NPRE 477
NPRE 498ESU
NPRE 498ESG
Energy Storage Engineering
Fall 2023

Online Temporary Alternative Coverage and access during Covid-19 Pandemic and possible resurgence through mutations and variants

1. Please read the assigned-reading lecture-notes chapters.
2. Then answer the corresponding written assignment,
3. For questions about the assignments, please access the teaching assistants by email:
https://www.mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/talist.htm
4. Submit the corresponding written assignment through email to https://canvas.illinois.edu
5. Please use either the Word or pdf formats
6. In case of internet "rationing" (e. g. to health and government authorities), instability, or collapse through overload, please read the lecture notes and submit the corresponding assignments. Already-taken tests and submitted assignments would be used in assessing the final grade.

Threat of Nuclear War:
https://www.youtube.com/watch?v=M7hOpT0lPGI

Regrettably, some 3,278 colleges and universities across the USA have been impacted by the Covid-19 pandemic, with many temporarily closing their campuses and switching to online classes, affecting more than 22 million students.
To all and everyone we wish good health and well-being.

<table>
<tr><th>Number</th><th>Date Assigned</th><th>Due Date</th><th>Description</th></tr>
<tr><td>1</td><td>8/21</td><td>8/28</td><td>Reading Assignment
Preface
Written Assignment
Using a Ragone plot, compare the following energy storage options:
1. Chemical storage using Li-ion batteries,
2. Fuel cells using hydrogen as an energy carrier.

Using the table, estimate the needed rated power for a solar or wind energy installation to provide the power needs for a family of four in different countries, assuming the presence of a capability to store the energy in battery banks, an overall conversion efficiency of 30 percent, and an intermittence (capacity) factor of 40 percent for both wind and solar.
<table>
<tr><th>Country</th><th>Energy consumption
[kWe.hr / (capita.year)]</th></tr>
<tr><td>USA</td><td>12,878</td></tr>
<tr><td>Japan</td><td>7,432</td></tr>
<tr><td>Switzerland</td><td>7,206</td></tr>
<tr><td>Germany</td><td>6,027</td></tr>
<tr><td>Hong Kong</td><td>4,847</td></tr>
<tr><td>China</td><td>1,899</td></tr>
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2	8/23	8/30	**Reading Assignment** Preface **Written Assignment** Draw a diagram for the Internet of Things (IoT) envisioned for energy systems showing its components and the interconnections between them. Construct a table showing the allocation of electrical energy production, storage (pumped), export and use on a given day at two different times of the day. Use the link: Energy mix in electrical production, France **https://www.rte-france.com/en/eco2mix/eco2mix-mix-energetique-en** or: **https://www.rte-france.com/en/eco2mix/power-generation-energy-source**
3	8/25	9/1	**Reading Assignment** Preface Introduction **Written Assignment** List the characteristics of a viable energy Storage System. List the advantages of energy storage in conjunction with renewable and conventional Energy systems. An electrical storage battery is charged from a power supply at 1 kW for an hour. If its efficiency is 60 percent, how long would it take to totally discharge it if it used to supply a load at 100 Watts?
4	8/28	9/4	**Reading Assignment** **1. Energy Storage Options** **Written Assignment** To produce Hydrogen as an energy carrier, balance the thermos-chemical reactions used in the high temperature Iodine Sulfur (IS) hydrogen production process: $2H_2SO_4 \rightarrow 2H_2O + ? + O_2$ $2I_2 + ? + 4H_2O \rightarrow 4HI + ?$ $4HI \rightarrow 2H_2 + ?$ ____________________ $2H_2O \rightarrow 2H_2 + ?$ In the simple pendulum without friction, energy that is stored as potential energy at the top of its stroke ($E_p = mgh$) is transformed into kinetic energy at the bottom of the stroke ($E_k = \frac{1}{2} mv^2$), then back as potential energy in a cyclic manner. 1. For a stored potential energy of 1 joule what would be the speed v of a 1 kg pendulum at the bottom of its stroke? 2. To what height h will the pendulum rise at the highest point in its stroke?
5	8/30	9/6	**Reading Assignment** Solar Thermal Power and Energy Storage Historical Perspective **Written Assignment** Henry E. Willsie identified the major weakness of all the previously built solar engines in their inability to overcome the intermittency problem of solar radiation. As an energy storage medium, he used large flat-plate collectors that heated water, which he kept warm all night in a large, insulated basin.

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Identify the working medium that he used to extract the stored solar energy.
What was earlier pioneer Charles Tellier' s choice?

In the Concentrated Solar Power (CSP) projects shown in the following table, calculate the corresponding idealized Carnot Cycle efficiencies.
Rank the thermal energy storage media according to the achievable thermal cycle efficiency.
<table>
<tr><th rowspan="2">Project</th><th rowspan="2">Type</th><th rowspan="2">Storage medium</th><th rowspan="2">Cooling loop</th><th colspan="2">Nominal temperature [ºC]</th></tr>
<tr><th>Cold</th><th>Hot</th></tr>
<tr><td>Irrigation Pump Coolidge, Arizona, USA</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>200</td><td>228</td></tr>
<tr><td>IEA-SSPS Almeria, Spain</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>225</td><td>295</td></tr>
<tr><td>SEGS I Daggett, California, USA</td><td>Parabolic Trough</td><td>Oil</td><td>Oil</td><td>240</td><td>307</td></tr>
<tr><td>Solar One Barstow, California, USA</td><td>Central Receiver</td><td>Oil
Sand
Rock</td><td>Steam</td><td>224</td><td>304</td></tr>
<tr><td>CESA -1 Almeria, Spain</td><td>Central Receiver</td><td>Molten salt</td><td>Steam</td><td>220</td><td>340</td></tr>
<tr><td>THEMIS Targasonne, France</td><td>Central Receiver</td><td>Molten salt</td><td>Molten salt</td><td>250</td><td>450</td></tr>
<tr><td>Solar Two, Barstow, California, USA</td><td>Central Receiver</td><td>Molten salt</td><td>Molten salt</td><td>275</td><td>565</td></tr>
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<td>6</td>
<td>9/1</td>
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Reading Assignment
Solar Thermal Power and Energy Storage Historical Perspective
Written Assignment
Calculate the theoretically achievable Carnot cycle efficiencies for the following liquid thermal energy storage media used in solar thermal applications
<table>
<tr><th rowspan="2">Storage medium</th><th colspan="2">Operational Temperature</th></tr>
<tr><th>Cold [ºC]</th><th>Hot [ºC]</th></tr>
<tr><td>Mineral oil, liquid petroleum (alkanes, cyclic paraffins, petroleum jelly)</td><td>200</td><td>300</td></tr>
<tr><td>Synthetic oil, polyalphaolefin, synthetic</td><td>250</td><td>350</td></tr>
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<tr><td>esters, hydrocracked/hydroisomerized base oils.</td><td></td><td></td></tr>
<tr><td>Silicone oil, polymerized siloxanes, …Si-O-Si-O-Si…</td><td>300</td><td>400</td></tr>
<tr><td>Nitrite salts, KNO_2, $NaNO_2$</td><td>250</td><td>450</td></tr>
<tr><td>Nitrate salts, $NaNO_3$, KNO_3</td><td>265</td><td>585</td></tr>
<tr><td>Carbonate salts, Na_2CO_3</td><td>450</td><td>850</td></tr>
<tr><td>Liquid Na</td><td>270</td><td>530</td></tr>
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<td>7</td>
<td>9/6</td>
<td>9/13</td>
<td>Reading Assignment
3. Thermal Energy Storage
Written Assignment
Classify CSP plants according to their operational conditions.

List the eutectic mixtures considered for thermal energy storage.

Compare the heat capacities and heat of fusion of energy storage materials used in flat-plate solar collectors.</td>
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<td>8</td>
<td>9/8</td>
<td>9/15</td>
<td>Reading Assignment
4. Thermal Energy Storage with Solar Power Generation
Written Assignment
List then compare the options considered for Concentrated Solar Power Generation, CSP.

List the reflecting materials used in CSP applications.

Define the Concentration Ratio CR in solar CSP applications.

List the types of tracking in CSP applications.

List the choices of collector glazing materials in CSP applications.

Draw a diagram showing the favored energy storage strategy in CSP applications.</td>
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<td>9</td>
<td>9/11</td>
<td>9/18</td>
<td>Reading Assignment
5. Battery Technology
Written Assignment

In the SI system of units, compare the units of the following figures of merits used to compare storage batteries:

1. Specific Energy,

2. Specific Power,

3. Energy Density,

4. Power density.

Compare the different options under consideration for a future fleet of Electrical Vehicles (EVs).
Describe the different usages of battery storage technology in:
1. Hybrid Electric Vehicles, HEVs,
2. Plug-in Hybrid Electric Vehicles, PHEVs,
3. Electric Vehicles EVs.</td>
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10	9/13	9/20	**Reading Assignment** 6. Electric Vehicles Technology **Written Assignment** Compare the specific energy content of hydrogen and of lithium-ion batteries as energy storage media in automotive energy storage options. Compare a vehicle weight using hydrogen fuel cell vs. Li-ion batteries as a function of the attainable cruising range. Compare the material compositions (other than Li) of the following Li -ion batteries: 1. LCO 2. NCA 3. LMO 4. NMC How do the LCO batteries differ from the other types?
11	9/15	9/22	**Reading Assignment** 7. Energy Hydrogenation and Decarbonization **Written Assignment** Write a one-page summary of the paper discussed in the class: Rachel Beck and Magdi Ragheb, "Production of Carbon-Neutral Hydrocarbons From CO_2 and H_2 In Lieu of Carbon Capture and Storage (CCS)," 10th International Conference on "Role of Engineering Towards a Better Environment, RETBE14, Alexandria University, Faculty of Engineering, 15-17 December 2014. Write down the equations describing the production of green diesel fuel from carbon dioxide and hydrogen. Write down the two half equations and their combination describing the operation of a typical fuel cell.
12	9/18	9/25	
13	9/20	9/27	

Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.
The first five minutes of the class period will be devoted for turning in, and returning graded assignments.
Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more.
If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be emailed to TA's, but face-to-face interaction is more beneficial.
Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning, and are unacceptable.
For further information, please read the detailed assignments guidelines.