The proposed model divides the UPFC operating modes into four states, namely the UPFC up state, STATCOM state, SSSC state and UPFC down state, in order to improve the accuracy of the model by recognizing the practical operating states of a UPFC. The new model also incorporates an AC flow-based optimal load shedding approach to assess the impact of bus voltages and reactive power flow on UPFC in order to decide appropriate load curtailment in the reliability evaluation process. The performance of the proposed model is verified using a test system, and compared with different reliability models of UPFC. Various operating schemes, such as different placement locations of UPFC, and different capacities of UPFC are used to illustrate the advantages of the developed models, and to examine the impacts of UPFC on the system reliability.

Keywords- Unified power flow controller; reliability evaluation; bulk power system; load curtailment model

I. INTRODUCTION

It becomes important to develop appropriate reliability models for flexible alternating current transmission system (FACTS) devices in order to carry out realistic reliability evaluation of power systems that incorporate FACTS devices. A number of studies have been conducted recently to investigate the impact of FACTS devices on the system reliability. Most researchers have focused on conventional FACTS devices, such as Static Var compensator (SVC), thyristor-controlled series compensator (TCSC) and thyristor-controlled phase angle regulator (TCPAR). There is relatively little research reported on the reliability implications of unified power flow controller (UPFC).

UFPC is currently the most versatile FACTS device available as it combines the good properties of both the static synchronous compensator (STATCOM) and the static synchronous series compensator (SSSC). UPFC is capable of providing active and reactive power control, as well as adaptive voltage magnitude control. Reference proposes a reliability model of TCSC based on a state-space method, and the TCSC is used to adjust the power distribution between two different parallel transmission lines. A DC flow-based optimization model is developed to evaluate the impact of TCSC on the reliability of a power system in References and present analyses of the reliability effects of TCSC, SVC and TCPAR using expanded optimal power flow (OPF) method to evaluate the control capabilities of the three FACTS devices. A UPFC system is classified into three subsystems, and a three-state reliability model is developed based on the state-space method in. A reliability model of UPFC, considering only the failures of the converters and the control units is proposed using a state-space method in, and the model is used with the Dig Silent power system analysis software for reliability evaluation of a BPS. A three-state model of a transmission component with FACTS is developed to study the impacts of UPFC on the reliability of a bulk power system (BPS) in [10]. A network flow method is used to curtail the load, and the impacts of UPFC on bus voltage and reactive power are not considered in the model.

II. RESEARCH METHODOLOGY

Unified Power Flow Controller:

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously.

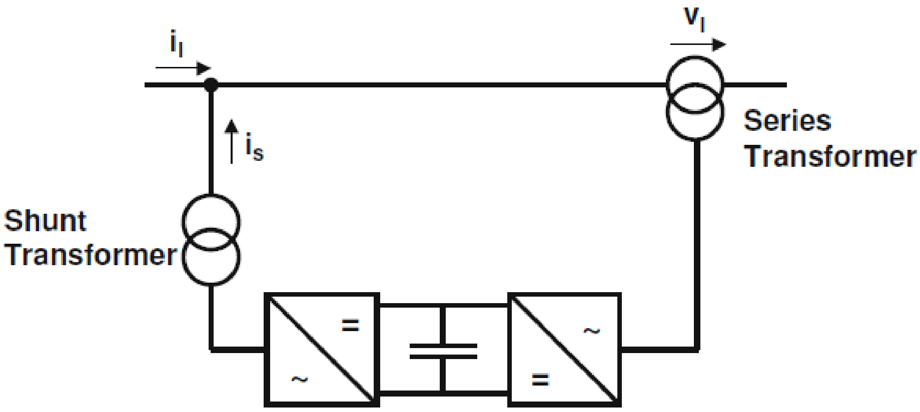


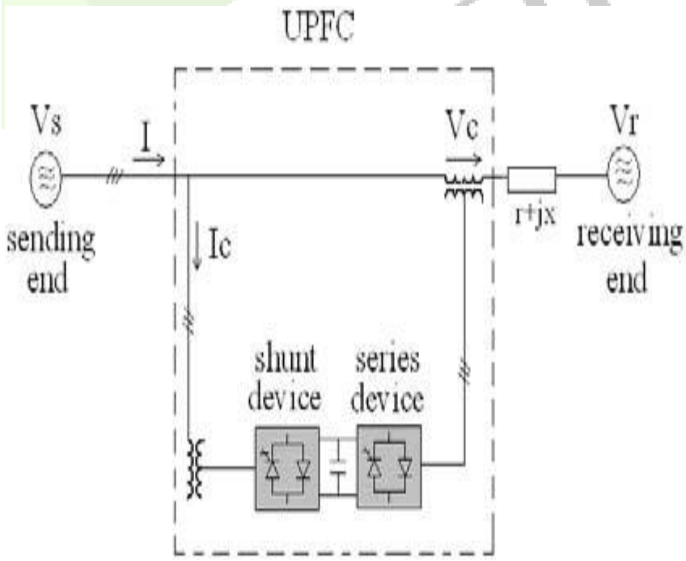
Fig1.21. Principle configuration of an UPFC

The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. This setup, as shown in Figure 1.21, provides the full controllability for voltage and power flow. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously.

OPERATING PRINCIPLE OF UPFC

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.

A basic UPFC functional scheme is shown in fig.1



The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point.

The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power low on the transmission line.

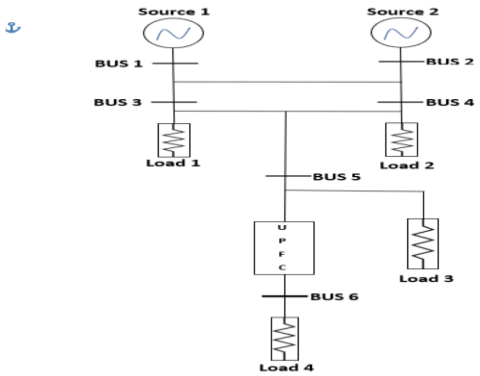
The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, is into the transmission line. The shunt inverter can be controlled in two different modes:

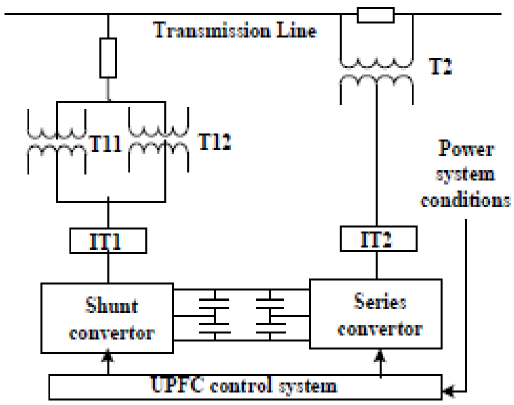
VAR Control Mode: The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control, a feedback signal representing the dc bus voltage, Vdc, is also required.

Automatic Voltage Control Mode: The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer.

The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways.

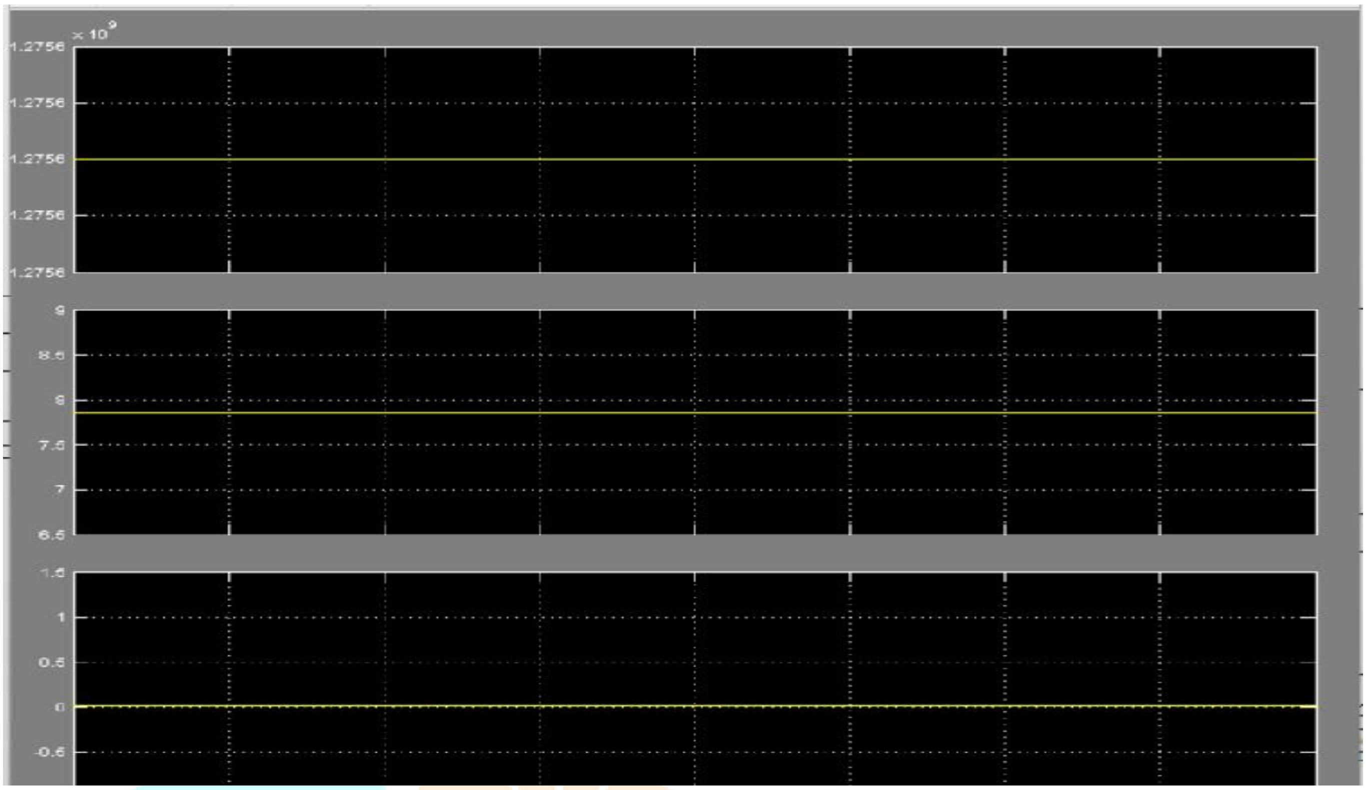
Main block diagram and working principle of UPFC





It has two voltage-sourced converters. The two converters are labeled as 'Shunt converter' and 'Series converter'. The shunt converter is connected in shunt with the transmission line through two redundant shunt-connected transformers T11 and T12, and the series converter is connected in series with the transmission line through a series insertion transformer T2. The DC terminals of the two converters are connected together with a common DC link and four DC capacitors. Each converter consists of two identical converting bridges connected in parallel. IT1 and IT2 are intermediate transformers.
The basic operating principle of the UPFC is as follows. The series converter provides the main function of the UPFC by injecting an AC voltage with controllable magnitude and phase angle in series with the transmission line via the series transformer T2. The basic function of the shunt converter is to supply or absorb the real power demanded by the series converter at the common DC link. In an ideal condition, the active power supplied to the shunt converter must satisfy the active power demanded by the series converter. In other words, the UPFC does not consume any active power.
UPFC (Unified Power Flow Controller) is a combination of STATCOM and SSSC, which are coupled via a common DC link, to allow bi-directional flow of real power between the series output terminals of the SSSC and the shunt output. terminals of the STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source.
The series converter provides the main function of the UPFC by injecting an AC voltage with controllable magnitude and phase angle in series with the transmission line via the series transformer T2.

III. RESULTS AND DISCUSSION



The above graphical representation shows that the power across the transmission lines is not disturbed if we connected the UPFC Facts device in series with the transmission lines. The non-linear loads will produce the harmonics in the lines so that the reactive Power will increase in the line and there by the active power transfer will decrease in the line. Here bulk power system has different Loads, if any load is to be get fault, the UPFC will active and it will activate real and reactive power based on the load variation and keep the bulk power system should be reliable. Here we conclude that the bulk system should be reliable by using the facts device as UPFC.

IV. CONCLUSION

This project proposes a new four-state reliability model for a UPFC. A methodology that incorporates the UPFC model in an AC flow-based optimal load shedding approach to identify optimum load curtailment in the reliability evaluation process is presented. Comparisons of the impacts of the UPFC on the system reliability using different models show that the precision of the proposed model is relatively higher than the traditional models.

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