Motor and Generator Basics, etc

Name___________________________ ECE 3600 Homework SG1 Due: Sat, 2/15/25

1. a) List at least 3 different synchronous motor speeds in the US, in rpm.

   b) List at least 3 different synchronous motor speeds in a country with 50-Hz power, in rpm.

   c) Could a motor designed to operate from 60-Hz power safety operate at 50 Hz? If yes, should you modify other operational parameters of the motor? Specify what parameters should also change and by how much.

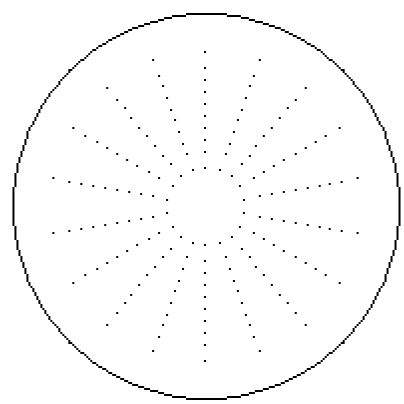
2. Generators are designed differently depending on the mechanical power source.
   a) Name 2 mechanical power sources typically used to drive 2-pole generators?

   1. 2.

   b) Name a mechanical power source typically used to drive 4-pole generators?

   c) Name a mechanical power source typically used to drive 10-pole generators?

3. In a 6-pole machine, what are the 6 poles?
   Show them on as magnetic field vectors.



4. A hydro-electric turbine and generator is 90% efficient. The "head" is 100 ft. That means the surface height of water is 100 ft (30.48m) above the turbine. How much water must flow through the turbine to produce 10MW of electrical power?

$P_{out} := 10 \cdot MW$ $100 \cdot ft = 30.48 \cdot m$ $g = 9.807 \cdot \frac{m}{sec^2}$ Density of water = $\rho := 1 \cdot \frac{kg}{liter}$ $1 \cdot ft^3 = 28.317 \cdot liter$

$watt = 1 \cdot \frac{joule}{sec} = 1 \cdot \frac{N \cdot m}{sec}$

5. Your 2-pole generator is producing 120MW of electrical power. Assume it's ideal, so there are no mechanical or electrical power losses in the generator.

a) Find the shaft speed in both rad/sec and rpm. givens $f := 60 \cdot Hz$ $N_{poles} := 2$ $P_{3\phi} := 120 \cdot MW$

b) how many hp does the mechanical power source provide? $1 \cdot hp = 745.7 \cdot W$

c) How much torque is being applied to the input shaft?

d) Find the required shaft diameter for a 2x factor of safety. Material & mechanical properties are given below.

Yield strength of high-quality carbon steel = $\sigma_{yield} := 400000000 \cdot \frac{N}{m^2}$

Shear yield stress = $\tau_{yield} := 75 \cdot \% \cdot \sigma_{yield}$ $\tau_{yield} = 3 \cdot 10^8 \cdot \frac{N}{m^2}$

For a 2x factor of safety, do not exceed $1.5 \cdot 10^8 \cdot \frac{N}{m^2}$ torque

Moment of Inertia of cylindrical shaft = $J = \frac{\pi}{2} \cdot r^4$ r = radius of the shaft (in meters) $1 \cdot m = 39.37 \cdot in$

Shear stress $\tau = \frac{T_{mech} \cdot r}{J}$ For a 2x factor of safety, do not exceed $\tau = 1.5 \cdot 10^8 \cdot \frac{N}{m^2}$

e) The prime mover of this generator is a steam turbine. The turbine is part of a 40% efficient Rankine cycle How much natural gas are you burning per hour (in cubic feet)?

A "therm" is approximately equivalent to 100 cubic feet of gas and provides about 100,000 BTU .

$1\,BTU = 1055 \cdot joule$ (British Thermal Unit)

f) Natural gas costs about \$3 per decatherm (ten therm) or MMBtu (one million BTU).
How much are you spending on natural gas per hour? Per day?

e) If you sell the electrical power for 6 cents per kWh (1000 Watt-hours), what is your gross revenue per day?

g) How much heat energy must you get rid of every hour?

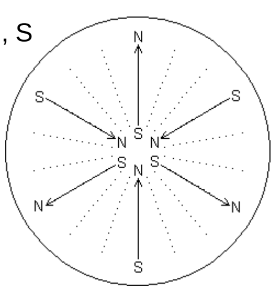
h) According to the Pacific Gas and Electric Company emissions rate, burning natural gas produces, on average, 13.45 pounds (6.1 kg) of carbon dioxide per therm. How many pounds of CO_2 are you producing each hour?

Answers

1. a) $\frac{3600 \cdot \text{rpm}}{\text{any\_integer}}$ b) $\frac{3000 \cdot \text{rpm}}{\text{any\_integer}}$ c) Yes, but derate voltage and motor power by factor of $\frac{5}{6}$

2. a) Gas-turbine Steam-turbine b) Piston-based internal combustion engine c) Hydro-turbine

3. N, S, N, S, N, S



4. $37.2 \cdot \frac{\text{k} \cdot \text{liter}}{\text{sec}} = 1300 \cdot \text{cfs} = 2600 \cdot \frac{\text{acre} \cdot \text{ft}}{\text{day}}$

5. a) $377 \cdot \frac{\text{rad}}{\text{sec}}$ $3600 \cdot \text{rpm}$ b) $161 \cdot \text{k} \cdot \text{hp}$ c) $318 \cdot \text{kN} \cdot \text{m}$

d) $8.7 \cdot \text{in}$ e) $1\text{million} \cdot \frac{\text{ft}^3}{\text{hour}}$ f) \$3.1k/hour \$74k/day

e) \$173k/day g) $614 \cdot \text{M} \cdot \text{BTU}$ h) $138 \cdot \text{k} \cdot \text{lb}$