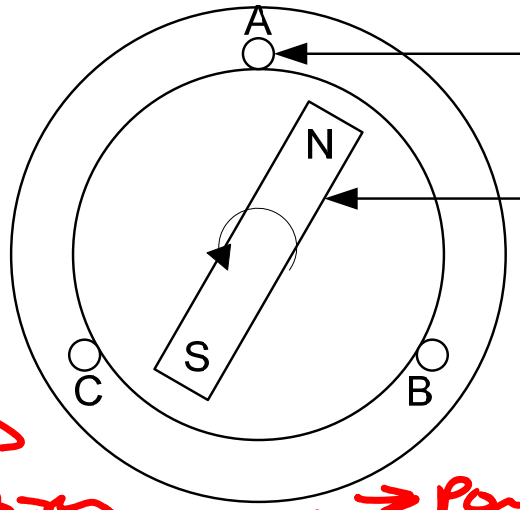
Wind Turbine Electricity Generation

C. Synchronous Generator

PRINCIPLE OF OPERATION

BOTH STATOR & ROTOR HAVE ROTATING MAGNETIC FIELD



ANGLE BETWEEN ROTOR & THE RESULTANT FIELD → POWER ANGLE δ

$\delta > 0$ GENERATOR

$\delta < 0$ MOTOR

IF FIELDS ROTATE ALIGNED NO FORCE ACTING ON THEM TO REALIGN THEM

IF FIELDS BECOME MISALIGNED BY DISPLACING ROTOR SLIGHTLY A TORQUE IS PRODUCED TO REALIGN THEM

IF AN EXTERNAL TORQUE IS PROVIDED TO THE ROTOR THE MISALIGNMENT CAN BE PRESERVED → CONSTANT ANGLE δ BETWEEN FIELDS

THE FIELDS MAY BE SUMMED (SUPERPOSITION) TO PRODUCE NET FIELD

Wind Turbine Electricity Generation

C. Synchronous Generator

FOR THE PURPOSE OF ANALYZING THE SYCHRONOUS GENERATOR → EQUIVALENT CIRCUIT

NEGLECTING RESISTANCE (NORMALLY SMALL)

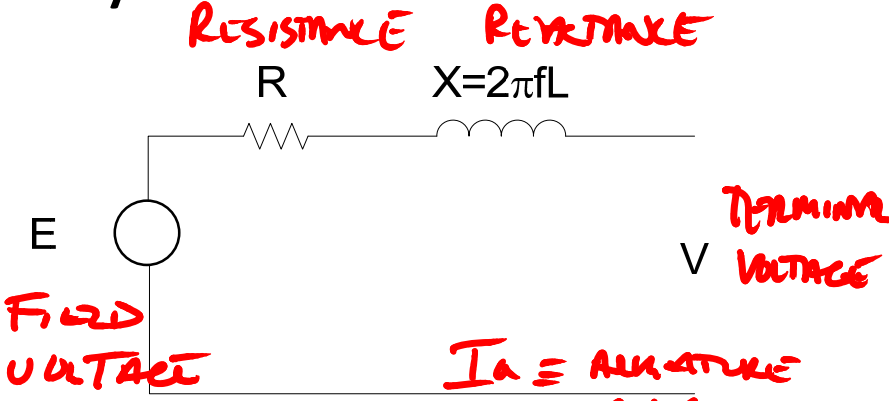
$$\hat{E} = \hat{V} + jX_s\hat{I}_a \qquad (\hat{\ }) \equiv \text{PHASOR}$$

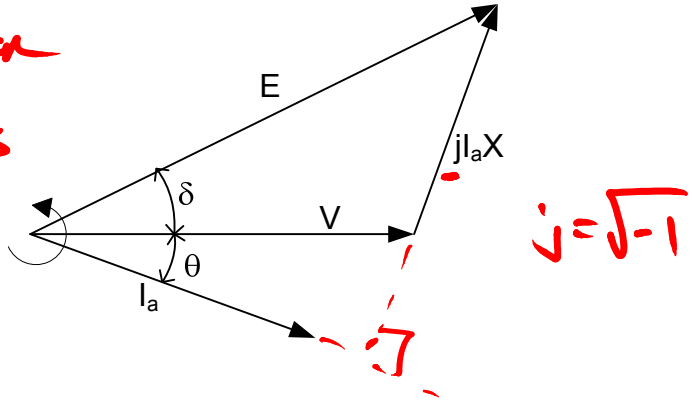
THERE ARE TWO DIFFERENT RELATIONSHIPS BETWEEN CURRENT & VOLTAGE V

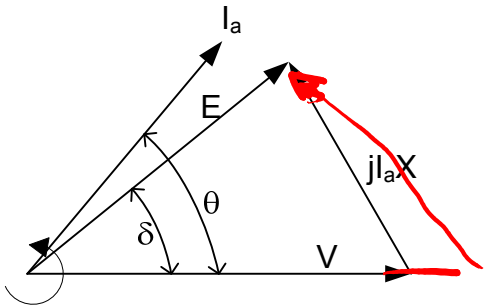
I_a LAGS V LAGGING POWER FACTOR

I_a LEADS V LEADING POWER FACTOR

IN BOTH CASES E LEADS V AS IT MUST IN GENERATORS $\delta > 0$







Wind Turbine Electricity Generation

BOTH ARE NEEDED

C. Synchronous Generator

MUST DISCUSS APPARENT, REAL, & REACTIVE POWER

REAL POWER

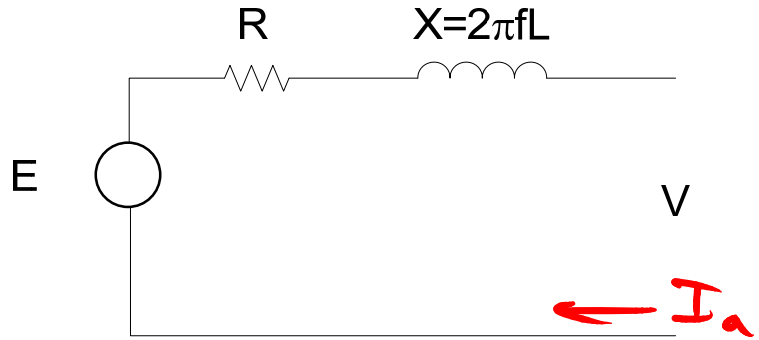
$$P = V_{rms} I_{rms} \cos\theta$$

REACTIVE POWER

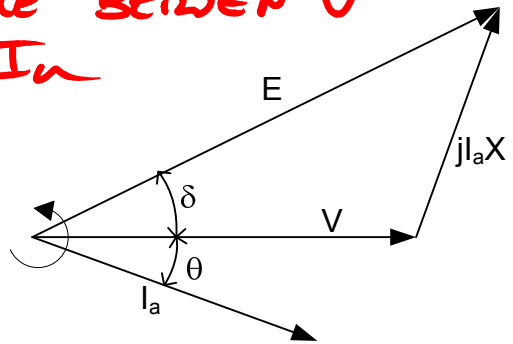
$$Q = V_{rms} I_{rms} \sin\theta$$

ASSOCIATED WITH CAPACITANCE OR INDUCTANCE

PURELY RESISTIVE CIRCUIT $\theta \to 0$ & NO REACTIVE POWER



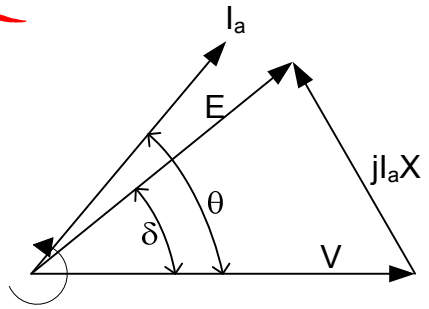
θ = ANGLE BETWEEN V & I_a



WITH MANIPULATION

$$P = \frac{|E||V|}{X_s} \sin\delta$$

$$Q = \frac{|\hat{E}||\hat{V}|}{X_s} \cos\delta - \frac{|V|^2}{X_s}$$



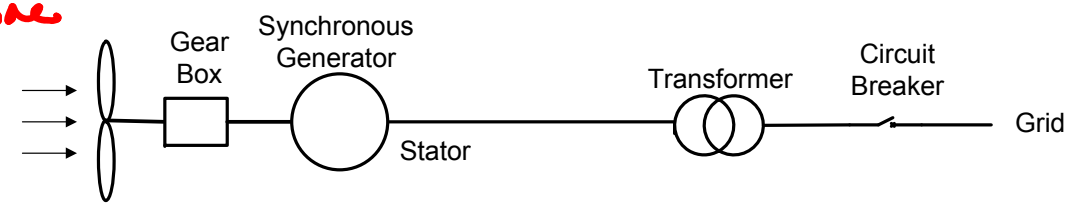
Wind Turbine Electricity Generation

C. Synchronous Generator

START-UP

WIND STARTS GENERATOR ROTATING. WHEN GENERATOR REACHES APPROPRIATE SPEED, CAREFULLY SYNCHRONIZE TO GRID & THEN CONNECT

Synchronous – Direct Connected

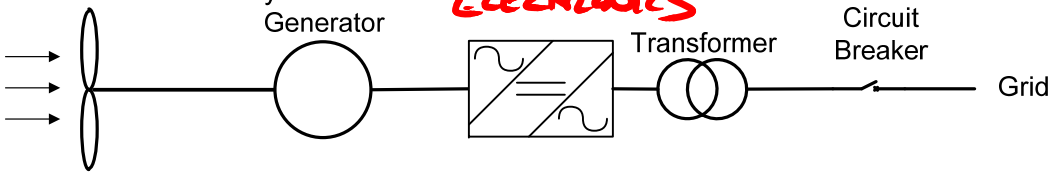


START-UP

STARTS PRODUCING ELECTRICITY AS SOON AS IT STARTS TO ROTATE

NO GEAR BOX ++

Synchronous – Direct Drive



Wind Turbine Electricity Generation

D. Induction Generator

DESIGN FEATURES

STATOR WITH MULTIPLE WINDINGS

ROTOR – CONDUCTING BARS

POWER EXTRACTED FROM STATOR

ALTERNATIVE DESIGNS

- ROTORS ARE WOUND ALSO
- POWER FROM BOTH ROTOR & STATOR IS TAKEN (DFIG)

DOUBLY FED INDUCTION GENERATOR

DESIGN CHALLENGES

- ENSURE CONSTANT FREQUENCY SOURCE TO CONTROL ROTATION SPEED
- EXTERNAL SOURCE OF REACTIVE POWER
- OFTEN OPERATE WITH POOR POWER FACTOR → CAN BE OVERCOME WITH CLEVER ELECTRICAL DESIGN