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UPFC based distance relays for protection of transmission systems employing FACTS

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Abstract
This paper focuses on the application of the distance relays for the protection of transmission systems using versatile electricity transmission controllers like the Unified Power Flow Controller (UPFC). Firstly, an in-depth model of the UPFC and its control is papered and so it's integrated into the gear for the needs of accurately simulating the fault transients. The simulation results show the impact of UPFC on the performance of a distance protection relay for various fault conditions and for various fault location.

Keywords: distance relay, FACTS controllers, grid protection, UPFC

1. Introduction
Power transfer, in most integrated transmission systems, is forced by transient stability, voltage stability, and power stability. These constrain limit the complete utilization of accessible transmission corridors. FACTS is a technology that gives the requisite corrections of transmission practicality to completely utilize existing transmission systems and, therefore, minimizes the gap between the steadiness and thermal limits. FACTS technology is predicated on the utilization of reliable high-speed power physics, advanced control technology, high-octane microcomputers and powerful analytical tools. The key feature is that the accessibility of power electronic shift devices that may switch electricity at power unit levels (kV levels). The impact of FACTS controllers on transmission systems is seems to own a big impact on grid networks worldwide. Amongst the various varieties of FACTS controllers, UPFC is taken into account to be one among the foremost effective within the control of power flow. It contains 2 succeeding gate-turn-off thyristors (GTO) based on voltage supply converters (VSCs) connected by a dc -link electrical condenser. An exciting electrical device connecting one VSC is organized in shunt and a boosting electrical device linking the second VSC is inserted into the conductor. By virtue of its ability to manage freely and severally 3 major parameters in power transmission viz. the road resistivity and therefore the magnitude and section of the voltage, it provides each voltage regulation and improvement in stability. Thanks to the presence of FACTS controllers in a faulted loop, the voltage and current signals at the relay purpose are going to be affected in each the steady state and therefore the transient state. This successively can have an effect on the performance of existing protection schemes, like the space relay that is one among the terribly wide used strategies in conductor protection [4], [5]. The most principle of this method is to calculate the resistivity between the relay and fault points; the apparent resistivity is then compared with the relay trip characteristic to determine whether it's an inside or external fault. A typical technique of hard this resistivity is mistreatment power frequency parts of voltage and current signals measured at the relay purpose. The paper [6] has conferred some analytical results supported the steady-state model of STATCOM, and have studied the impact of STATCOM on a distance relay at totally different load levels. In [6], the voltage-source model of FACTS controllers has been utilized to review the impact of FACTS on the tripping boundaries of distance relay. All the studies clearly show that once FACTS controllers are in a faulted loop, their voltage, and current injections can have an effect on each the steady-state and transient parts in voltage and current signals, and therefore the apparent resistivity seen by a traditional distance relay is totally different from that for a system without FACTS.

2. Unified Power Flow Controller (UPFC)
The UPFC is a device which may control at the same time all 3 parameters of line power flow (line resistivity, voltage and section angle). Such "new" FACTS device combines the options of 2 "old” FACTS devices: The Static Synchronous Compensator (STATCOM) and therefore the Static Synchronous Series Compensator (SSSC). These 2 devices are 2 Voltage supply Inverters (VSI’s) connected severally in shunt with the conductor through a shunt electrical device and serial with the conductor through a series electrical device, connected to every alternative by a typical dc link together with storage electrical condenser.

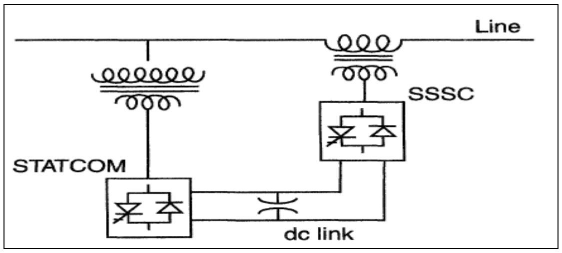

Fig 1: UPFC model diagram

The shunt electrical converter is employed for voltage regulation at the purpose of association injecting An opportune reactive power flow into the road and to balance the $64000 power flow changed between the series electrical converter and therefore the conductor. The series electrical converter is often accustomed control the $64000 And reactive line power flow inserting an opportune voltage with a governable magnitude and innovate series with the conductor. Besides, the UPFC permits a secondary however necessary perform like stability control to suppress grid oscillations rising the transient stability of the grid. because the want for versatile and quick power flow controllers, like the UPFC, is predicted to grow within the future because of the changes in the electricity markets. a mix of Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC) that are coupled via a typical dc link, to permit two-way flow of real power between the series output terminals of the SSSC and therefore the shunt output terminals of the STATCOM, and are controlled to produce coincidental real and reactive series line compensation without an external electrical energy supply. The UPFC, by means that of angularly at liberty series voltage injection, is ready to manage, at the same time or by selection, the conductor voltage, impedance, and angle or, or else, the $64000 and reactive power flow within the line. The UPFC can also offer severally governable shunt reactive compensation. The UPFC model for conductor shown in Figure (1).

3. Distance Protection for Transmission Lines

The operation of the relays mentioned up to now depended upon the magnitude of current or power within the protected circuit. However, there's another cluster of relays during which the operation is ruled by the quantitative relation of an applied voltage to current within the protected circuit. Such relays are known as distance or resistivity relays. In a resistivity relay, the torsion made by a current component is opposed by the torsion made by a voltage component. The relay can operate once the quantitative relation V/I are but a reference price. A system with fast resistivity relays, set to act on impedances but or adequate to the impedances, of a district as shown in Figure (2.3) would be tough to regulate, a fault close to the junction of 2 sections is probably going to cause the operation of 2 relays. The voltage component of the relay is happy through a possible electrical device from the road to be protected. This component of the relay is happy from current electrical device serial with the line. The road is that the protected zone. Beneath traditional operative conditions, the resistivity of the protected zone is that the relay is thus designed that it closes its contacts whenever resistivity of the protected section falls below the reference price. A distance or resistivity relay is actually A meter and operates whenever the resistivity of the protected zone falls below a reference price. There are 2 varieties of distance relay in use for defense of power provide, namely;

(i)Definite-distance relay that operates instantly for fault up to a preset distance from the relay.

(ii)Time –distance relay during which the time of operation is proportional to the space of fault from the relay purpose. A fault nearer to the relay can operate it ahead of a fault farther far away from the relay.

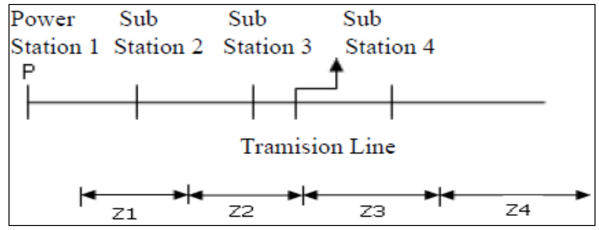

Fig 2: Distance protection of line

4. UPFC Transmission Lines Simulation Models

In ac power systems, given the insignificant electrical storage, the electrical generation and cargo should balance the least bit times. To some extent, the electrical system is self-activating. If a generation is a smaller amount than load, the voltage and frequency drop, and thereby the load, goes right down to equal the generation minus the transmission losses. However, there are solely some p.c margins for such a self-regulation. If the voltage is propped up with reactive power support, then the load can go up, and consequently, the frequency can keep dropping, and therefore the system can collapse. Alternately, if there's inadequate reactive power, the system will have voltage collapse. once an adequate generation is out there, active power flows from the excess generation areas to the deficit areas, and it flows through all parallel ways on the market which often involve additional high-voltage and medium-voltage lines. Often, long distances are attached masses and generators on the manner. Presence of an outsized range of powerful low resistivity lines on that loop. There are in truth some major and an outsized range of minor loop flows and uneven power flows in any power gear.

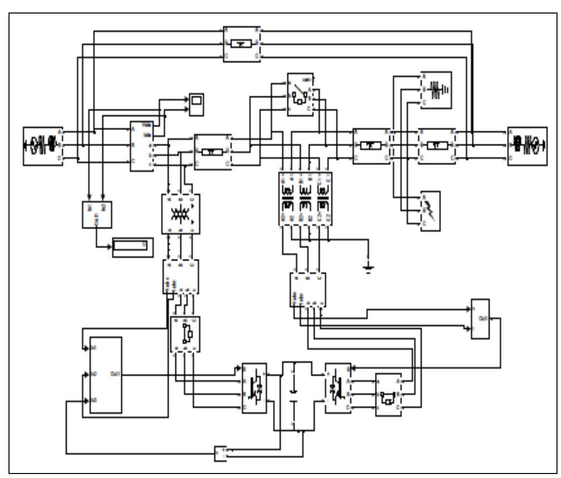

Fig 3: Simulink diagram of conductor with UPFC model

Comparing the resistivity mechanical phenomenon for a system with UPFC and without UPFC, it's apparent that the degradation in relay performance is much worse within the case of a system using the complete UPFC and as mentioned before, this is directly attributed to the generation of an outsized zero-sequence voltage part within the injected voltage. Here single section of the ground is taken into account. If this zero sequence voltage part of the injected voltage were too familiar and therefore the relaying purpose voltage was then changed, then the resistivity mechanical phenomenon shifts quite near the relay conductance unit boundary. When each the shunt and series components work along, the UPFC works as a whole device and its performance is to each regulate the facility flow within the conductor and maintain the voltage at the STATCOM connecting purpose. Once there's a phase-to-ground fault at saying one hundred fifty metric meter, the simulation results show that the zero sequence part voltage of the UPFC is way beyond the positive and negative sequence parts and this can dominate the relay purpose voltage and so incorporates a massive impact on the apparent resistivity. once one section to ground fault is on the proper facet of UPFC, i.e., at a fault distance of one hundred fifty metric meter from the relay purpose, and therefore the desired voltage, the apparent resistivity mechanical phenomenon seen by the A-ground component of the system with UPFC. From the higher than, it are often seen that each the resistance and electrical phenomenon parts of the gear apparent resistivity with UPFC are larger than for the system without UPFC, it's apparent that once the fault is on the left facet of UPFC (i.e., <100km), the apparent resistivity is seen by the space relay is sort of identity as that for the system without UPFC; but, once the fault is the proper facet of UPFC, each the apparent resistance and electrical phenomenon of the system with UPFC are larger than for the system without UPFC.

5. Results & Discussion

This section presents the results of the proposed approach wherein the Table 1 indicates the comparison of resistivity price with and without UPFC and Table 2 Comparison of resistivity changes in section to section fault. The Figure 4 shows modification of the fault position.

Table 1: Comparison of resistivity with and without UPFC

Condition	Impedance	Type of Fault
Without UPFC	0.00054	L-G Fault
With UPFC	0.04	L-G Fault

Table 2: Comparison of resistivity changes in section to section fault

Location of Faults	100km	125km	150km	175km	200km
Impedance	1	1.5	2	2.7	3.6

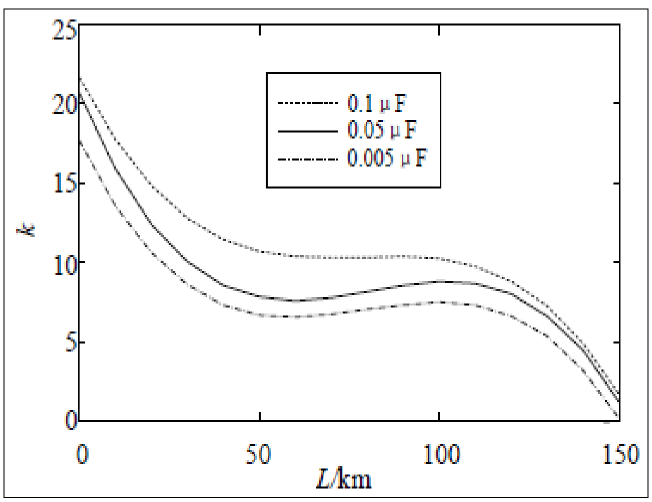

Fig 4: Modification of the fault position

6. Conclusion

This paper presents an in-depth model of a gear using UPFC. There is an advantageous effect of the presence of a UPFC on the performance of a distance relay. The simulation results show the impact of UPFC once it's operated with UPFC and without UPFC, severally, on the space relay. Significantly, the impact on the performance of a distance relay is considerably higher once the complete UPFC is operating compared to a system using solely without UPFC; this is often by the fact that within the case of the former, there's active and reactive power injected by each STATCOM and therefore the SSSC. The results conferred during this paper clearly highlight the elemental issues of protective a gear using a UPFC mistreatment distance protection.

7. Future Work

This work can be extended to identify, locate and classify faults at remote locations using distance relays and STATCOM.

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