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Enhancement of Power Quality of System Network Using Interline Power Flow Controller

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***Abstract*— Flexible AC transmission systems (FACTS) are a promising technology for improving the performance of power systems due to the rapid development of power electronic technology. This paper investigates the performance of IPFC, the latest Facts device, in multiline transmission system. IPFC is a flexible and dynamic controller and can adjust several parameters, such as active and reactive power, current, series impedances, line voltages, and current. The IPFC system proposed in this research work consists of two back-to-back VSC connected in series with the transmission lines. Inverter and converter circuits were designed by using IGBTs. IPFC effectively maintains voltages of transmission lines by compensating reactive power in case when line gets heavily loaded. Simulation model and hardware of proposed system have demonstrated the usefulness of IPFC on transmission line models.**

***Index Terms*— — Facts Devices, IPFC, SSSC, VSC**

I. INTRODUCTION

Coordination between demand and generation is essential in a power system. The need for electricity is growing every day. All the components must be running at full capacity to meet this requirement. Widespread failures are common in power system networks. As demand for the current power transmission infrastructure rises, the operation of the power system network becomes more challenging and less secure.

One of the phenomena that led to a major blackout was voltage instability. The issue of voltage stability and voltage collapse has also emerged as a key concern in the design and operation of deregulated power systems because many of the old transmission lines could not keep up with the rising demand for electricity. [1,2]

Earlier, these issues were resolved by connecting a capacitor, reactor, or synchronous generator with the aid of mechanical switches. This enhanced the transmission line's capacity for power transfer and improved the voltage stability, transient stability, voltage regulation, reliability, and thermal limits of the transmission network. However, employing mechanical switches has a lot of drawbacks. The mechanical switches must contend with wear and tear, and it responds slowly. To

improve the controllability and stability of the transmission line, these solutions are therefore unreliable.

Flexible AC transmission systems (FACTS) are a promising technology for improving the performance of power systems due to the rapid development of power electronic technology. [3,4]

For most effective power flow control, a new kind of inverter-based FACTS controller called the Interline Power Flow Controller is used. The IPFC likewise uses voltage-sourced converters connected [5]

back-to-back via a shared DC link, just as the STATCOM, SSSC, and UPFC [6,7]. The IPFC may control power flow for the compensation of many

transmission lines, in contrast to all FACTS devices, which are designed to compensate a single transmission line.[8] The IPFC is focused on addressing the overload issue and has two converters equipped through a series transformer to balance out two lines that extend from the same bus. [9,10]

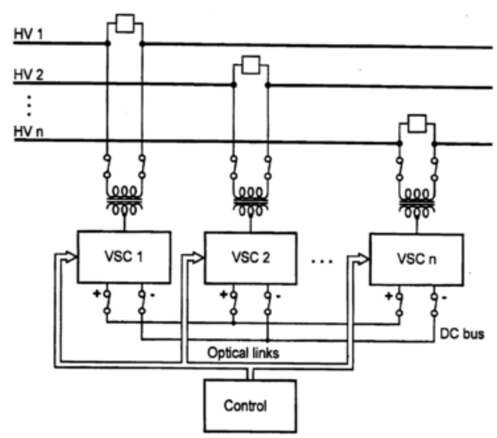

Fig 1: Basic circuit diagram of IPFC

II. METHODLOGY

The system proposed in this research can maintain voltage stability of transmission line when different loads are connected to the system. initially a single-phase transmission line model 1 was developed with two loads and the voltages stability was analyzed at different loads connected to transmission line i.e. firstly load 1 was connected with line and efficiency of the transmission line was observed after that when load 2 was connected voltages become unstable at that instant across loads. Then transmission line model 2 was developed which was working at its maximum capacity

The controller was designed which integrated with conventional models of transmission line. At the instant when loads are connected to the line model 1 and voltages become unstable, the controller makes the system stable by injecting voltages into the unstable system.

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A series controller known as a static synchronous series compensator (SSSC) is connected in series with the transmission line1through a series transformer, and another SSSC controller is connected in series with the transmission line 2 through a series transformer. A common dc link capacitor connects these two voltage source converters (VSCs) back-to-back.[12] The major job of converter 2 is to supply or absorb the active power needed by converter 1 through a shared dc link. It also controls the reactive power of the bus separately. By adjusting the voltage's magnitude and phase angle, converter 2 injects a variable magnitude voltage.
In this system line model 1 is the master line and line model 2 is considered as slave line. Power will be delivered from line model 2 to line model 1. A master converter system capable of controlling Line 1 impedances. The dc-link voltage of the voltage source converter is controlled at a specified level by a slave converter system.

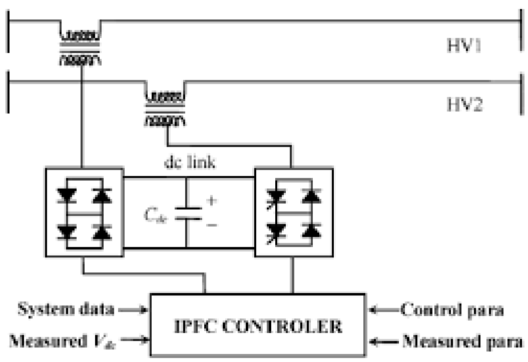

Fig 2: IPFC installed in power system.

III. SIMULATION OF LINE MODEL WITHOUT IPFC

To observe the performance of the transmission line under abnormal conditions, single-phase AC transmission lines of 230 volts are built in the MATLAB Simulink. The 230 V transmission voltages from the grid station or power station were utilized. Due to safety reasons low voltage transmission lines were built. It consists of 230V of supply, RL branch, RL load, circuit breakers, and a meter for measuring current, voltage, active power, and reactive power on the transmission line. The circuit breaker operates at t=0.3sec and connects the extra load in the system as shown in figure.

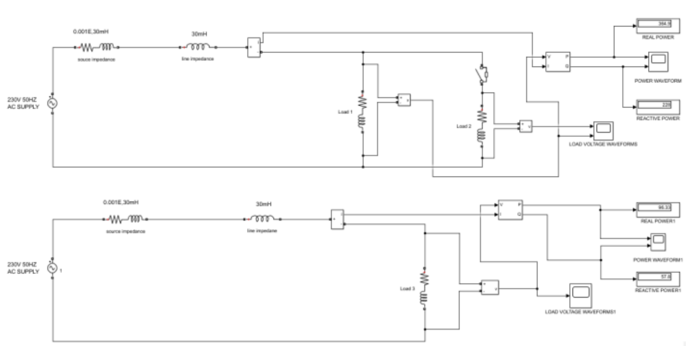

Fig 3: Models of Transmission Line

The above figure shows the transmission line 1 or master line without the Interline Power Flow Controller. The Load 1 on first transmission line is initially connected and running fine but as the load 2 is connected which is known as heavy load change the whole situation and suddenly the whole transmission line is overloaded in result the voltage profile is disturbed while the power factor is lowered, and line losses are increased.
The transmission line 2 or the slave line has no effect when the IPFC is not in the system because the loads are constant or have no change.

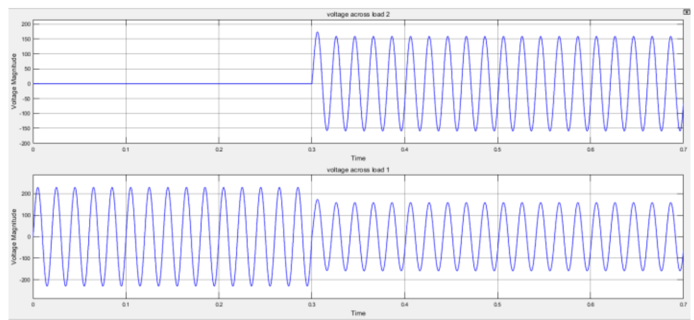

Fig 4: Voltages across loads of uncompensated master line in case of overloading.

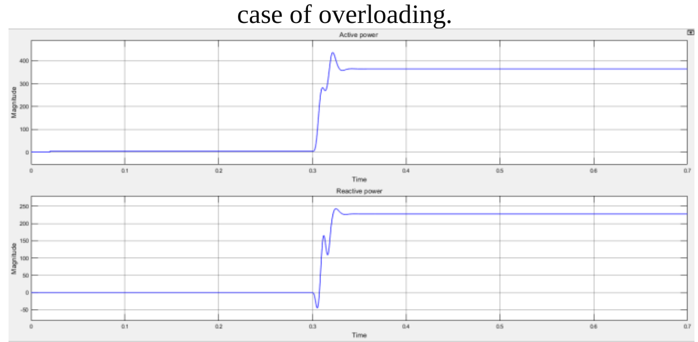

Fig 5: Active & Reactive power of uncompensated transmission line (master line).

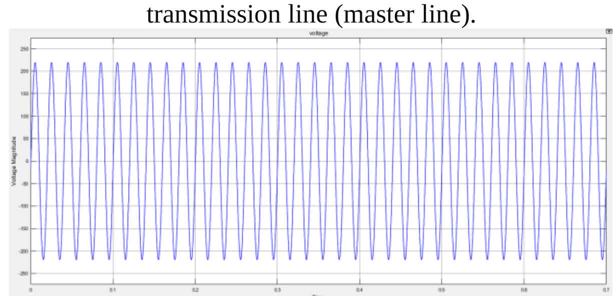

Fig 6: Voltages across the transmission line model 2 (slave line).

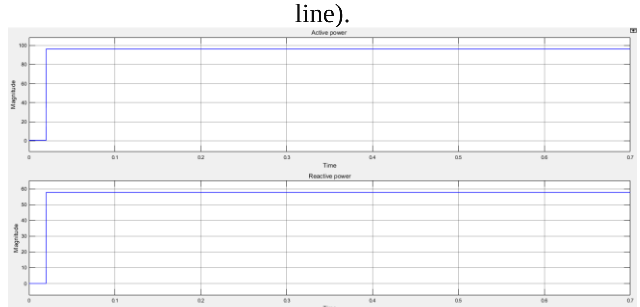

Fig 7: Active & reactive power of slave line

IV. SIMULATION OF LINE MODEL WITH IPFC

IPFC is built utilizing two voltage source converters that use IGBTs and are interconnected by a 220uf dc link capacitor. The transistors (IGBT) are triggered by a pulse generator. For the pure sinusoidal wave, the RL filter is utilized at the inverter's output as shown in figure 8.

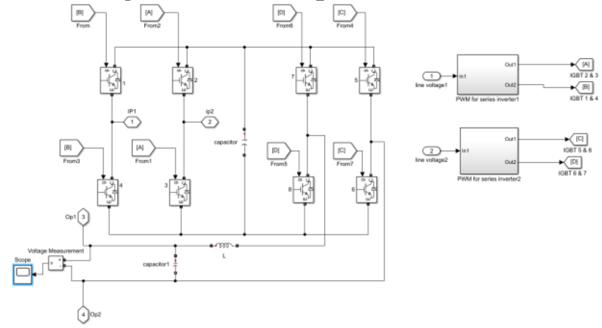

Fig 8: Rectifier inverter system

To observe the performance of the IPFC connected to the transmission line under abnormal conditions, single-phase AC transmission lines of 230 volts were built in the MATLAB Simulink. The 230v transmission voltages from the grid station or power station were utilized. Due to safety reasons low voltage transmission lines were built.

It consists of 230V of supply, RL branch, RL load, circuit breakers, and a meter for measuring current, voltage, active power, and reactive power on the transmission line. The circuit breaker operates at t=0.3sec and connects the extra load in the system as shown in figure 9 below.

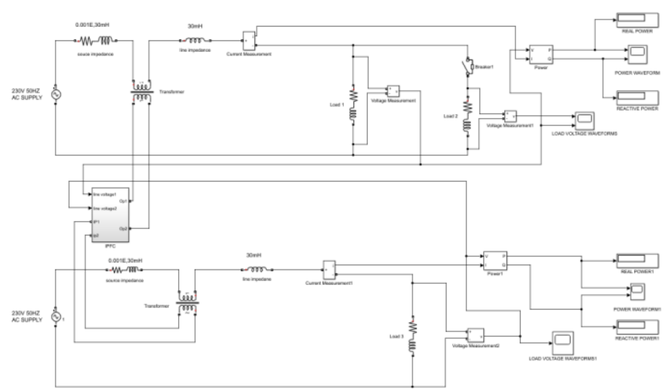

Fig 9: Transmission line models with IPFC

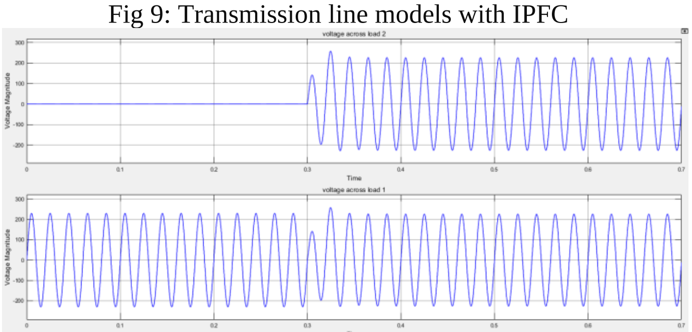

Fig 10: Voltages across loads of compensated master line in case of overloading.

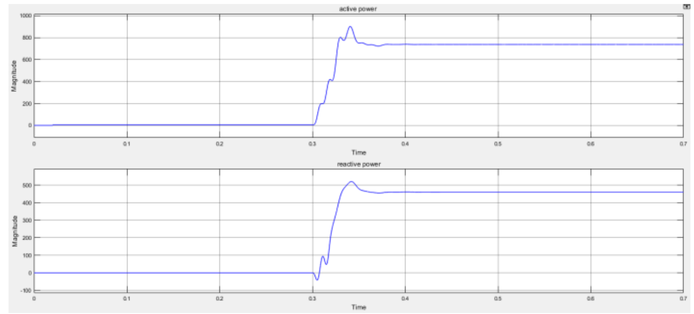

Fig 11: Active & Reactive power of compensated transmission line (master line).

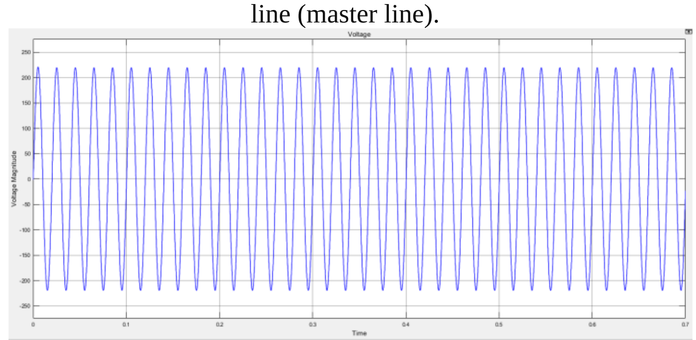

Fig 12: Voltages across transmission line mode 2 (slave line) after compensating line 1 (master line).

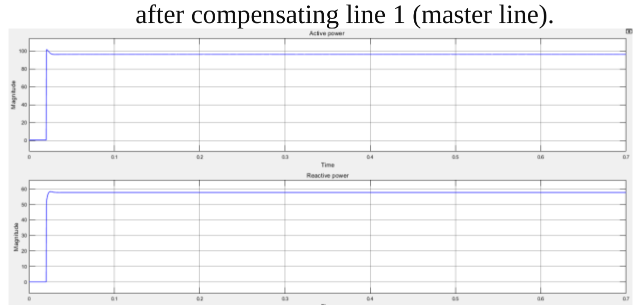

Fig 13: Active & reactive power of slave line after compensating master line.

The above figure shows the transmission line 1 or master line with the Interline Power Flow Controller. The Load 1 on first transmission line is initially connected and running fine but as the load 2 is connected which is known as heavy load change the whole situation and suddenly the whole transmission line is overloaded in result the voltage profile is disturbed so IPFC gets activated and maintain the same voltage profile in milliseconds by sharing load from the slave line

V. HARDWARE IMPLEMENTATION AND RESULTS

This hardware model was created to compare the results and performance analysis with the model which was created on MATLAB Simulink.

The Hardware model of IPFC consists of a power circuit and control circuit. The power circuit consist of transmission lines, loads, rectifier, dc link (capacitor), inverter, transformer and the control circuit which is used for switching of MOSFETs in the inverter, the pulses are given by the gate driver (EGS002) that includes the voltage feedback for accurate results and having protections such as over voltage and over current protection. The supply voltage is reduced to 24v setup for safety reasons. The experimental setup is shown below.

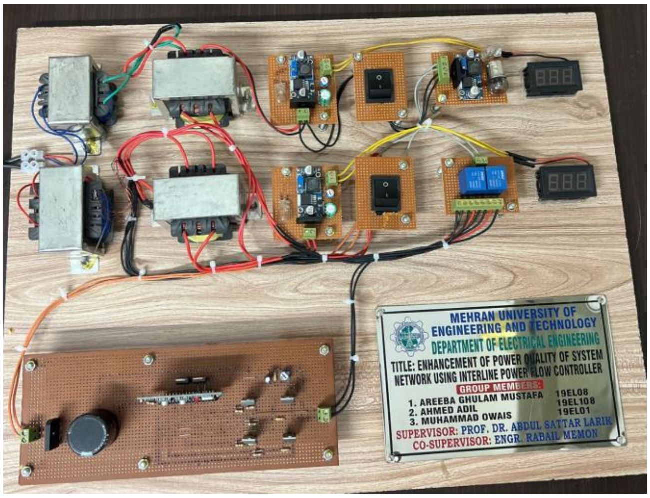

Fig 14: Experimental setup of IPFC

Results

a. Normal condition

Fig 15: Voltage of master line

Fig 16: Voltage of Slave line

b. Heavy Load Turn “ON”

Fig 17: Voltage of master line

Fig 18: Voltage of Slave line

c. Compensation by IPFC

Fig 19: Voltage of master line

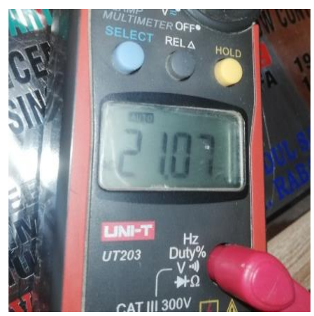

Fig 20: Voltage of Slave line

VI. CONCLUSION

MATLAB Simulink is used for simulating the transmission line models and analyzing the results with IPFC and without IPFC. The IPFC is used to enhance the power quality of system network. Investigating voltage compensation via IPFC shows the increase in active power and reactive power of the system network. Results from simulation and hardware model shows effectiveness of IPFC

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