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UNIT-VIII

①

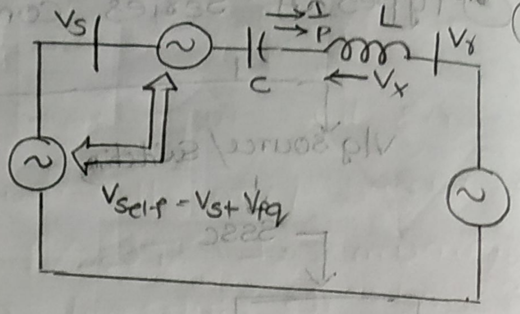
Dual converter.

Unified power flow controller (UPFC): [Shunt → STATCOM, Series → SSSC

Reversal of power flow possible (V/g & ph.)

Def:

UPFC is a generalised synchronous v/g source represented at the fundamental frequency by v/g phasor V_{pq} with controllable magnitude $(0 \leq V_{pq} \leq V_{pq\,max})$ and angle δ $(0 \leq \delta \leq 2\pi)$ in series with Transmission line.

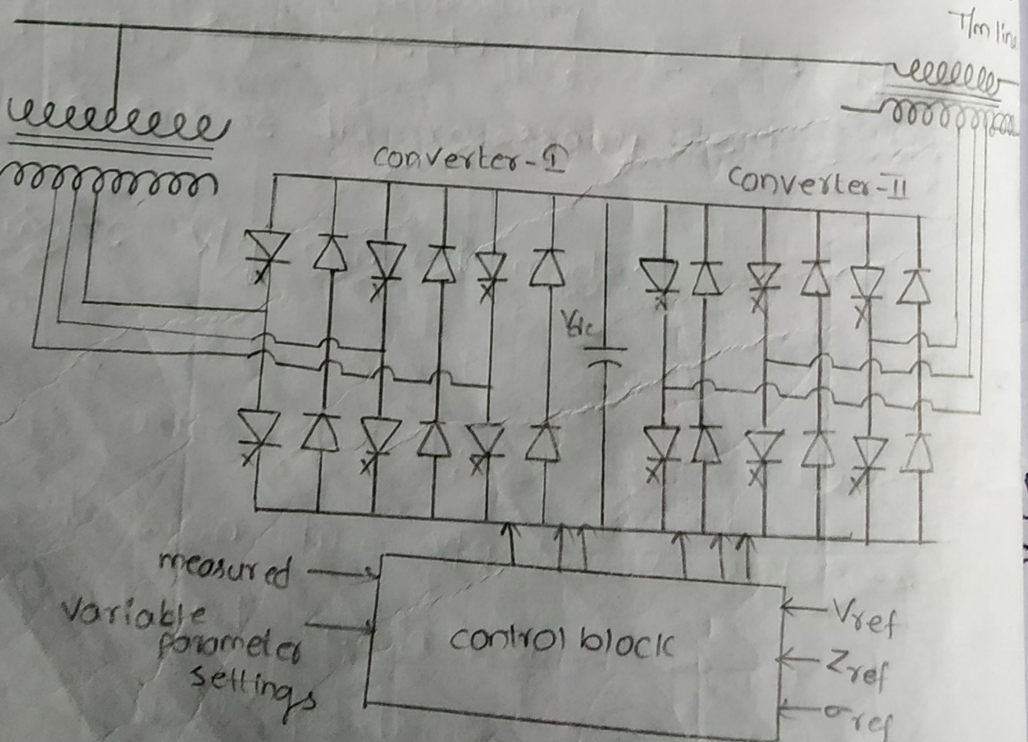


UPFC in a two machine system

Basic operating principle control structure independent real & reactive power control.

UPFC ~ Shunt-Series
↓
AC-AC converter
↓
AC v/g controller
cyclo Converter
matrix converter

Imp
Basic function of UPFC:- (Operating principle of UPFC)



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UPFC consists of v/g source converters namely converter I and converter II operated from common dc link provided by DC storage capacitor. (2)

- These arrangement functions as AC to AC power conversion in which real power flows in either directions. b/w ac terminals of two converters and each converter generate (or) absorb reactive power at ac o/p terminals.

- Basic Function of converter-I is to supply (or) absorb the real power demand at converter-II. The common dc link to support real power exchange resulting from series v/g injection.

- converter II provides main function of UPFC by injecting a v/g V_{pq} Controllable in magnitude & Phase angle in series with the line. These injected v/g acts as a synchronous v/g source.

- If the transmission line current flows through the v/g source resulting real power & reactive power exchange b/w transmission line and ac system.

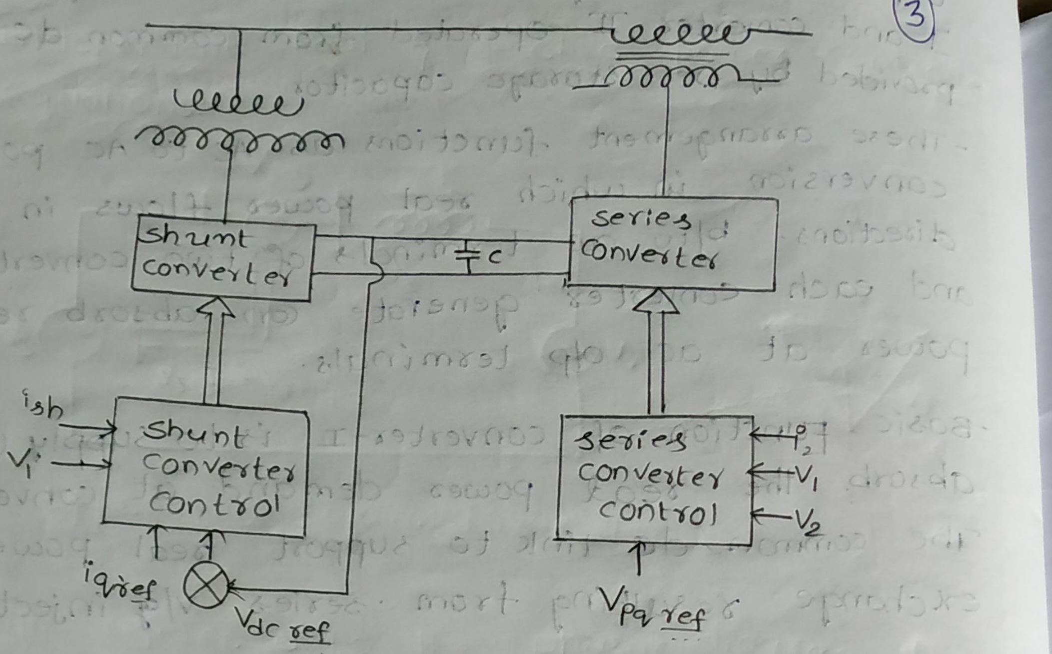
Converter-I acts as a shunt controller for real power flow control.

Converter-II acts as a series controller for reactive power flow control.

- converter-I can be operated at unity P.F for more reactive power exchange at Converter-II.

Imp
14m.

Control Structure of UPFC:-



V_1 = Bus i/p v/g ; V_2 = Bus o/p v/g

$V_1 = V_{dc}$; $V_2 = V_{pq}$

$V_1 + V_{pq} = V_2$

Functional scheme of the shunt converter: current injection

The shunt converter is operated so as to draw controlled current I_{sh} from the line.

(i) **Reactive power control mode:**

In this mode reference i/p is inductive (or) capacitive VAR.

A feedback signal ~~replacing~~ representing dc bus v/g at C' is used to ensure the necessary DC line v/g.

(ii) **Automatic v/g control mode:**

In this mode shunt converter reactive current is automatically regulated ~~to~~ maintain the transmission line v/g to a reference value of the point of connection,

It uses feedback signals usually representing magnitude of Positive sequence component of bus v/g 'v_i'.

Functional control of Series converter:- (4)

The series converter controls the magnitude angle of the injected v/g in series with the line.

(i) Direct v/g injection mode:-

Injected v/g V_{pq} is kept in phase ($V_{pq} = V_2$) with the system v/g for v/g magnitude control & in quadrature with line current ($V_{pq} = I_2$) provides reactive power compensation.

(ii) Bus v/g regulation & control mode:-

Injected v/g V_{pq} is kept in phase with the i/p v/g V_1 & its magnitude is controlled ($V_{pq} = V_1 \rightarrow$ control, $V_{pq} = V_2$) to maintain the magnitude o/p bus v/g V_2 at the reference value.

(iii) Line Impedance compensation mode:-

The magnitude of injected v/g is proportional to magnitude of line current. ($V_{pq} = I_2$)

The desired impedance is specified by reference i/p and it may be complex impedance of resistive or reactive with either polarity.

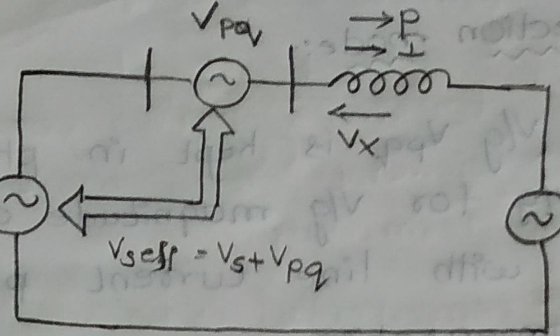
(iv) phase angle regulation mode:-

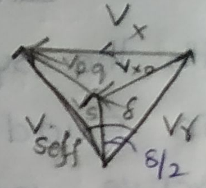
The injected bus v/g is controlled w.r.t i/p bus v/g V_1 so that o/p bus v/g V_2 is phase-shifted without any magnitude change.

(v) Automatic power control mode:-

The series injected v/g is determined automatically & continuously by ~~w.r.t~~ closed loop control system to ensure that desired P & Q maintained w.r.t power changes.

Independent Real & reactive power controller Equations:- (or) (power angle curves)





V_{seff} - Sending effective voltage

UPFC is a two machine system

With reference to the phasor diagram the transmitted power P and the reactive power jQ_r supplied by the receiving end can be expressed as

$$P - jQ_r = V_r \left[\frac{V_s + V_{pq} - V_r}{jX} \right]^* = VI^*$$

where X = conjugate of a complex number

$$j = e^{j\pi/2} = \sqrt{-1}$$

$V_{pq} = 0$ then describes the ~~co~~ uncompensated line

$$P - jQ = V_r \left[\frac{V_s - V_r}{jX} \right]^* \sim \text{Real power}$$

Thus when $V_{pq} \neq 0$ the total real & reactive power can be expressed as

$$P - jQ_r = V_r \left(\frac{V_s - V_r}{jX} \right)^* + \frac{V_r V_{pq}^*}{-jX}$$

Substituting $V_s = Ve^{j\delta/2}$

$$= V\left(\cos\frac{\delta}{2} + j\sin\frac{\delta}{2}\right)$$

$$V_r = Ve^{-j\delta/2}$$

$$= V\left(\cos\frac{\delta}{2} - j\sin\frac{\delta}{2}\right)$$

$$\cancel{V_{pq}} = V\left(\cos\frac{\delta}{2} - j\sin\frac{\delta}{2}\right)$$

$$V_{pq} = V_{pq}\, e^{j\left(\frac{\delta}{2}+\delta_0\right)}$$

$$= V_{pq}\left[\cos\left(\frac{\delta}{2}+\delta_0\right) + j\sin\left(\frac{\delta}{2}+\delta_0\right)\right]$$

$$P[\delta_0, \delta] = P_0(\delta) + P_{pq}(\delta)$$

$$P[\delta_0, \delta] = \frac{V^2}{X}\sin\delta - \frac{V V_{pq}}{X}\cos\left(\frac{\delta}{2}+\delta\right)$$ ~ real power

$$Q(\delta_0, \delta) = Q_0(\delta) + Q_{pq}(\delta)$$

$$Q[\delta_0, \delta] = \frac{V^2}{X}(1-\cos\delta) - \frac{V V_{pq}}{X}\sin\left(\frac{\delta}{2}+\delta\right)$$ ~ reactive power