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Active Power Control during Contingency using UPFC

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Abstract

The ability of FACTs devices to control phase angle, bus voltages and line impedance in transmission line is what make it capable of controlling power flow. In this paper, we have studied one of most effective FACTS device known as UPFC. Analysis under the contingency is done using 10 bus system and contingency condition is being introduced in three-phase, delta-delta connected transformer i.e. one base is damaged or accidently opened. Now, it got changed to open delta connection. The open delta transformer still continues to operate as a three-phase bank with decreased rating. The rating of three phase bank then becomes 57.7% of that of actual bank. But power which was flowing earlier through the original transformer bank is much above the new rating of the transformer, which could damage three phase transformer and eventually make system unstable. So, to solve this problem we introduced Unified power flow controller (UPFC) in the system. UPFC controls the power at all buses in power system and keeps power under normal level. After simulating the system with and without UPFC, it clearly showed the effect in form of power reduction below new rating. UPFC regulated the power not only in the area where it was connected but in the whole power system.

Keywords: FACTS, Simulation, UPFC (Unified Power Flow Controller), Contingency Condition, Transformer, MATLAB

INTRODUCTION

Today, we have profoundly complex and interconnected power systems and there is a need to advance power utilization along with keeping reliability and stability. The problem of degradation of voltage profile occurs due to overload in some of the lines, which affects the overall voltage profile and this in turn affects the stability of the system. Due to these problems of overloading and stability, it is required to control the power flow for stabilizing the system and to handle the above problem power electronics based device is used such as FACTs [1, 2].

As we know that sending end voltage, receiving end voltage, line impedance, and phase angle between receiving and sending end voltages mainly affects the flow of power in transmission line. So, real and reactive power can be controlled by controlling one or more power flow arrangements. FACTs devices such as SVC, STATCOM, SSSC and UPFC i.e. unified power flow controller etc., phase angle, receiving and sending end voltages and line impedance of system can be controlled quickly using above FACTs. Above FACTs device are voltage source converter based and these FACTs devices helps in improving stability, power flow of system, reducing cost of generation, power transfer capacity and improving security of system [3].

Flexible AC Transmission System (FACTS) are very reliable and helps in finding the solution. FACTs devices gives a good solution to the rising demand of power flow control and system

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instability caused by it. To get the solution to the problem, we have used unified power flow controller (UPFC), which is the combination of two FACTs devices namely STATCOM i.e. static synchronous compensator and SSSC i.e. static series synchronous compensator). The STATCOM is shunt converter which helps to fulfill reactive and active power requirement of the system. SSSC helps in controlling the magnitude of voltage and also phase angle in series to line. There are two methods by which we can compensate the reactive power i.e. by receiving end voltage control or by dipping reactance of the line. UPFC is connected for controlling voltage and control the power flow (active power along with reactive power) in transmission line. To know the line in which UPFC is to be inserted and its effect, we do MATLAB simulation. For this paper we have used 10 bus system and simulated it using MATLAB Simulink. A contingency condition is simulated in one of the transformer and power at all buses is observed in case of contingency and then UPFC is introduced in power system and its effect observed on power system [4].

UPFC

One of the majorly used Flexible Alternating Current Transmission System (FACTS) devices is UPFC (Unified Power Flow Control) which belongs to the family of power electronics-based devices that enable enhanced system controllability and the stability thereby improving power transfer capability of the entire system. The UPFC is made up two devices namely STATCOM (Static Synchronous Compensator) and SSSC (static synchronouss series compensator). These two devices are coupled via a common DC voltage link [5].

OPERATION OF UPFC

Among the various FACTS controller devices, the UPFC has all the capabilities of phase shifting, series compensation, voltage regulation. It has the ability of controlling the real and reactive power flows in the transmission without any dependence on any external devices. The configuration comprises of two voltage source converters coupled through a common dc terminal (Figure 1) [6, 7].

- The Voltage Source Converter 1 through a coupling transformer is connected in shunt with the line.
- The VSC 2 through an interface transformer is placed in series with the transmission line.
- The common capacitor bank acts as a bank for providing dc voltage to both the converters.
- The VSC series is designed to inject Vpq in series with the line, ranging from 0 to Vpq max.
- The Vpq phase angle may be adjusted between 0 and 360 degrees.
- The VSC in series with the transmission line exchanges actual and reactive power.
- The dc storage device, such as a capacitor, generates or absorbs the actual power. VSC in series generates or absorbs reactive power internally.

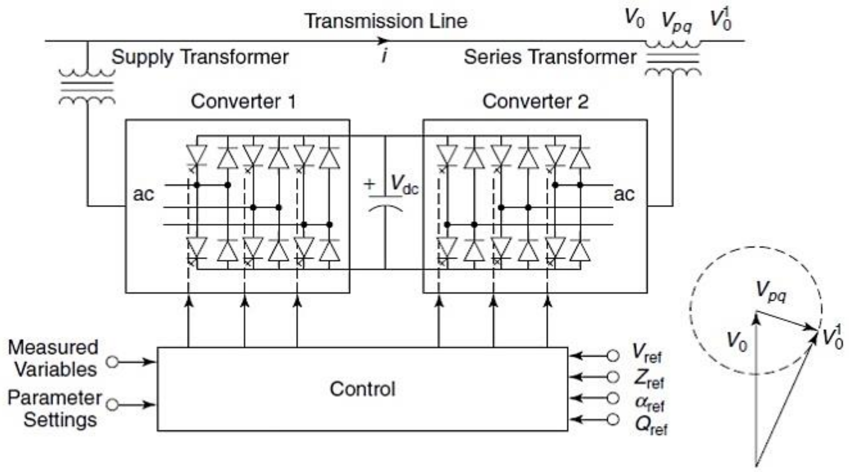

Figure 1. Operation of UPFC.

- The shunt VSC supplies the real power demand to the series VSC, which is obtained from the transmission line. It basically maintains constant voltage.
- As a result, the true power drawn in an AC system is equal to the loss of the converters and transformers combined.
- By creating or absorbing a certain quantity of reactive power, the shunt VSC adjusts the bus's terminal voltage [8, 9].

CONTINGENCY STATE OF TRANSFORMER

Contingency in a power system is when element of system fails e.g. generator, substation, transmission line, transformer and for this, contingency analysis is done using computer model of grid to understand the effect of element failing. this analysis is required to find ways to maintain the power system operation even when one or more element fail and its aim is to recognize overload and difficulties that can happen due to contingency [10].

In this case, one phase of a 3-phase delta–delta connected transformer is damaged or accidently opened, the transformer, however, continues to function as a three-phase bank with a lower rating (Figure 2). The open delta or V-V delta connection is what it's called. The transformer bank's rating is decreased to 58 percent of the actual bank. In the Power System, the power transmitted through the transformer is above the rating of the transformer during contingency which can damage the transformer and cause a failure in the power system [11].

SIMULATION MODEL

We have made efforts to study the effect of UPFC on active power of a Power System. In this model we have analyzed a 10 bus system with and without UPFC (Simulink model without UPFC is shown in Figure 3 and with UPFC is shown in Figure 4). These buses are connected through transmission lines and four transformer banks and a UPFC is installed between transformer 1 and 2. In ordinary conditions, 1200 MW active power is being transmitted to the load. During contingency, one phase of the transformer is faulty so the capacity of transformer is reduced to 800 MW but more than 800 MW power is transmitted through bus 4 which can damage the equipments. So, we have used UPFC to limit the excess power through all buses and regulate its flow [12].

SIMULATION RESULTS

Simulation results are shown in Figures 5–9 the effect of UPFC on system shown in Table 1.

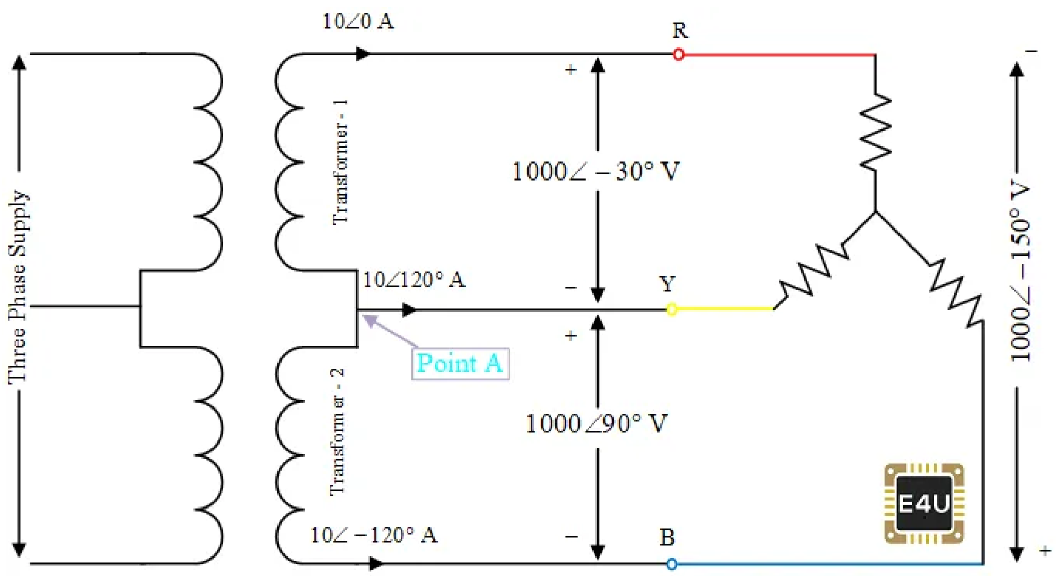

Figure 2. Connection diagram of Open Delta Transformer.

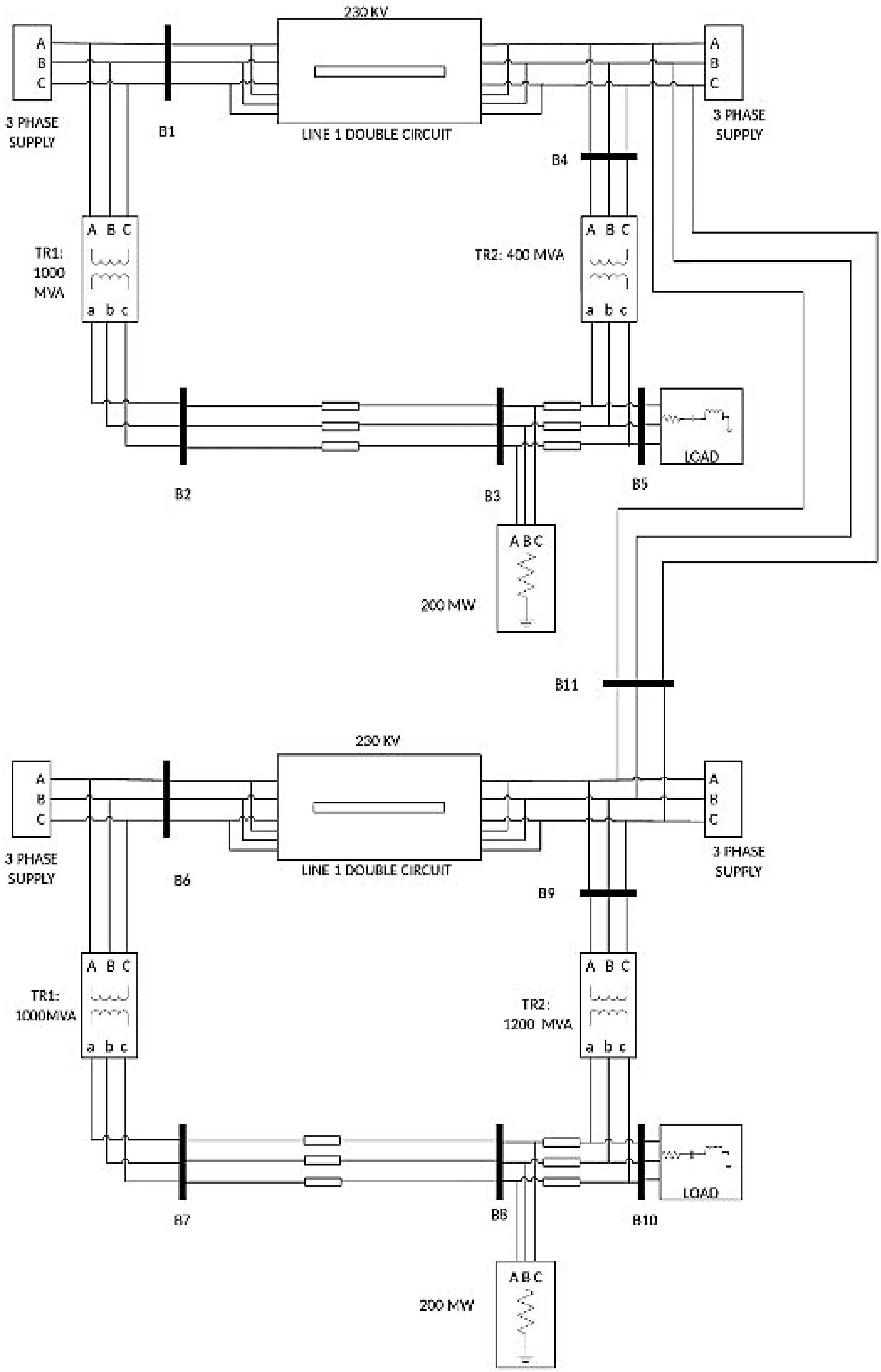

Figure 3. Simulation Model without UPFC.

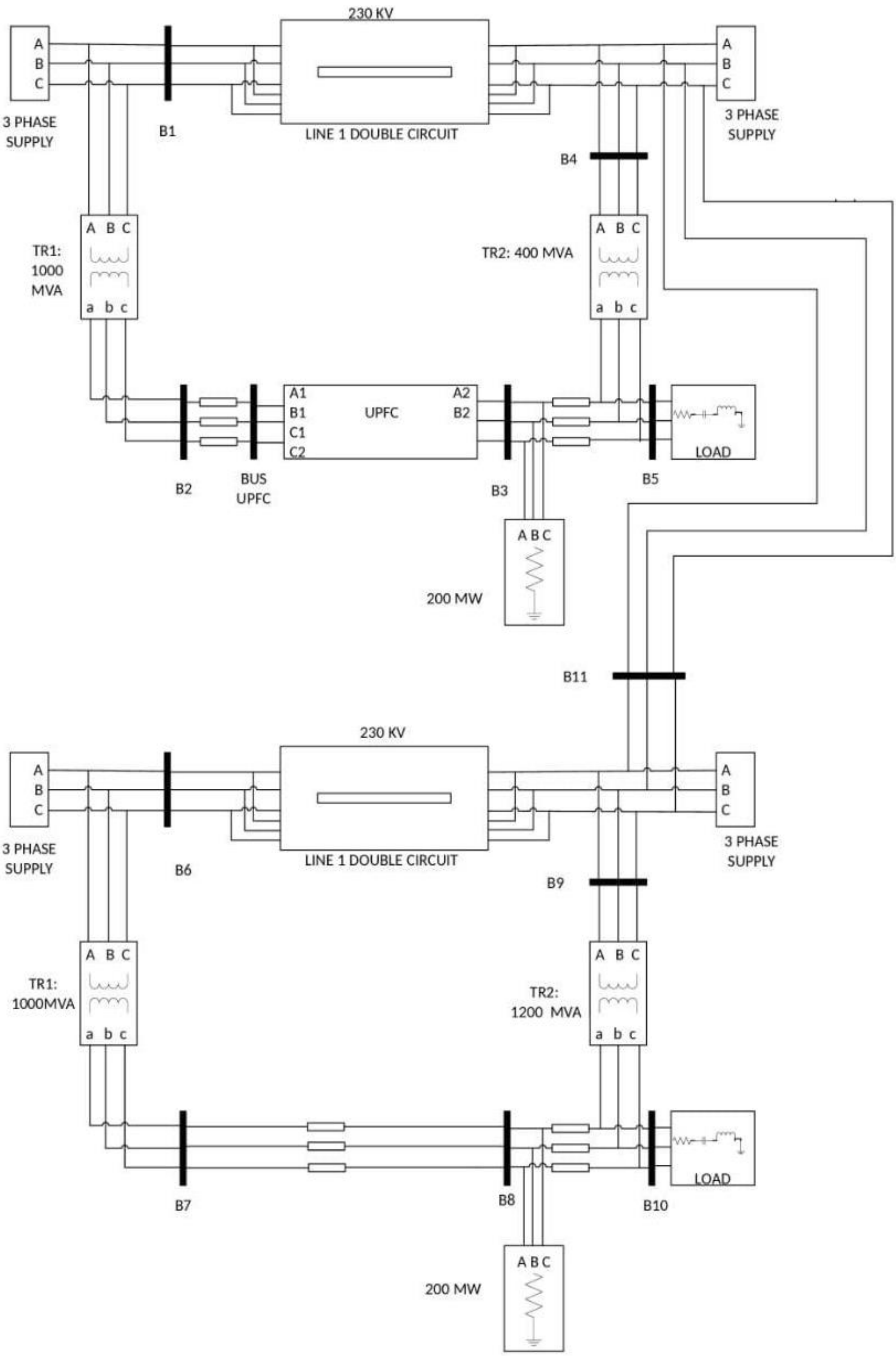

Figure 4. Simulation model with UPFC.

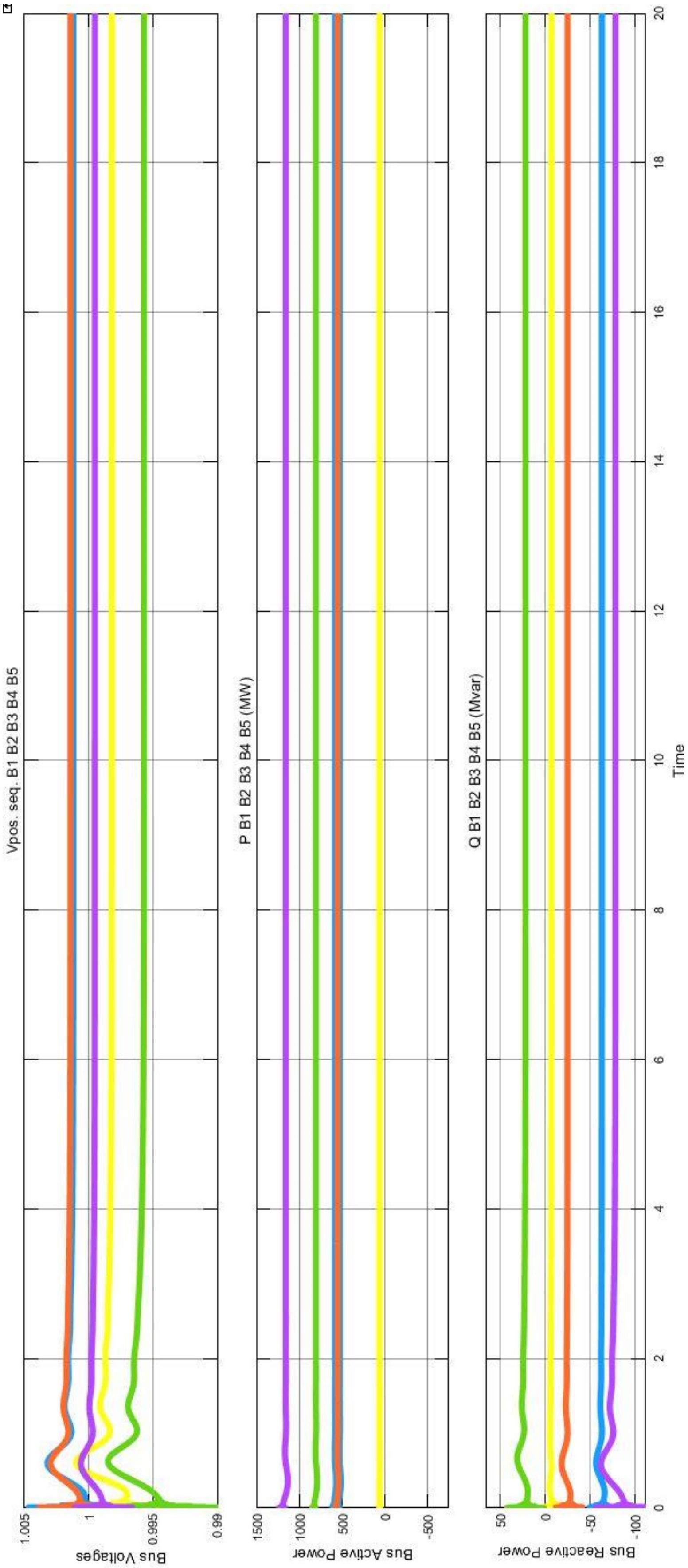

Figure 5. Area 1 VPQ Waveforms without UPFC.

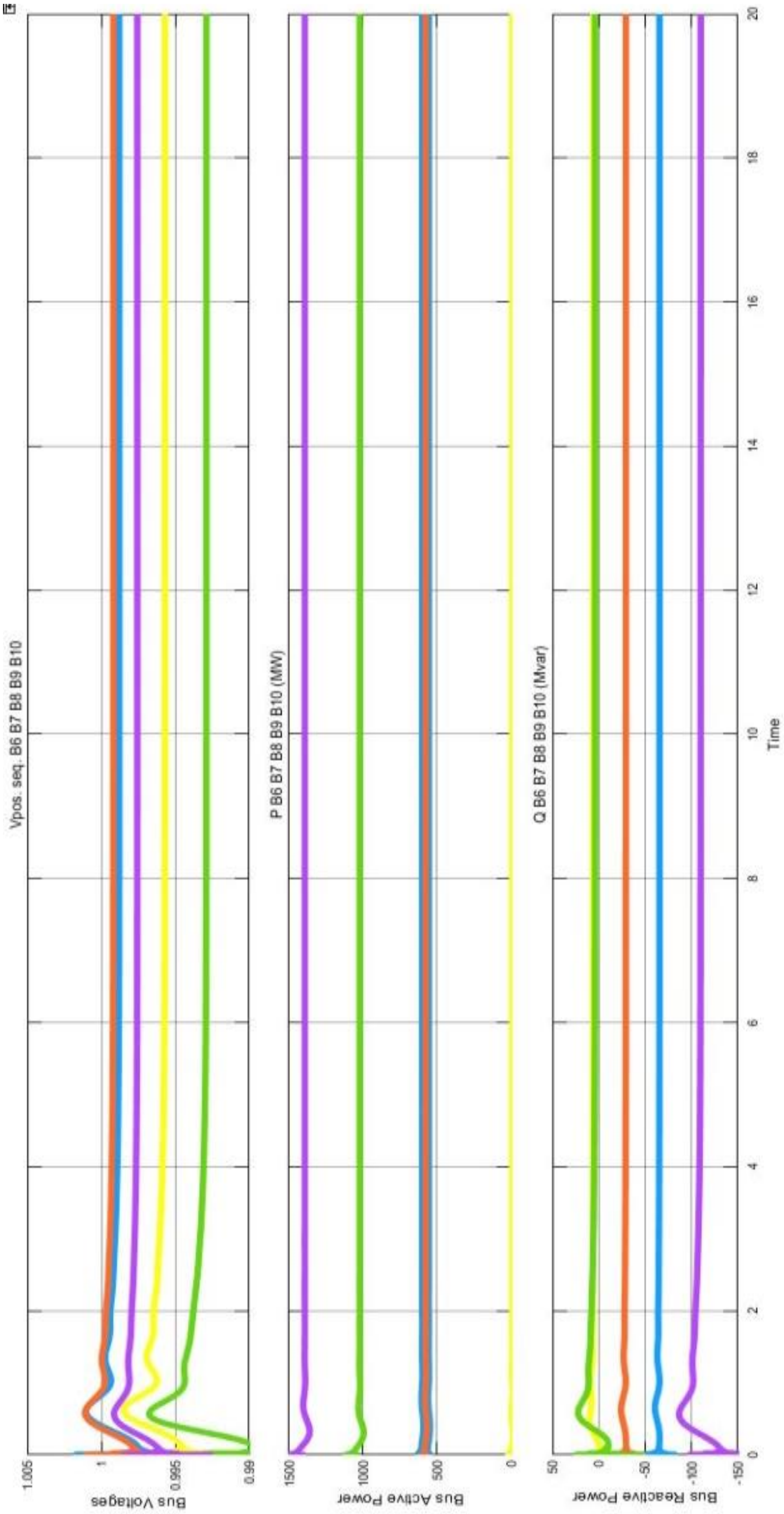

Figure 6. Area 2 VPQ Waveforms without UPFC.

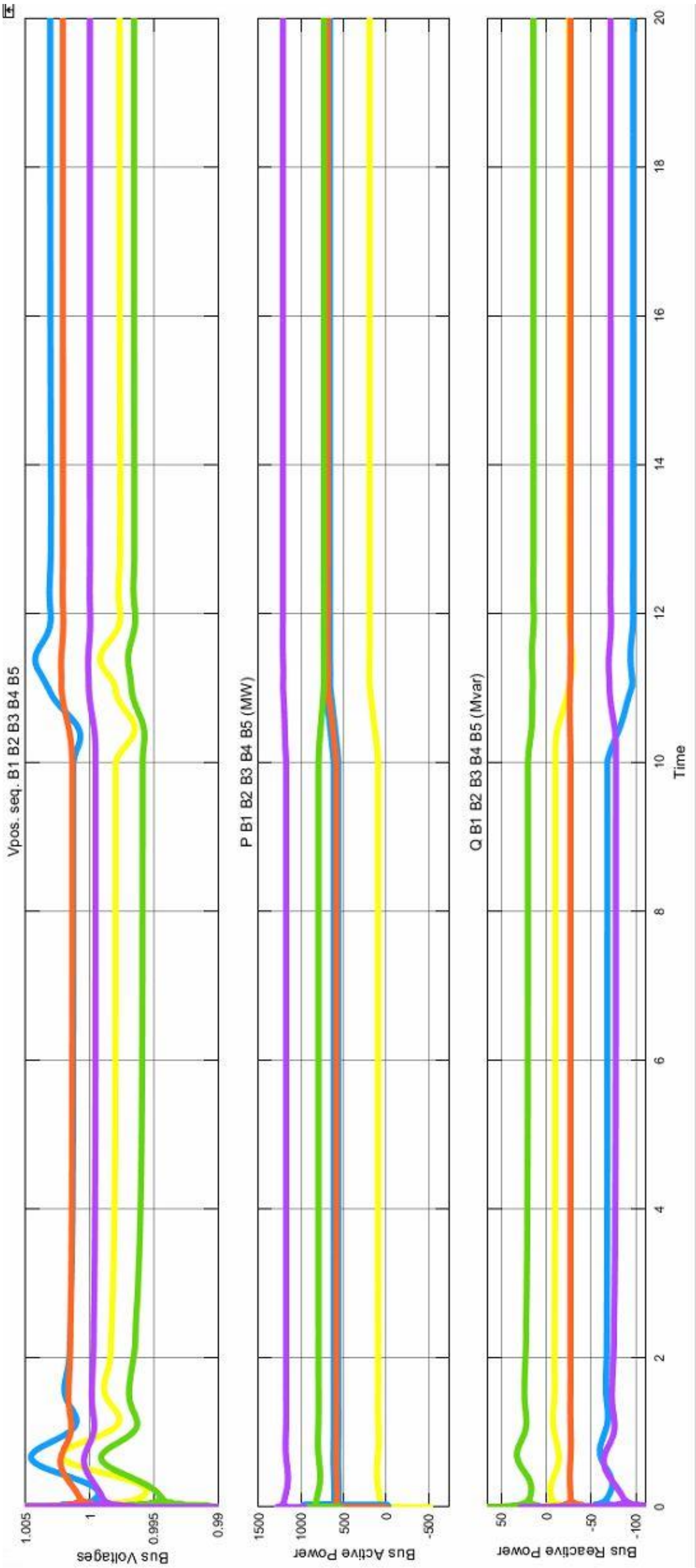

Figure 7. Area 1 VPQ Waveforms with UPFC.

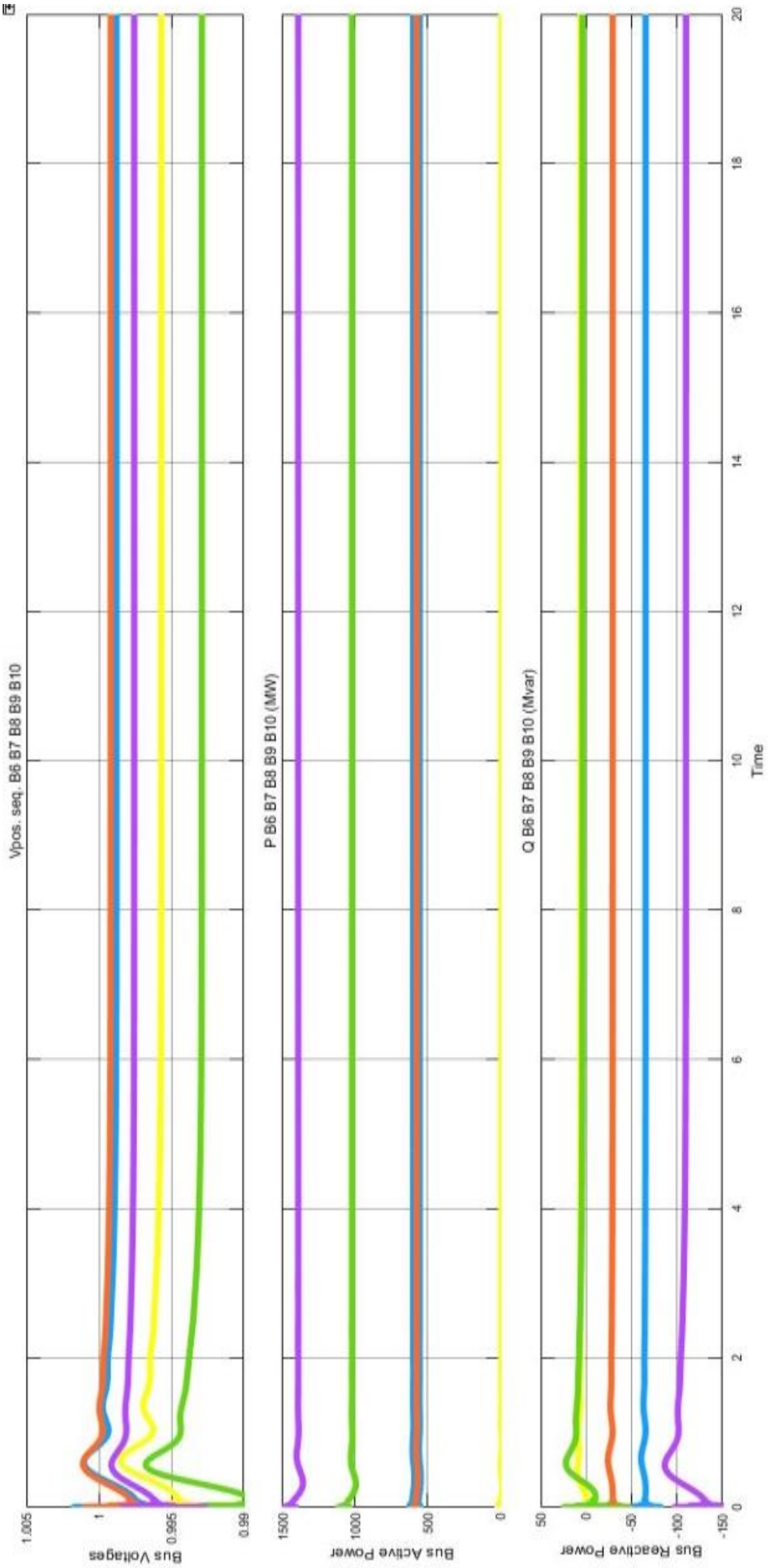

Figure 8. Area 2 VPQ Waveforms with UPFC.

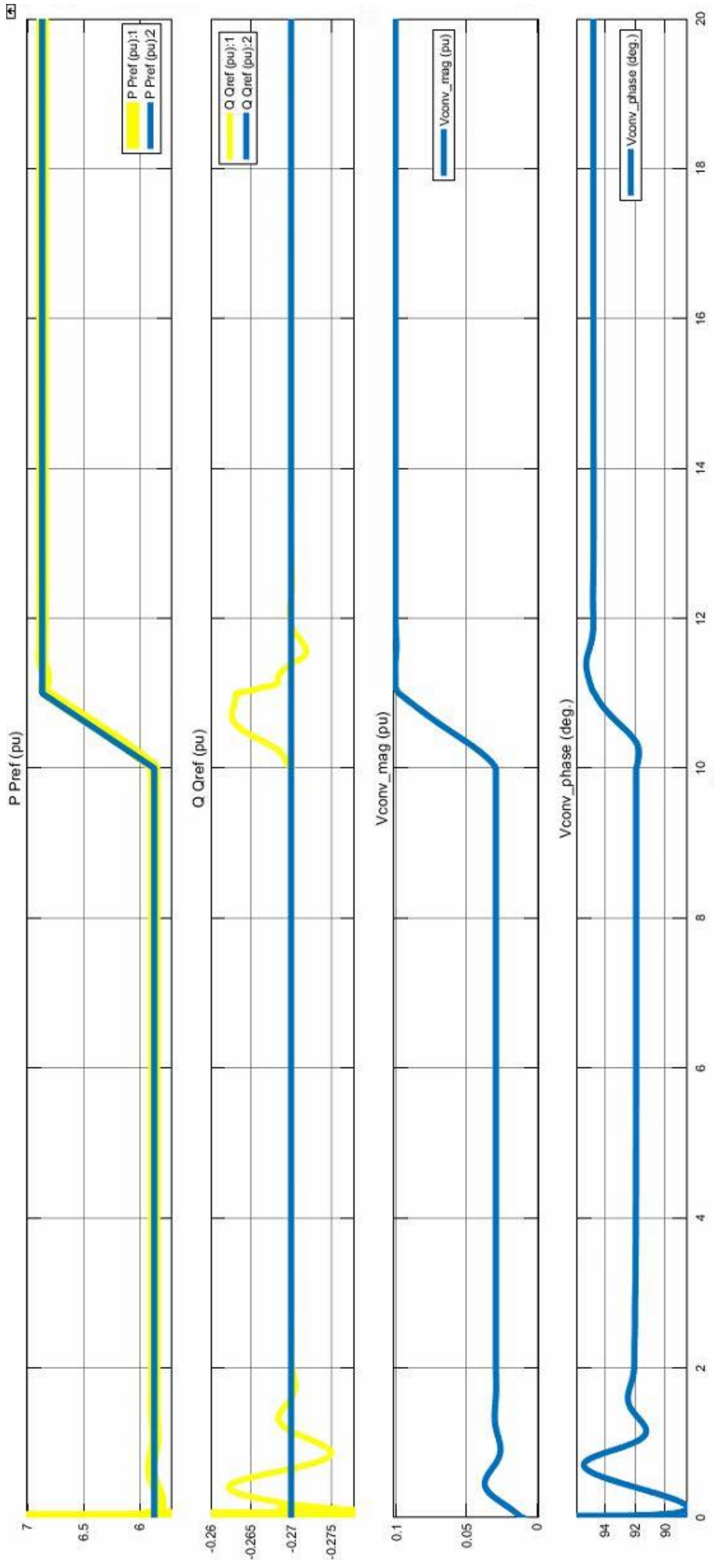

Figure 9. UPFC Box Area 1.

Table 1. Power transfer capability of the system with or without UPFC.

Buses	Active Power without UPFC (MW)	Active Power with UPFC (MW)
B1	66.82	196.3
B2	560.6	689.4
B3	559	686.7
B4	813.3	680
B5	1166	1214
B6	28.84	9.592
B7	578.8	546.9
B8	577.1	545.4
B9	1023	1004
B10	1394	1343

CONCLUSION

We have observed from the Simulink results and observations that the power transfer capability of the system has been improved with the use of UPFC and active power on all buses of the system has been controlled and brought within the maximum capability of system. Also, the UPFC provided in one area can help in achieving active power control in other connected areas as well. For this reason, UPFC is a true alternative to standard strategies used and it can be effortlessly included in present systems. Also, it is cost effective than most of traditional alternatives of transmission line reinforcements in long term.

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