Impact of UPFC on Distance Relay: A Case Study

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***Abstract*-- In the power transmission system FACT controller is incorporated in the transmission line in order to increase power transfer capability as well as reactive power control. The FACT devices which combine the feature of shunt fact devices and series fact devices are considered i.e. UPFC (Unified power flow controller) which address the issue of adaptive protection of a transmission line where this device is located at the different position of transmission line like middle of the transmission line, sending end and receiving end of transmission line. Design and simulating the UPFC incorporated in transmission line is done in PSCAD/ EMTDC software. The impact of UPFC on the distance relay is described by impedance trajectory, disturbance in voltage and current and apparent impedance is carried out in the presence of UPFC for different fault calculation.**

***Index Terms*-- UPFC, PSCAD/EMTDC, FACTS, Apparent Impedance.**

I. INTRODUCTION

The development of power electronics applications in power systems provides great benefits in technical or economical terms. Applying FACTS series compensators is one of the electronics controllers that enhanced power transfer capability, transient stability and damping of power transfer through transmission lines. However, one of the difficulties of having FACTS compensation is that the calculation of capacitor voltage drop cannot be estimated using conventional methods [1] [2].

The operation of FACTS devices introduces harmonics and non linearity's to the power system, which adversely affect the protection systems and the fault detection methods. Transmission power systems today are complex networks which include long transmission lines necessary to transport energy from large generation units to bulk consumption loads. The compensation of transmission lines is a mature technique which can greatly increases the amount of power to be transported. The improvements in the field of power electronics have had major impact on the development of the concept itself. These controllers are based on voltage source converters and include devices such as Static Var Compensators (SVCs), Static Synchronous Compensators (STATCOMs), Thyristor Controlled Series Compensators (TCSCs), the Static Synchronous Series Compensators (SSSCs), and the Unified Power Flow Controllers (UPFCs).

The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The UPFC can provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. It is recognized as the most sophisticated power flow controller currently, and probably the most expensive one.

We know that the compensating equipment should be installed in transmission lines longer than 100 Km. The compensating factor, which is the ratio between the reactance of the compensating element and the total reactance of the transmission line, ranges between a minimum of 20% - 40% up to a limit of 75%. The selection of this compensating factor heavily depends on the network configuration, the system security and stability criteria.

Distance protection relays for non-compensated lines are not normally designed for non linear line impedance changes. Such relay should not be used in a line compensated environment. In such context, out of using high-cost pilot protection, solutions fingers to develop new algorithm fully committed to correctly detect faults and distance under the conditions imposed by the transient behavior of voltage and line current fed to the distance relay [1-8].

II. UNIFIED POWER FLOW CONTROLLER

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 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 [1].

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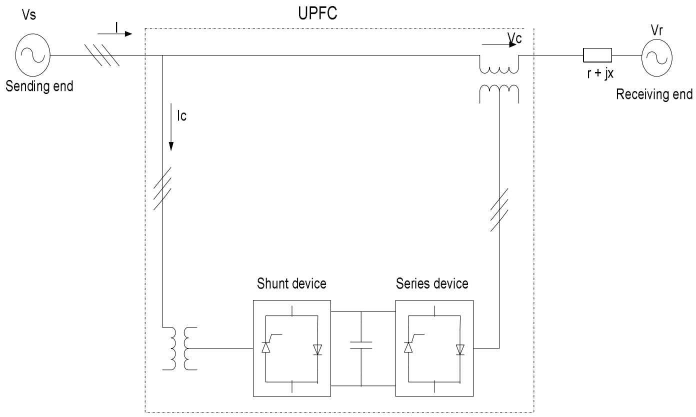
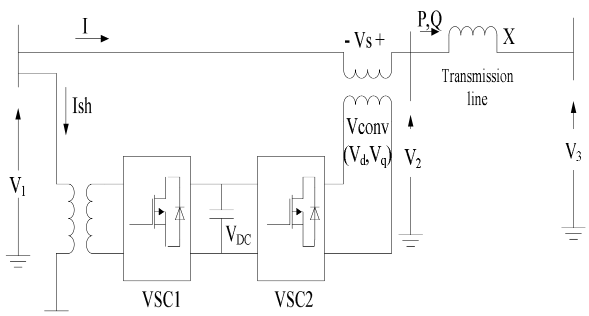


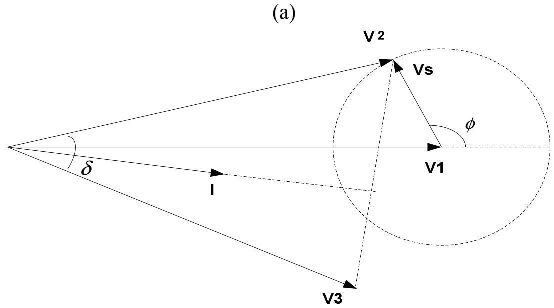
Fig.1 Basic Functional Scheme of UPFC

Control of power flow is achieved by adding the series voltage, V_S with a certain amplitude, and phase shift, φ to V_1. This will gives a new line voltage V_2 with different magnitude and phase shift. As the angle φ varies, the phase shift δ between V_2 and V_3 also varies. Fig.2 shows the single line diagram of the UPFC and phasor diagram of voltage and current.

$$P = \frac{V_S V_R \sin\delta}{X}, Q = \frac{V_S(V_S - V_R \cos\delta)}{X} \quad (1)$$



(a)



(b)

Fig. 2 (a) Single Line Diagram of UPFC and (b) Phasor Diagram of Voltage and Current

With the presence of the two converters, UPFC not only can supply reactive power but also active power. The equation for the active and reactive power is given as follows:-

$$P_{12} = \frac{V_1 V_2}{X_{12}} \sin\delta \quad (2)$$

$$Q_{12} = \frac{V_1 V_2}{X_{12}} (\cos\delta + 1) \quad (3)$$

Although the UPFC improves the power flow in the transmission line, its presence imposes number of problems including distance protection. The apparent impedance seen by a distance relay is influenced greatly by the location and parameters of UPFC besides the fault resistance magnitude of the arc in case of a ground fault. If the impedance seen by a relay is lower or higher than the actual line impedance, the distances relay either over reaches or under reaches. Thus an adaptive relay setting of the distance protection is required to cope up with the problems of over reach or under reach [9].

III. FAULT ANALYSIS AND RESULT

The fault analysis has the main purpose of understand the temporal behavior of line current and voltage at one end of the transmission line at different fault location and compensation levels by using impedance trajectory. The results provided are needed to determine particular traces helpful to discriminate between fault events occurring before or after the UPFC. Table 1 shows the general data of the test system.

Table I
General Data of the Test System

Element	Value
Generator 1,2	100MVA
kV Generator V1,V2	230 kV
Frequency	50 Hz
Source Impedance	
Zs_1	0.238+5.72jΩ
Zs_0	2.738+10jΩ
Z_{R1}	0.238+6.19jΩ
Z_{R0}	0.833+5.12jΩ
δ	15
Transmission Line Length	200 Km
Line R1, R0	0.0275,0.275 Ω/Km
Line L1,L0	1.35,3.75 mH/Km
Line C1,C0	9.48, 6.711 nF/Km

The transmission line is simulated in two ways and for single phase- ground fault (A-G); in the first case compensation is not providing with the line and fault is created in the different location from the source end. Fig.3 shows the result of case 1.

And in second case compensation is providing with the transmission line and fault is created in the line at a distance of 150 km and 50 km from the source i.e. after the UPFC and before the UPFC. Fig.4 shows the result of case 2. In Fig 3& 4; the Mho characteristic shows the effect of the UPFC when it is connected in the transmission line.

In Fig. 4 (a) are for the fault after the UPFC and by comparing this to the Fig.3 (a), it shows that how the apparent impedance seen by the relay is change and in Fig.4 (b) & Fig.3 (b) have same impedance characteristic, the fault after the UPFC i.e. 50 km from the source has same impedance characteristic as in the transmission line which do not have the UPFC compensation. This describes how the apparent impedance changes, when the UPFC is incorporated with the transmission line.