The Academic
International Journal of Multidisciplinary Research

An Online Peer Reviewed / Refereed Journal
Volume 1 | Issue 1 | April-June 2023
Website: www.theacademic.in

Improvement of Transmission Line Efficiency using DPFC

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ARTICLE DETAILS

Research Paper

Article History

Received : April 16, 2023

Accepted : June 05, 2023

Keywords :

FACTS Devices, Unified Power Flow Controller, Distributed Power Flow Controller, DC-link.

ABSTRACT

In modern era, the increased complexity of power system causes less-efficiency, which is mainly due to inductive and varying loads in the power system. To overcome such problem various methods are normally used as: static capacitor banks, tap changing transformers, phase advancer and FACTS devices. The currently used most efficient device for power transmission is called UPFC. The device, however, has a major disadvantage of having a DC-link used as a bridge for power transfer, which in case of failure brings the power transmission to a complete halt. In this research, the overall efficiency profile of Distributed Power Flow Controller (DPFC), in high voltage transmission line is analyzed and modified. Instead of DC-link, as used in UPFC, a common point (node) is provided for the power transfer. A computer model with UPFC, DPFC and without any FACTS device in MATLAB software tool is constructed for the comparison of results. The results show that the load bus voltage, voltage regulation and power efficiency of the network with UPFC is better than that with UPFC, respectively. The outcomes of the study are expected to provide a safer, reliable and more efficient tool for high voltage transmission line.

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I. Introduction

The desire to control power system parameters for enhancing the efficiency of the system is increased. For the accomplishment of such desire, a set of FACTS devices has been developed. These devices are widely used for the enhancement of system efficiency in Europe and China [1]. Now-a-days majority of such devices are used such as: STATCOM, UPFC, SVC and SSSC to mitigate low efficiency problems [2]. Nowadays, UPFC is considered as the most effective and powerful tool to solve many problems by controlling all the parameters like voltage profile, impedance and phase angle to enhance the transmission line efficiency. In view of configuration, it is comprised of two (02) power flow controlling devices that are STATCOM and SSSC. In UPFC, as represented with the help of Figure 1, we have two (02) converters which are connected to each other with the help of a DC-link [3]. The device, however, has a major disadvantage of having a DC capacitive link, which is used as a power transfer tool, but in case of its failure, it brings the power transmission to a complete halt.

As compared to UPFC, there is no common DC-link in the DPFC as a bridge for power transfer, as represented with the help of Figure 2. It is basically consisting of one shunt and other series FACT controller. As the shunt with the entitlement of STATCOM and series with the entitlement of “Distributed Synchronous Series Compensator” (hereinafter referred to as DSSC) concept, which is actually a topology in which, multiple single-phase converters are used instead of using only one three-phase converter. Each mounted converter within the DPFC would not have to rely on any DC link as in case of UPFC [4]. So, in case of such topology there is no need to transfer the power by a common DC-link. Instead of a common DC-link, as used in UPFC, a common point (node) is provided for the power transfer in case of DPFC [5].As illustrated in the Figure 2, the precise design scheme of DPFC is elaborated as:

- HPF herein after refers to as “high pass filter” that should be connected to the terminating end of the transmission line.
- A Wye to Delta transformer on each side of the line should be mounted [1] [5].

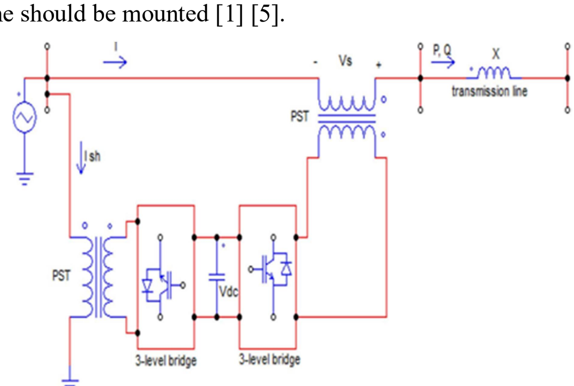

Figure 1: UPFC Configuration [3]

By the comparative analysis of the UPFC and DPFC configurations, as represented with the help of Figure 1 and Figure 2, one can easily delineate a major difference between these two controlling devices.

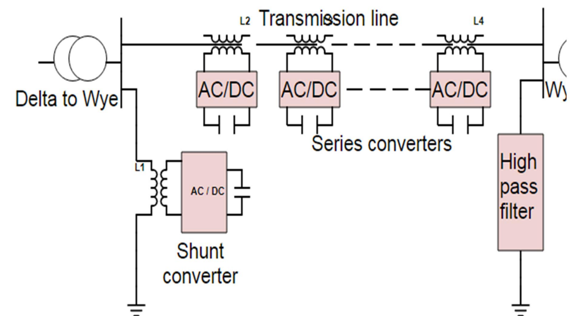

Figure 2: DPFC Configuration [5]

II. Foundation of Research Paper

The standard simple power network is opted as a foundation for the research paper, is shown with the help of Figure 3. It is comprised of three (03) buses. Moreover, one generator is connected to Bus 1 and Bus 2, therefore, during the analysis these buses are called as “Generator Buses”. The Bus 3 is connected with load, therefore during the analysis this Bus is called as “Load Bus” [3]. It is to be noted that in the given network, the power demand of only one load is fulfilled with the help of two generators; therefore the power efficiency of the system even without any FACTS device is quite considerable.

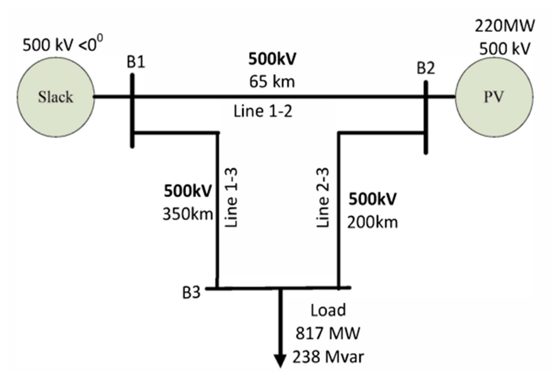

Figure 3: Standard IEEE 3-Bus System.

III. Method of Analysis and Results

As, it has been discussed, that a computer model with UPFC, DPFC and without any FACTS device in MATLAB-Simulink is constructed for the comparison of results. The detail about the different power systems made in the MATLAB Simulink is delineated in the following lines:

A. Simulation model of the network

The case study has been made in software known as MATLAB Simulink for theoretical study. The way is made is well explained with the help of the Figure 4. To obtain the same results RLC parameters has been calculated according to the parameters of transmission line. The ode45 has been chosen as a solver in MATLAB Simulink. To instigate load flow BUS 1 is made as swing, BUS 2 as PV and BUS 3 as constant PQ.

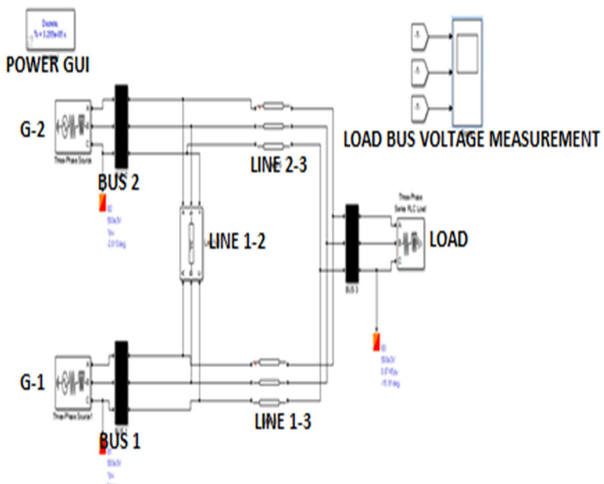

Figure 4: Simulink model of the network without UPFC.

A. analysis of the network

The results obtained from the simulation model are represented with the help of Figure 5 and Table 1. It is analyzed that the “Load Bus” (B3) voltage is dropped to “0.87 p.u”, which clearly indicates considerable voltage drop scenario, and the value of voltage regulation in percentage is 14.9 %.

As, the base voltage is selected as 500 kV, so the value of the Load Bus (B3) voltage in Volt will be 435 kV. Thus, 65 kV of voltage level has been reduced from sending to receiving end. This is a major drawback in the network, so there is a need to incorporate a FACTS device into the network.

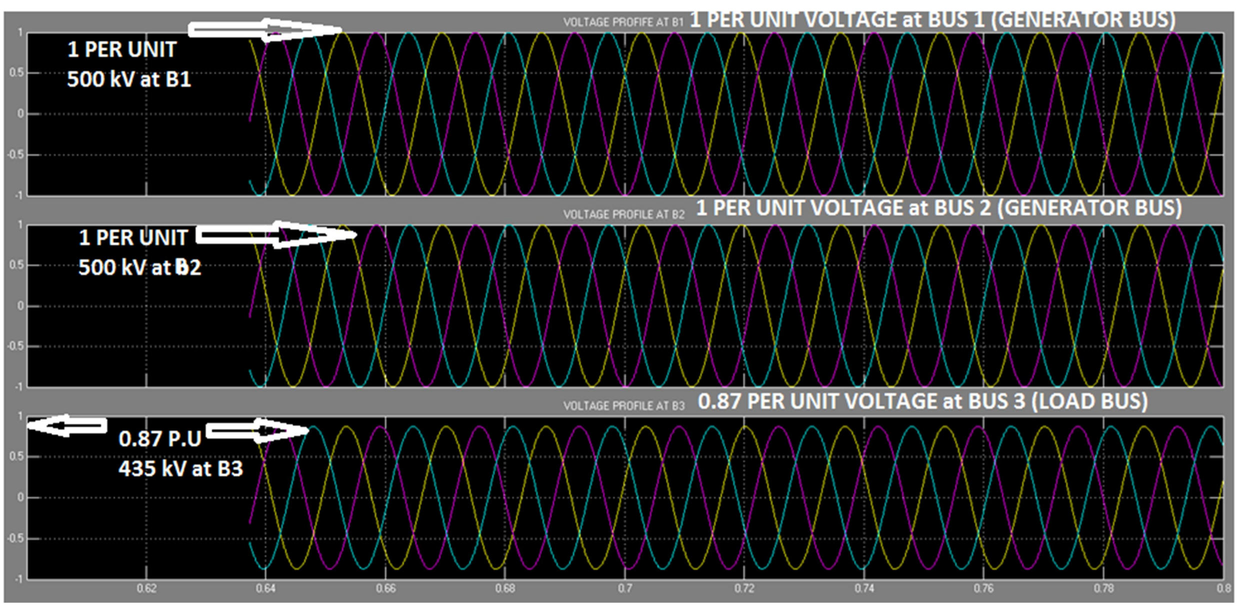

Figure 5: Voltage profile of Buses without any FACTS device.

BUSES	Generator Bus B1	Generator Bus B2	Load Bus B3
Measured Voltage (p.u)	1	1	0.87
Measured Voltage (kV)	500	500	435
Voltage regulation (%)	0	0	14.9

Table 1: Voltage profile and voltage regulation of the network without any FACTS device.

B. Simulation model of the network with UPFC

As, by the analysis of Table 1, it is clear that an under voltage problem has been occurred at Load Bus (B3). So, to overcome this problem, a device UPFC is incorporated into the system, for the improvement of transmission efficiency. The MATLAB Simulink model of the power network with UPFC is illustrated with the help of Figure 6.

Figure 7: Voltage profile of Buses with UPFC

B. Analysis of the network with UPFC

The results obtained from the simulation model are represented with the help of Figure 7 and Table 2. By the incorporation of UPFC the load bus voltage has been increased from" 0.87 p.u" to "0.91 p.u" and voltage regulation has reached to 9.9 %.

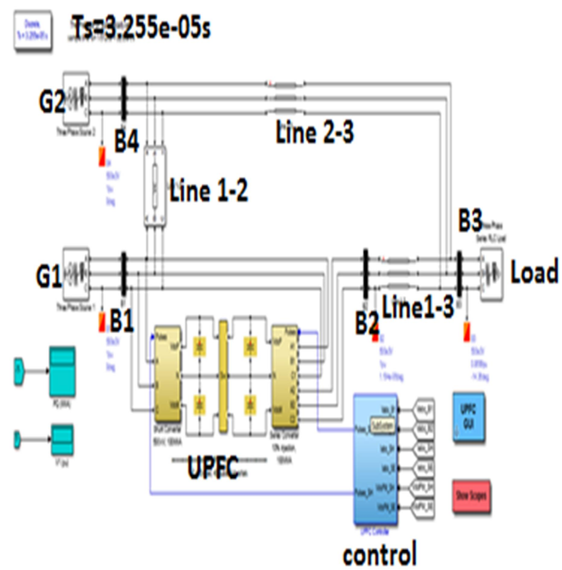

Figure 7: Simulink model of the network with UPFC.

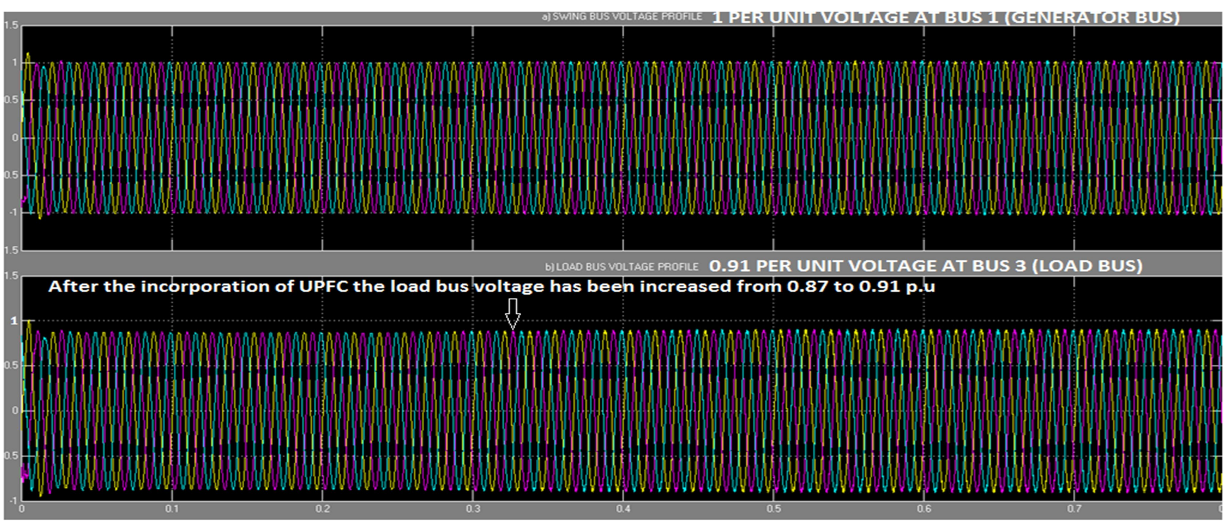

Figure 6: Voltage profile of Buses with UPFC

BUSES	Generator Bus B1	Generator Bus B2	Load Bus B3
Measured Voltage (p.u)	1	1	0.91
Measured Voltage (kV)	500	500	455
Voltage regulation (%)	0	0	9.9

Table 2: Voltage profile and voltage regulation of the network with UPFC.

C. Simulation model of the network with DPFC

The MATLAB Simulink model of the power network with DPFC is illustrated in the Figure 8.

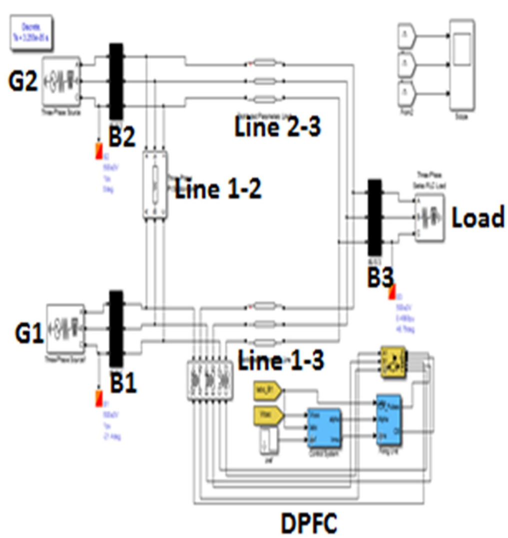

Figure 8: Simulink model of the network with DPFC.

C. Analysis of the network with DPFC

The results obtained from the simulation model are represented with the help of Figure 9 and Table 3. By the incorporation of DPFC the load bus voltage has been further increased from "0.91 p.u to 0.97 p.u" and voltage regulation has reached to 3.09 %.

BUSES	Generator Bus B1	Generator Bus B2	Load Bus B3
Measured Voltage (p.u)	1	1	0.97
Measured Voltage (kV)	500	500	485
Voltage regulation (%)	0	0	3.09

Table 3: Voltage profile and voltage regulation of the network with DPFC.

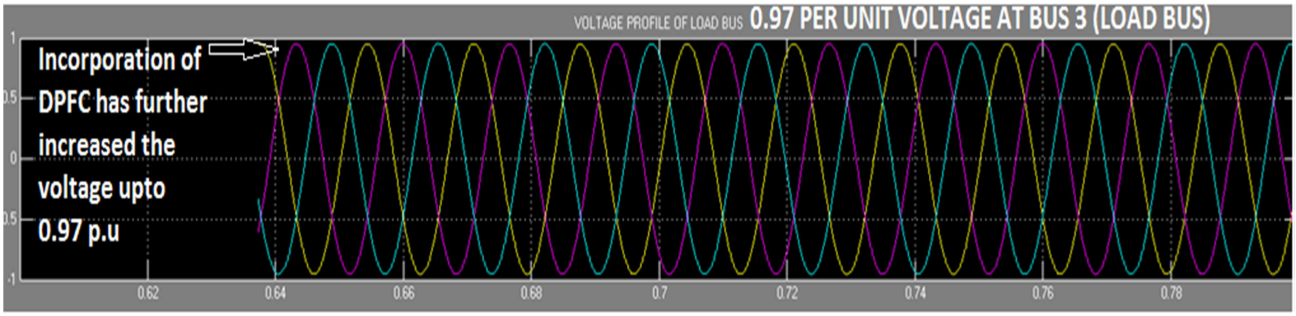

Figure 9: Voltage profile of Buses with DPFC

IV. Calculation of Power Efficiency:

To calculate the power efficiency for a given network following formula is used:

$$\eta = \frac{S_{TOTAL} - S_{LOSS}}{S_{TOTAL}}$$

Where,

$S_{LOSS} = S_1 + S_2 - S_3$

And,

$S_i = V_i$ conjugate $(Y_{i1}V_1 + Y_{i2}V_2 + Y_{i3}V_3)$

The power efficiency of the network with UPFC will be as:

$$\eta = \frac{S_{TOTAL} - S_{LOSS}}{S_{TOTAL}} = \frac{1-0.1021}{1} = 89.8\%$$

The power efficiency of the network with DPFC will be

$$\eta = \frac{S_{TOTAL} - S_{LOSS}}{S_{TOTAL}} = \frac{1-0.1021}{1} = 89.9\%$$

Simulink model description	Without any FACTS	With UPFC	With DPFC
Power efficiency (%)	89.7	89.8	89.9

Table 4: Comparison of power efficiencies.

For convenience purpose, all the quantities are converted into per unit by selecting base power as 100 MVA.

So, the power efficiency of the network will be as:

$$\eta = \frac{S_{TOTAL} - S_{LOSS}}{S_{TOTAL}} = \frac{1-0.1029}{1} = 89.7\%$$

V. COMPARISON OF RESULTS:

Comparison of Load Bus (B3) voltage, voltage regulation (VR) and power efficiency for all the three models may be well explained with the help of Table 5, Chart 1, Chart 2 and Chart 3

Simulink model description	Without any FACTS	With UPFC	With DPFC
Measured load-bus Voltage (p.u)	0.87	0.91	0.97
Voltage regulation (%)	14.9	9.9	3.09
Power efficiency (%)	89.7	89.8	89.9

Table 5: Comparison of results

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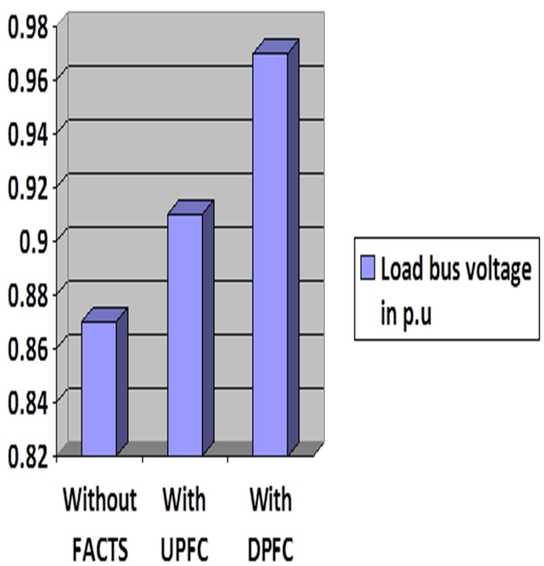

Chart 1: Comparison of load bus voltages in per unit.

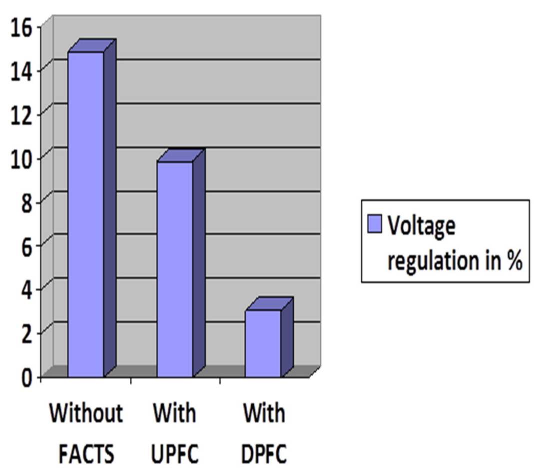

Chart 2: Comparison of load bus voltage regulations in percentage.

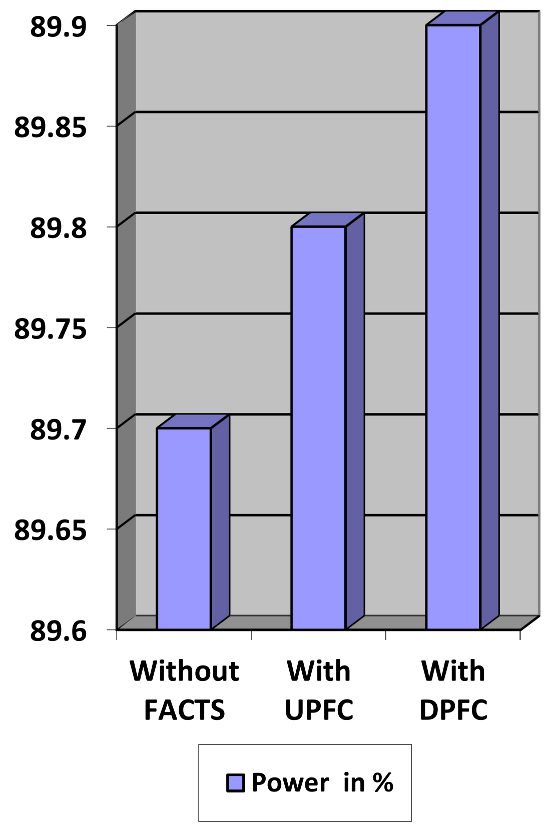

Chart 3: Comparison of power efficiencies

VI. CONCLUSION

Eventually, by the comparative analysis it has been justified that the voltage regulation and power efficiency of the network with UPFC is 0.91 p.u (per unit), 9.9 and 89.8%, respectively. Moreover, the load bus voltage, voltage regulation and power efficiency of the network with DPFC is 0.97 p.u (per unit), 3.09 and 89.9%, respectively. So, with the comparison of results it is concluded that the load bus voltage efficiency, voltage regulation and power efficiency performance of DPFC is 6.59%, 6.81% and 0.1% better than that with UPFC, respectively. The outcomes of the study are expected to provide a safer, reliable and more efficient tool for high voltage transmission line.

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