DETERMINATION OF POWER-ANGLE CHARACTERISTIC OF A TRANSMISSION LINE

Objective:

1. To draw the power -angle characteristic
2. To study the change in power transfer for variations in transfer reactance, and sending end and receiving-end voltages

Theory:

A transmission line may be considered as a two-terminal pair network and for such a network the power at the two ends is given by

Sending end

$$P_s = [V_s V_r \cos(\delta-\beta) - D\, V_r \cos(\beta-\Delta)]/B$$

Receiving end

$$P_r = [V_s V_r \cos(-\delta+\beta) - A\, V_r \cos(\beta-\alpha)]/B$$

Where **Vs** = Vs $\angle\delta$, sending end voltage,

Vr = Vr$\angle 0^{0}$, receiving-end voltage. The symbols in bold indicate complex quantities.

Generalised circuit constants:

A =A$\angle\alpha$
B = B$\angle\beta$
D =D$\angle\Delta$

If a lossless line is considered, the generalised circuit constants will be

$A= 1\angle 0^{0}$, $B= X\angle 90^{0}$, C =0, $D=1\angle 0^{0}$

In this case, the power at the two ends will be the same and equal to

$$P_s = P_r = V_s . V_r \sin\delta / X$$

The expression shows that the transfer of power between sending-end & receiving-end is directly proportional to the sine of the angle between the voltages at the two ends. Keeping the magnitude of the voltage constant, a plot between the power and the phase angle δ, known as the power -angle characteristic can be drawn.

Pre-experimental quiz

1. What is the power-angle curve? Explain briefly its significance in stability studies.
2. What is synchronising power coefficient? What is its limiting value for system stability?
3. Formulate the synchronous and load stability criteria for a simple electrical system.
4. What is the effect of the X/R ratio of a transmission line on the power angle curve?
5. What is the receiving end power chart of a transmission line? How is it helpful in determining the steady -state power limit of the line?
6. What are the differences in the normal, faulted and the post-fault curves of a system?

Precautions

1. The voltmeter across the switch connecting the two systems should have double the range of Vs(or Vr)
2. Use low power factor wattmeters preferably.
3. If an iron-cored choke is used for the tarnsmission line model, the choke should not saturate

Procedure:

1. Set the value of the transmission line (a variable inductance may be used as a transmission line) reactance X = 520 mH(r= 5 ohms). Keeping the switch S open in Fig.1, adjust the 3-phase & 1-phase variacs to obtain100 V in voltmeters Vs & Vr. Adjust the 3-phase phase shifter to obtain zero voltage across the switch S. Close S and check the readings of ammeters & wattmeters. They should be zero. Set the dial indicator of the phase shifting transformer to zero value. Increase the phase angle δ up to 180 degrees in steps of 10 degrees with the help of the phase shifter. Note the ammeter & wattmeter readings for each value of δ. The value of Vs & Vr should be held constant at 100 V. The current in the ammeters should not exceed 1.44 A
2. Repeat the experiment for X= 70 mH (r= 5 ohms00
3. Vary Vs & Vr from 100 V to 120 V in steps of 5 V and note the readings for ammeters & wattmeters for a fixed value of δ (say, 30 deg.)
4. Find out $\Delta P/\Delta V$ with $\Delta V = 5$ V

Observations:

1. Variation of δ and X with Vs = Vr = 100V

		X= 520 mH				X=70 mH			
S. No.	δ, Deg.	Is	Ws	Ir	Wr	Is	Ws	Ir	Wr
1	0								
2	10								
3	20								
4	30								
5	40								
6	50								
7	60								
8	70								
9	80								
10	90								
11	100								
12	110								
13	120								
14	130								
15	140								
16	150								
17	160								
18	170								
19	180								

2. Variation of Vs and Vr with δ = 30 deg. and X = 520 mH

S. No.	Vs	Vr	Is	Ws	Ir	Wr
1	105 V	105 V				
2	110 V	110 V				
3	120 V	120 V				

Report:

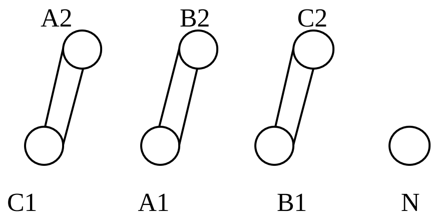
1. Plot the curves: (a) Ws versus δ, (b) Wr versus δ for the two values of reactances. Are Ws & Wr equal at any value of δ? If not, why not?
2. Find out the steady-state stability limits for the power-angle curve and compare it with the theoretical value.
3. Find out ΔP/ΔV at δ = 30 deg, and Vs=Vr=100V. Discuss the result.

Post-experimental quiz

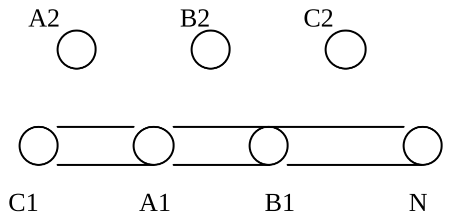
1. How does the reactance of the transmission line affect the steady-state power limit?
2. What conclusions can you draw about the system from the experimental values of $\Delta P/\Delta V$ and $\Delta P/\Delta\delta$ at $\delta = 30$ deg?
3. What conclusions can you draw about the system from the experimental values of $\Delta Q/\Delta V$ and $\Delta Q/\Delta\delta$ at $\delta = 30$ deg?
4. If the generator power is kept constant, how will Vs (or Vr) vary with δ? Can you arrive at the critical condition for steady-state power limit from the above relation?
5. Enumerate the various methods of increasing the steady-state power limit.
6. What are the various problems associated with series c-compensated lines?
7. A synchronous generator is supplying power to a static impedance load through a transmission line at a given power factor. Determine the expression for the steady-state power limit in terms of the sending -end voltage, line reactance, and the load power factor.
8. Draw the variation of receiving-end power versus receiving -end voltage for different power factors of the load for a synchronous system supplying a static load and therefrom determine the steady-state power limit of the system.
9. Study the power -angle curves for the following systems: (i) synchronouig generator supplying power to an induction motor through atransmission line (ii) synchronouig generator supplying power to a static load through atransmission line
10. Draw acurve showing the variation of δ versus Vs (or Vr) for constant power output.

Description of the phase -shifting transformer

The transformer provides convenient means for adjusting he phase angle or power factor in ac circuits. It comprises a wound stator and rotor similar to an induction motor. Fig.2 show s the arrangement of the terminal panels and the manner in which the change from star to delta is made.



Arrangement of links for delta connection



Arrangement of links for star connection

FIG.2

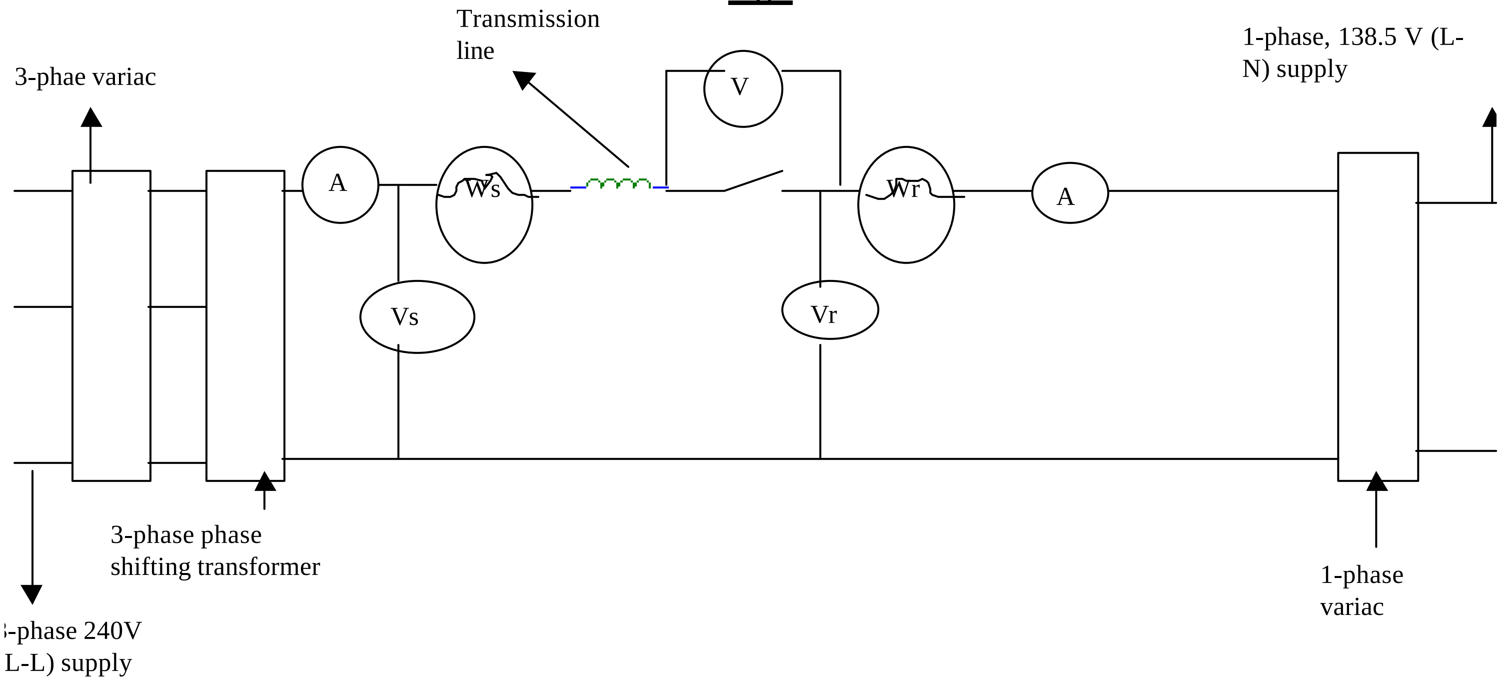
The phase shifter has a capacity of 600 VA and can be wound for any input or output voltage not exceeding 500 V.
The maximum output available when the input (stator) output (rotor) are connected in various ways is shown below. The table is based on a transformer wound on the input side for operation on 440 V and on the output for 254 V.

With primary connected	Input Volts		With secondary connected	Output Volts		Output (line) Amperes	Output VA
	Across phases	Phase to neutral		Across phases	Phase to Neutral		
Delta	440	-	Delta	254	-	1.36	600
Delta	440	-	Star	440	254	0.787	600
Star	440	254	Delta	147	-	1.36	350
Star	440	254	Star	254	147	0.787	350

Regulation of phase angle is effected by means of a worm gear and handwheel, giving an 80:1 reduction for extremely fine control. A double-ended adjustable pointer in combination with a scale of large diameter indicates the angle of lag or lead in electrical degrees. The vernier pointer operating over the degree scale is subdivided to give a precise scale reading. This pointer can be rotated relative to the rotor and locked in any position

FIG.1 is on the next page

Fig.1


Transmission line
3-phae variac
V
1-phase, 138.5 V (L-N) supply
A
Ws
Wr
A
Vs
Vr
3-phase phase shifting transformer
1-phase variac
-phase 240V
L-L) supply