International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://dx.doi.org/10.7324/IJASRE.2018.32636

Volume 4, Issue 3
March - 2018

Unified Power Flow Controller - A Dynamic Controller

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ABSTRACT

This paper presents the basic introduction of the Unified Power Flow Controller (UPFC), a FACT device, which is very dynamic in nature and has got tremendous applications in the power system. Basic information and operation along with control of the UPFC are presented.

Keywords : *Unified Power Flow Controller (UPFC), FACTS, Series converter, Shunt Converter.*

I. INTRODUCTION

FACTS technology have got tremendous applications in power control and increasing the usable capacity of already existing infrastructure of lines as well as new and restructured lines. The UPFC basically a second generation FACTS device is not only able to independently control active and reactive power but is also helpful in improving the reliability and quality of the power supply. The UPFC is a member of FACTS device having quite distinct and very attractive features [1]. The UPFC is so efficient that it controls all the parameters (voltage, impedance, and phase angle) that affect the power flow in the system selectively [2]. Currently it is the most sophisticated power flow controller, and the most expensive one. Because of such a sophisticated and brilliant design it is able to control the power flow in the transmission line and simultaneously control of the bus voltage and shunt reactive power. At present the UPFC is the most expensive but the efficient and sophisticated controller [3] [4].

II. UNIFIED POWER FLOW CONTROLLER. (UPFC)

STATCOM and the SSC together acting as the shunt compensating and phase shifting device simultaneously constitutes the UPFC. They are connected to two voltage source converters along with the shunt and series transformer, having a common link of DC capacitor. The main function of the DC circuit in the system is to have the exchange of active power between the shunt and series transformer in order to have the controlled phase shifting of the series voltage. This setup provides the full controllability for voltage and power flow. UPFC is getting quite expensive because of its protection scheme involved and circuitry parameters limiting its practical application in the systems involving continuous voltage and power flow control.

The series converter of the UPFC has got the control of the flow of active power in the transmission line, by adding the series voltage of controlled but adjustable magnitude and phase angle to the system [5]-[7]. The series part of the UPFC that is the SSSC can be controlled without any limitations.

The UPFC comprises of two VSCs along with semiconductor devices having turn-off capability, sharing a common dc capacitor and are connected to a power system through coupling transformers. The basic structure of UPFC is shown in fig. 1. The shunt converter is used which is able to meet the demand for real power of the series converter, connected at the terminal of the common DC link by providing the real power from the AC power system. It is also capable of generating or absorbing the reactive power at its ac terminal, being independent of the active power transfer to (or from) the DC terminal. Hence, it is able to compensate the reactive power in the transmission line and indirect regulation of voltage at the input terminal, if properly controlled and thus act like the advanced SVC which also does the same.

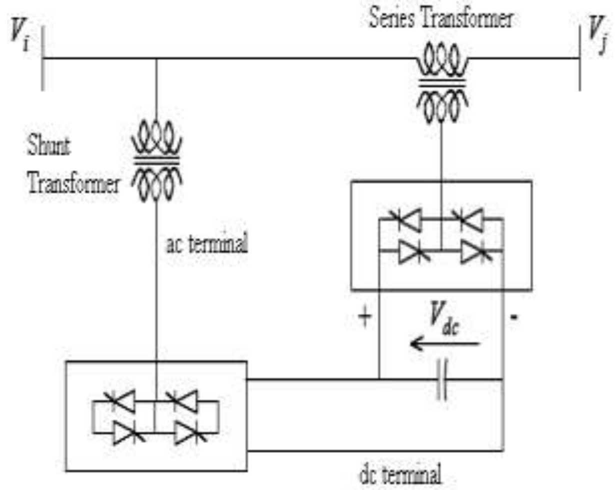

Fig. 1. *Configuration of UPFC [8]*

The boosting transformer which is in series connection with the system adds up the voltage generated by the series converter to the transmission line. The voltage generated by the series converter is having the fundamental frequency with variable voltage and phase angle.

For direct voltage control the inverter output voltage is injected in series with the line can be used for series compensation, etc. The reactive power that is used by the different controls in the system is generated by the voltage source and has got the ability to exchange the power at the DC terminal.

The dc link connected is providing the path to exchange active powers between the converters and the reactive power which is being generated/absorbed independently by each converter [9], [10].

The main function of the series converter is to inject a voltage in series with the system voltage through a series transformer. By controlling the magnitude and angle of the series-injected voltage, the flow of power through the line can be regulated. The injected voltage and line current determine the active and reactive power injected by the series converter in the system.

The converter electronically generates or absorbs the reactive power and hence both the series and shunt converters independently exchange reactive power with the ac system. However, the DC link must supply the injected active power and in turn take it from the ac system through the shunt converter. The overall active power exchange that occurs between the UPFC and the ac system becomes zero for the condition when the losses of the converters and the associated transformers are neglected [11], [12].

The branches can be made to work independently of each other by just separating the dc side. For this one need to provide each branch with its own DC capacitor. If this is done in the system the shunt-connected branch becomes a STATCOM that generates/absorbs reactive power to regulate the voltage magnitude at the AC terminal. The series branch corresponds then to a SSSC that generates/absorbs reactive power to regulate the current flow, and hence the power, of the transmission line. If these two devices are merged together through a common dc capacitor, real power can be exchanged at the AC terminals. The UPFC allows the free flow of power in either direction in the terminals of controller and behaves as an ideal AC to AC power converter. This basically results in a controllable phase shift between the terminal voltage as the two voltage-source inverters can interchange power. It should be noted that the real power is typically negotiated by the action of the series connected branch, whereas the shunt-connected branch is primarily used to feed real power from the ac system to the common dc link. The reactive power is generated or absorbed locally and independently from the real power by each branch and, therefore, it does not flow through the UPFC [13].

From the operational description, it can be concluded that the UPFC has the ability to:

1. Control terminal voltage by locally generating or absorbing reactive power;

2. Control power flows on the transmission line, both steady-state and dynamic, by regulating the real power flow through the controller (series capacitive/ inductive compensation and also phase shifting regulation);

3. Allow secure loading of transmission lines to their full thermal capability where desirable [13].

III. UPFC CONTROL

The operation of the UPFC is defined by its internal control system. The UPFC control system establishes the gating commands for the GTO valves so that the two inverters can perform their designated functions correctly under normal conditions. The controller is also responsible for taking action to prevent the equipment from operating in any region that would be damaging for the inverters or undesirable for the power system.

To draw a desired level of current from the line during the normal operation of the shunt inverter, the UPFC control system regulates its output AC voltage. The DC bus voltage in the UPFC is regulated by the real power component of the line current drawn from the line. The voltage reference input and droop factor for determining the voltage error versus the reactive current load of the shunt inverter is provided by the automatic voltage control that is almost similar to that which is commonly employed on conventional static VAR compensators.

In the case of the series inverter under normal operation, the UPFC control system determines the voltage to be injected in series with the transmission line. The injected voltage is a positive sequence vector quantity having magnitude and phase angle and its purpose is to influence the real and reactive power flow on the line. The phase angle reference is chosen to be the phase of the positive sequence voltage at the substation bus where the UPFC is installed.

The UPFC control system may be divided functionally into internal and external controls. The internal controls operate the two inverters so as to produce the commanded series injected voltage and, simultaneously, draw the desired shunt reactive current. The internal controls provide gating signals to the inverter valves so that the inverter output voltages will respond in accordance with the control structure.

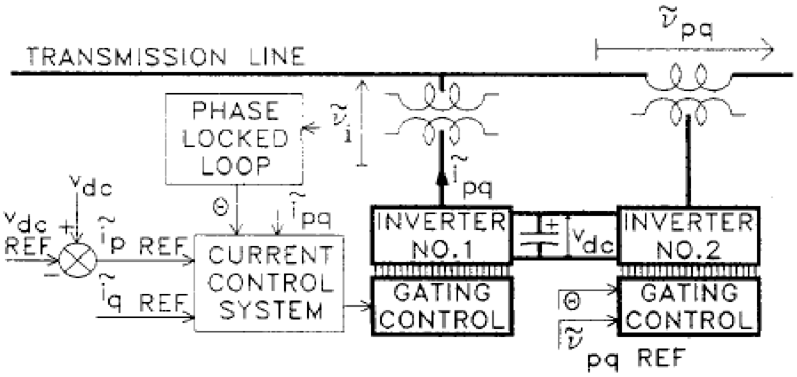

Fig. 2. *UPFC Internal Control [14]*

The shunt reactive power responds directly to an input demand. To ensure the real power balance between the two inverters, desired voltage level on the DC link needs to be maintained. For this another control loop that controls the shunt real power is utilized. The reactive power between the inverters is not exchanged via the link. The demands for the series voltage vector, V_{pq}, and shunt reactive current vector, i_q is generated by the external control loops. To meet the specific operating and contingency requirements, the demand values can be set to any desired arbitrary values either by the operator or by automatic control.

For the real and reactive power demand and automatic control it should be emphasized that this *P*, Q controller is not intended to simply reproduce the actions of conventional equipment such as, mechanical or thyristor-controlled, phase angle regulators, load tap-changers, and series capacitors. Instead, a generalized automatic P, Q controller is envisioned by which P and Q at a point (terminal) on the line are forced to and maintained at strategically chosen values by continuous closed-loop feedback control [14].

IV. CONCLUSION

The conclusion drawn for the UPFC is that it being a very dynamic controller if studied and implemented properly can be used for various purposes in the power system. UPFC is a second generation FACTS device helps in controlling the power flow in the power systems. It enables independent control of the active and reactive power and simultaneously helps in improving the quality and reliability of the power supply. UPFC fulfill the functions like shunt compensation, series compensation, phase shifting and voltage regulation.

DOI: dx.doi.org/10.7324/IJASRE.2018.32636

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