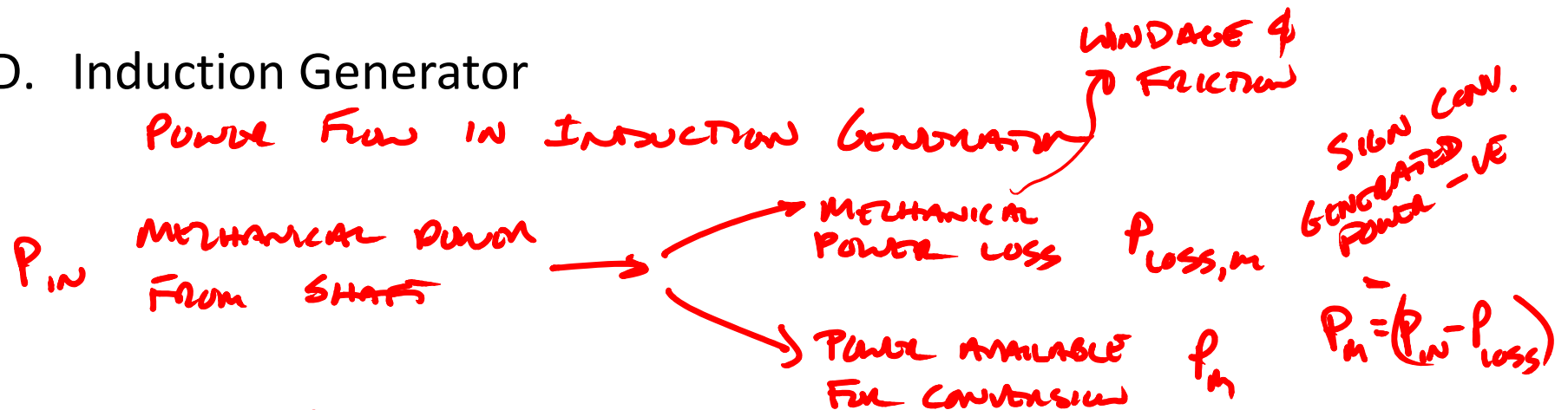


# Wind Turbine Electricity Generation

## D. Induction Generator



THIS POWER  $P_m$  IS TRANSFORMED INTO ELECTRICAL POWER

$$P_m = I^2 R'_r \frac{1-s}{s}$$

← POWER GENERATED IN ROTOR

SOME POWER LOST IN ROTOR → NET POWER ONLY IS TRANSFERRED

$$P_g = P_m - P_{loss,r} = I^2 R'_r \frac{1-s}{s} + I_r^2 R'_r$$

SIMPLIFY  $P_g = \frac{P_m}{1-s}$

SOME POWER LOST IN STATOR  $I_s^2 R_s = P_{loss,s}$

SO NET POWER DELIVERED AT TERMINALS  $P_{out} = P_g - P_{loss,s}$

# Wind Turbine Electricity Generation

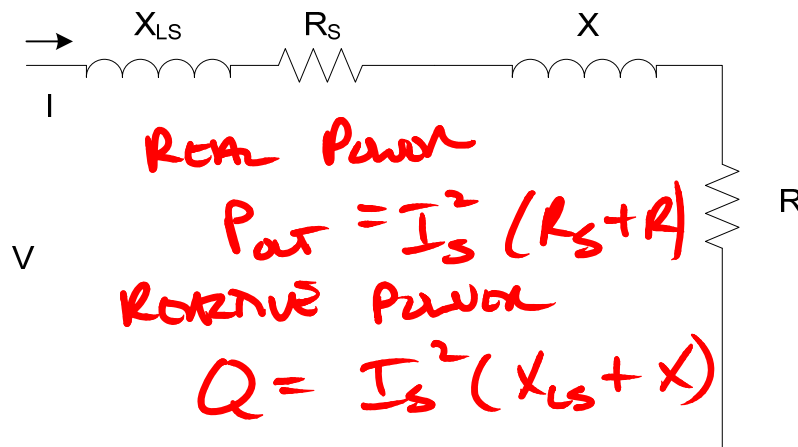
## D. Induction Generator

Efficiency

$$\eta = - \frac{P_{out}}{P_{in}}$$

Power Factor

$$PF = - \frac{P_{out}}{VI} = \frac{\text{Real Power}}{\text{Apparent Power}}$$



CAN LOOK AT THE INDUCTION GENERATOR IN TERMS OF MORE SIMPLIFIED CIRCUIT

$X \}$  NET REACTIVANCE &  
 $R \}$  RESISTANCE FROM  
 ROTOR & MAGNETIZING  
 REACTIVANCE &  
 RESISTANCE

COMPLEX IMPEDANCES

$$\hat{Z} = (R + R_s) + j(X + X_{Ls})$$

SO CURRENT  $\hat{I}$  IN CIRCUIT

$$\hat{I} = \frac{V}{\hat{Z}}$$

ALL PHASORS  
 $\hat{I}$  &  $\hat{V}$  ARE NOT IN PHASE

# Wind Turbine Electricity Generation

## D. Induction Generator

From previous discussion

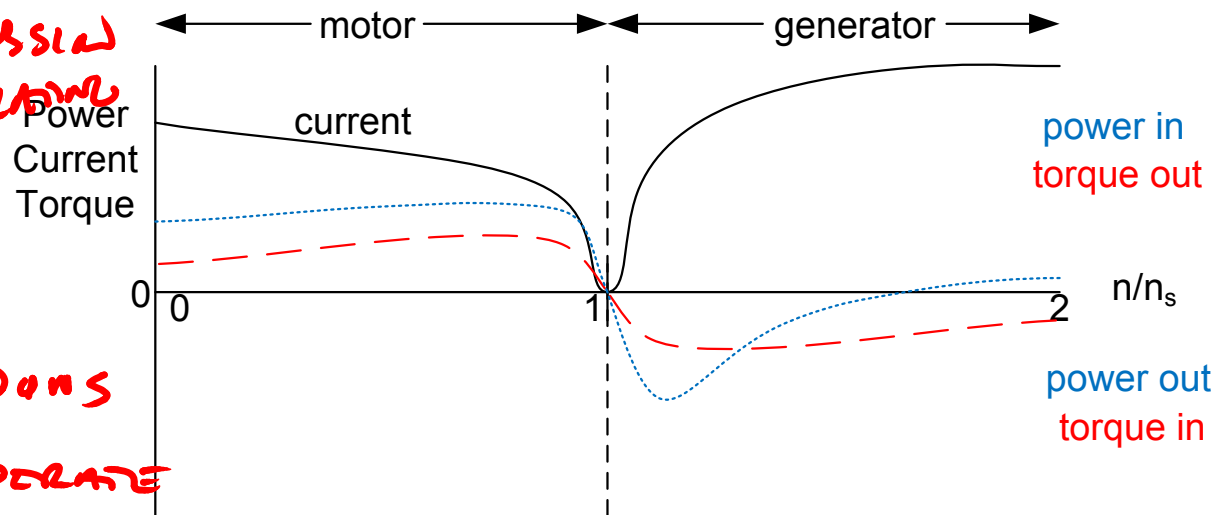
→ important operating parameters

determined from slip

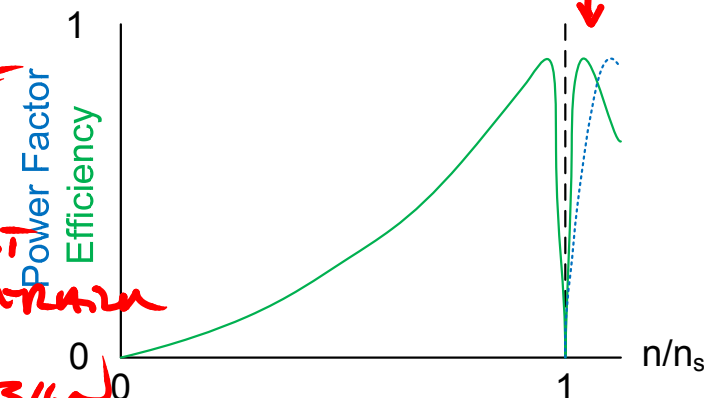
Important observations

- MACHINE WILL OPERATE AS A MOTOR DURING START UP & SHUT DOWN

- MACHINE MUST BE DESIGNED WITH TORQUE, POWER & CURRENT THAT MUST PASS THROUGH GENERATOR AT ALL OPERATING POINTS, NOT JUST DESIGN



Typical operating point



- GENERATOR OPERATES WITH  $S < 3\%$

- FOR SMALL SLIP PURE POWER FACTOR

# Wind Turbine Electricity Generation

## D. Induction Generator

### START-UP

- USE WIND TO BRING GENERATOR TO SPEED & THEN CONNECT TO GRID

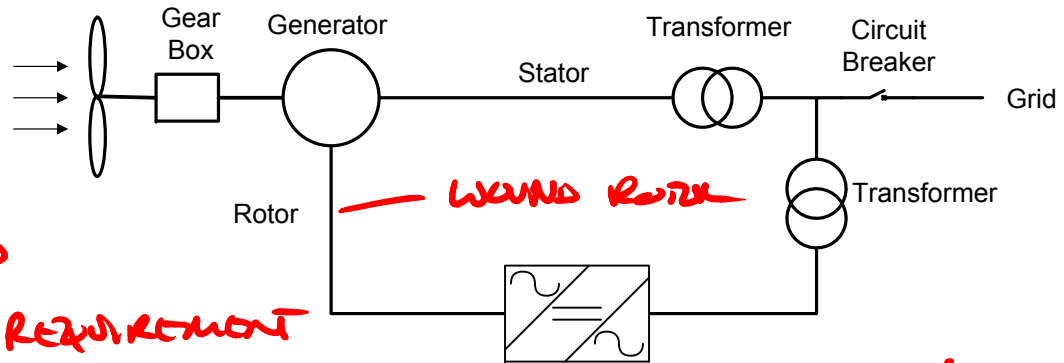
- SELF STARTING
- CONNECT WHEN GENERATOR AT  $n/n_s > 1$   $s < 0$

### INDUCTION GENERATOR



→ VARIABLE PITCH BLADES

### POWER FED INDUCTION GENERATOR (DFIG)



- USE GENERATOR AS A MOTOR TO BRING ROTOR UP TO SPEED

- NO SELF START REQUIREMENT

- REQUIRES MONITORING OF CONDITIONS

- AS TURBINE STARTS TO SPIN UP

- ROTATION ACCELERATES UNTIL INCREASES IN RUNS AT  $n/n_s > 1$  TORQUE DICTATES OPERATION POINT