

# Wind Turbine Electricity Generation

## B. Simple Electrical Machine

GENERIC NAME FOR MOTORS  
& GENERATORS

MOTOR ELECTRICITY  $\rightarrow$  MOTION

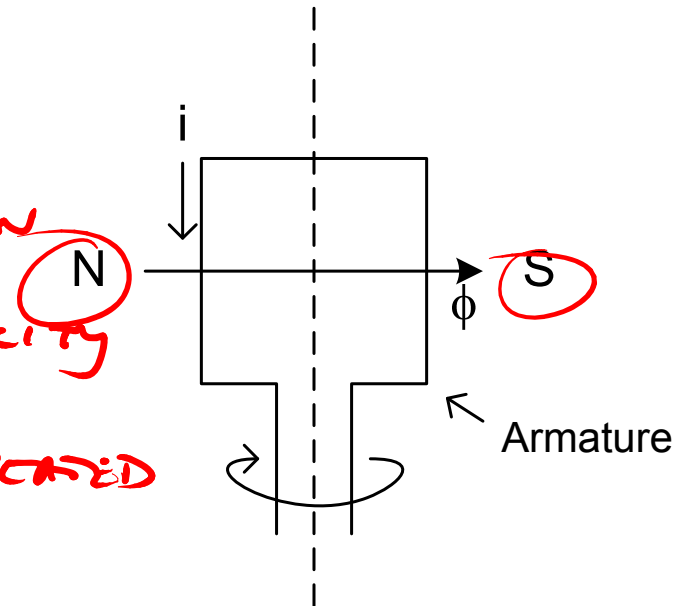
GENERATOR MOTION  $\rightarrow$  ELECTRICITY

CONSIDER A MAGNETIC FIELD CREATED  
BY TWO MAGNETIC POLES

IN THE MAGNETIC FIELD, WE PLACE AN  
ARMATURE  $\rightarrow$  ROTATING WIRE

IF CURRENT PASSES THROUGH ARMATURE — PRODUCES TORQUE  
 $\rightarrow$  MOTION

IF ARMATURE ROTATES THROUGH AN APPLIED  
TORQUE — CURRENT PRODUCED  
VOLTAGE GENERATED  
 $\rightarrow$  GENERATOR



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THE VOLTAGE  $E$  IS GENERATED  
ACCORDING TO

$$E = -\frac{d\phi}{dt}$$

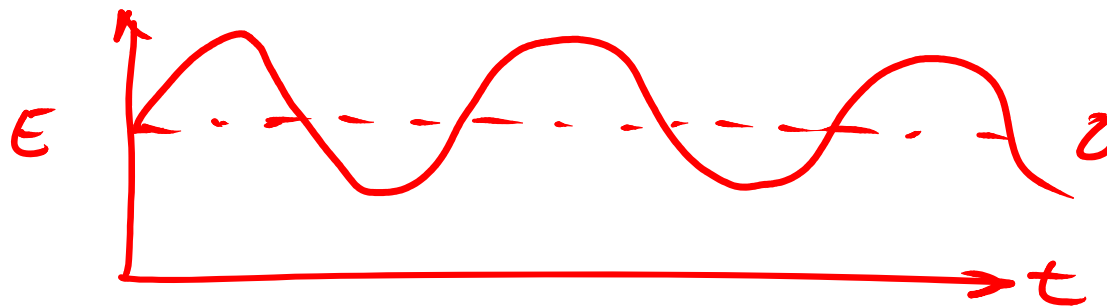
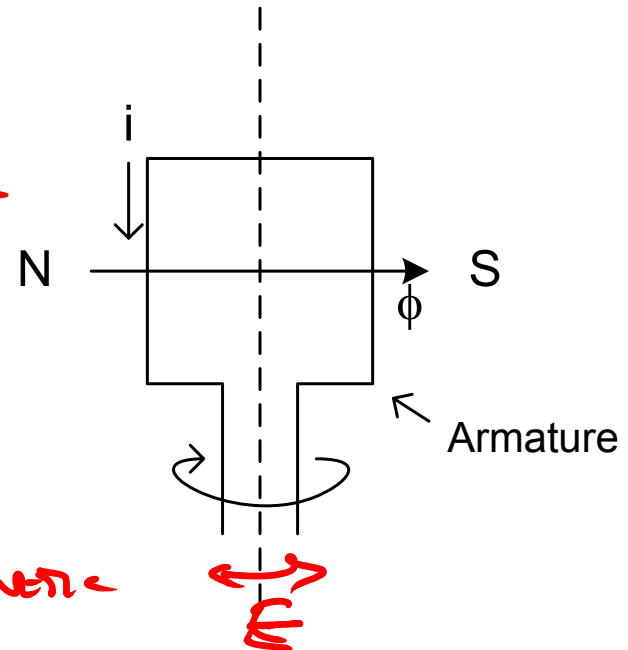
$\phi$  = MAGNETIC  
FLUX

$$\phi = \int B \cdot dA$$

$\uparrow$  MAGNETIC FLUX  
DENSITY

AS THE ARMATURE ROTATES, THE MAGNETIC  
FIELD CHANGES  $\rightarrow$  IT FLIPS

$\rightarrow$  THIS CAUSES VOLTAGE  $E$  TO CHANGE SIGN



VOLTAGE VARIES  
SINUSOIDALLY

$\rightarrow$  AC GENERATOR

$\swarrow$   
ALTERNATING  
CURRENT

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### 1. Real Machines vs. Simple Machine

SIMPLE MACHINE EXPLAINS WORKING PRINCIPLES OF ELECTRICAL MACHINES

REAL MACHINES INCORPORATE SOME IMPORTANT DIFFERENCES

- FIELDS ARE MOST OFTEN PRODUCED ELECTRICALLY (ELECTRO-MAGNETIC)  
PERMANENT MAGNETS ARE BECOMING MORE COMMON
  - ELECTRIC FIELD IS OFTEN ROTATED & ARMATURE IS STATIONARY
  - ARMATURE CAN ALSO HAVE A MAGNETIC FIELD THAT INTERACTS WITH ROTOR
- ROTATING PART → ROTOR  
STATIONARY PART → STATOR

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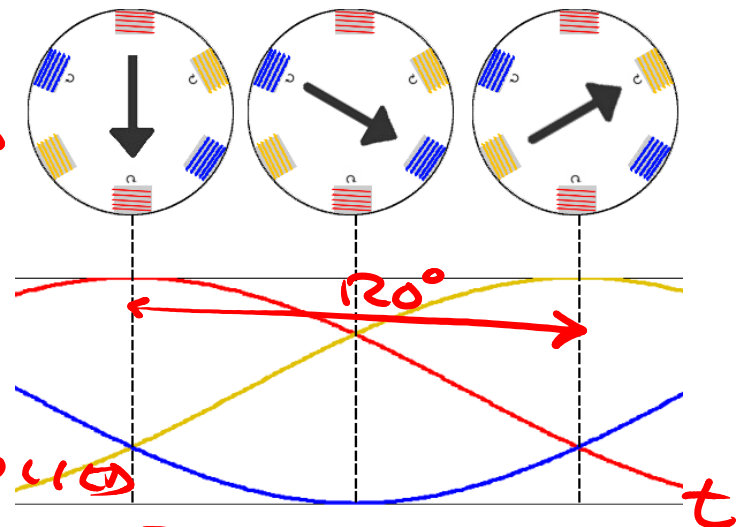
### 2. Rotating Magnetic Field

ROTATING MAGNETIC FIELD CAN BE CREATED WITH  
STATIONARY HARDWARE

IF AC CURRENT IS PROVIDED TO A SET OF POLES  
IT'S MAGNETIC FIELD WILL VARY SINUSOIDALLY

IF AC CURRENT IS SUPPLIED TO  
3 SETS OF POLES SEPARATED BY  
 $120^\circ$  AND THE CURRENT SUPPLIED  
TO EACH SET IS  $120^\circ$  OFFSET  
IN PHASE, A ROTATING MAGNETIC  
FIELD IS PRODUCED

PRACTICALLY SUPPLIED  
BY 3 PHASE POWER



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### 2. Rotating Magnetic Field

RESULTING ROTATING MAGNETIC FIELD HAS

- A CONSTANT MAGNITUDE

- ROTATES AT FREQUENCY OF CURRENT SUPPLIED

IN U.S.  $60 \text{ Hz} \times 60 \text{ sec} = 3600 \text{ rpm}$

IN REAL SYSTEMS, THERE ARE OFTEN MORE THAN 2 POLES PER PHASE (SHOWN HERE)

THE RPM OF MAGNETIC FIELD (IN U.S.) IS GIVEN BY

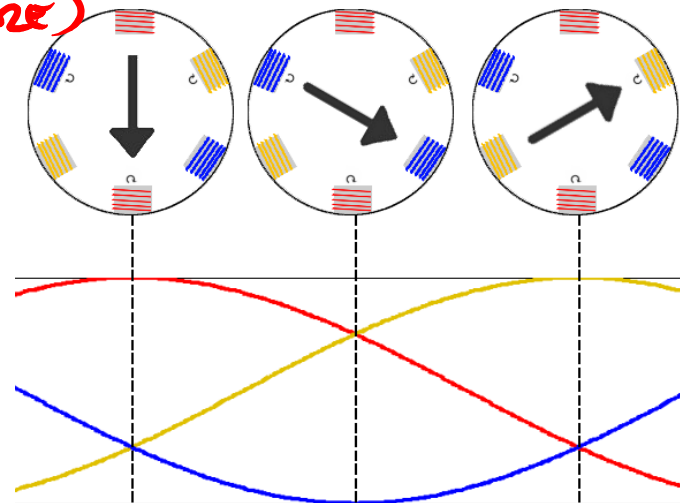
$$n = \frac{60 f}{P/2}$$

$n \equiv \text{rpm of magnetic field}$

$f \equiv \text{AC current frequency}$

$P \equiv \text{\# of poles per phase 2, 4, 6.}$

60 Hz	$\frac{P}{2}$	$\frac{n}{3600}$
	2	3600
	4	1800
	6	1200



# Wind Turbine Electricity Generation

## C. Synchronous Generator (ALTERNATOR)

PRIMARY GENERATOR USED IN LARGE POWER PLANTS

SAME DESIGN SOMETIMES USED IN WIND TURBINES RUNNING AT CONSTANT RPM

ALSO USED IN CONJUNCTION WITH POWER ELECTRONICS IN VARIABLE SPEED / DIRECT DRIVE APPLICATIONS

PRIMARY GENERATOR DESIGN FOR SMALL WIND TURBINES

BASIC COMPONENTS

ROTATING MAGNETIC FIELD ← NORMALLY CREATED BY DC CURRENT THROUGH WINDING

STATIONARY ARMATURE ← ROTATING FIELD CREATED BY OUT-OF-PHASE CURRENT

