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רשימת נושאים עבור פרויקט גמר לשנת לימודים 2020 - 2021

1. **תכן של מערכת משולבת המורכבת ממערכת פוטו-וולטאי המספקת חשמל למתקן יצור מימן דחוס עבור תאי דלק.**

פרויקט כולל תכן קונספטואלי של מערכת פוטו-וולטאי, תכן קונספטואלי של מתקן ליצור מימן דחוס ומערך תאי דלק שמשתמשת במימן דחוס כדלק. עבור פרטים נוספים נא ליצור קשר עם מנחה הפרויקטים (בוריס לאש).

2. **תכנון ואנליזה של מערכת אגירת "קור" לצילרים בעל צריכת הספק חשמלי גבוה.**

פרויקט כולל תכנות ואנליזת ביצועים של מערכת אגירת קור המבוססת אל ספיקה ושחרור האנרגיה תרמית תוך כדי שינוי מצב צבירה של חומר הממלא את נפח של מאגר קור. טענים את מאגר קור בזמן כאשר צילר חשמלי נאלץ לעבוד לפי תעריף חשמל נמוך יותר ודרישה להספק קירור גם יורדת. בתקופת היום כאשר תעריף חשמל עולה וגם דרישה להספקת קירור מים או אוויר היא בשיא, פורקים את מאגר "קור" וחוסכים כסף על צריכת חשמל ע"י צילרים חשמליים.

3. **תכנון ואנליזת ביצועים של מערכת מיזוג אוויר ובקרת קלים מסחרית/תעשייתית בעל מקדם ביצוע גבוה.**

פרויקט ייכלל תכן מערכתי ואנליזת ביצועים (כולל חישובים כלכליים) של מערכת מיזוג אויר ובקרת לחות בבניין מסחרי או תעשייתי. אחד מהדרישות למערכת זה יכול לבקר על טמפרטורת שונות במרחבים הסמוכים בזמנית עם דרישות שונות ללחות יחסית. יש לבצע את אופטימיזציה של התכן על פי פשרה בין נצילות ועלות המערכת.

4. **תכנון של התקני תמיכה מכנים והידראוליים עבור מאייד או משכן של קולט שמש בתחנה תרמו-סולרית.**

פרויקט כולל תכן מכני של מנגנוני תמיכה, אנליזת מעבר חום, אנליזת מאמצים, התעייפות תרמית וערכת עורך חיים של המבנה בתנאי תפעול הקיימים.

5. Design of Molten Carbonate Fuel Cell (MCFC) System for Cogeneration of Electricity & High Level Heat Using Compressed Hydrogen Fuel from Electrolysis Process

Project goal:

1. Using the latest technological advancements in Molten Carbonate Fuel Cell with solid ion exchange medium (that replaced liquid electrolyte) to design fuel cell module working on gaseous fuel (natural gas, methane, biogas, etc.) that generates 500 kW electricity and produces high level heat capable of heating air to about 1000 C.
2. To perform economic assessment of this technology.

Why Molten Carbonate Fuel Cells?

The MCFC offers high electric energy conversion efficiency (about 50 % based on the Lower Heating Value of natural gas) in a simple cycle configuration, so that it can significantly reduce the exploitation of non-renewable able energy sources. In addition, for equal power production, a high efficiency is translated into reduced carbon dioxide emissions.
The latest MCFC operates at about 1000°C, thus, differently from low temperature fuel cells, no precious metal is required as the fuel catalyst. Together with production cost saving, the main consequence of this is that carbon monoxide is not a poisoning element, but, on the contrary, that it can be used as a fuel. This allows the utilization of a variety of CO-containing fuels, such as hydrocarbons, syngas derived from biomass or coal, landfill gas, gas obtained from industrial or agricultural by-products.

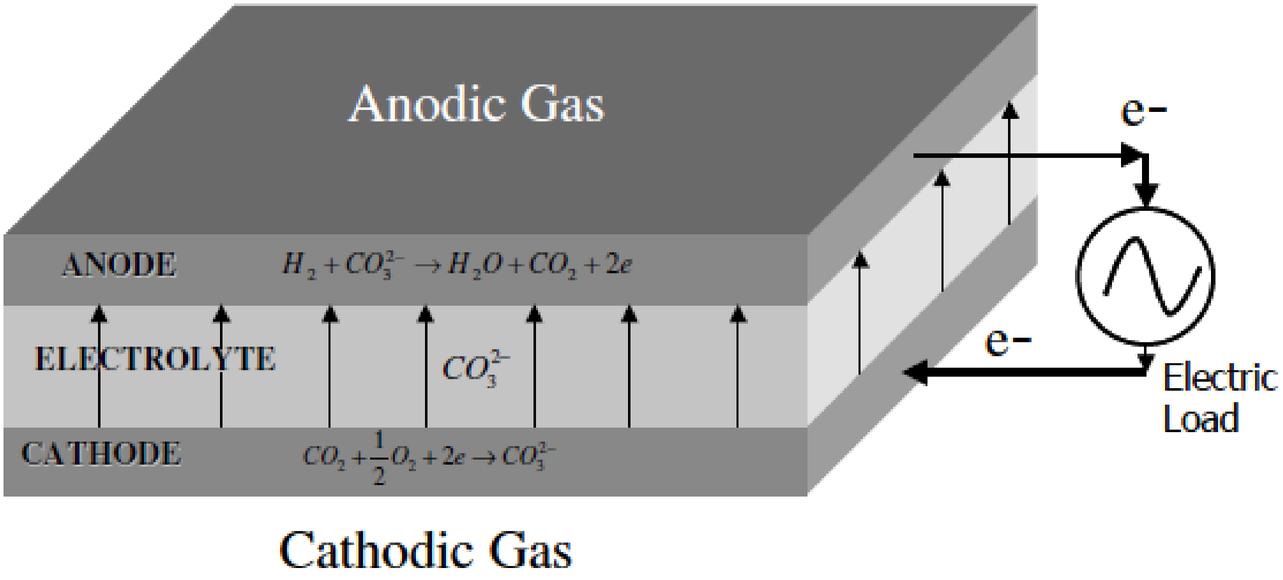

Figure A1. Schematic representation of a MCFC

The partial pressure of CO_2 is not necessarily the same in the cathode and in the anode, thus the Nernst equation, providing the ideal voltage, is the following:

$$E = E^0 + \frac{RT}{2F}\ln\frac{P_{H_2}P_{O_2}^{0.5}P_{CO_{2,cathode}}}{P_{H_2O}P_{CO_{2,anode}}} \qquad \text{(A4)}$$

where E^0 is the voltage at standard pressure, R, T, F are, respectively, the universal gas constant, the temperature and the Faraday constant, while P_i is the partial pressure of the i^th chemical species.

Materials state of the art

The materials typically used for manufacturing an MCFC are: Nickel-Chromium or Nickel-Aluminum for the anode, NiO Lithiate for the cathode, Li_2CO_3/K_2CO_3 for the electrolyte, and α-$LiAlO_2$ or γ- $LiAlO_2$ for the matrix ([13, 15, 16]).
In order to improve the cell performance and durability, as well the tolerance of some chemical substances, present in most of the fuels, alternative materials or particular treatment can be adopted.
As an example, $LiNixCo1\text{-}xO_2$ or coated nickel cathode can be considered as alternatives to the typical NiO Lithiate

6. Development of GT combined cycle new start-up procedure which reduces fatigue damage of HRSG and fuel consumption

Brief review of conventional start procedure of combined cycle

Conventional start procedure of combined cycle begins by gas turbine ventilation on crank rotation (about 500 rpm) during about 10 minutes. After the ventilation, fuel ignition is initiated in combustor(s) of gas turbine. At this moment a temperature of flue gases in gas turbine exhaust rises sharply from about 30ºC up to about 450ºC. During 3-5 minutes after the ignition, gas turbine rotation increases from crank speed (about 500rpm) to 3000 rpm – the synchronization speed. During these 3-5 minutes the exhaust temperature reduces by about 100ºC.

After gas turbine generator synchronization, gas turbine increases its output up to its minimum environmental load (the minimum load with low emissions, usually 40-50% of nominal load) by about 5-10 minutes. During this time the exhaust temperature increases from about 350ºC to about 500ºC. Gas turbine stays at this load until HRSG heats up and produces a stable steam flow through super-heater and re-heater, and steam turbine reaches synchronization speed. At this moment (in the case of multi-shaft configuration when steam turbine has its own electrical generator), the steam turbine generator is also synchronized. After this moment, both gas turbine and steam turbine raise their load up to their nominal load.

The gas turbine operation at minimum load (during HRSG and steam turbine heating up process) could take up to 90-100 minutes during a cold start, or 30-45 minutes during hot start.

This start procedure has two major drawbacks:

1. HRSG tubes suffer from sharp changes of inlet flue gas temperatures, which results in their thermal fatigue damage and, consequently, reduction of their life.
2. Prolonged stay of gas turbine on minimum load with extremely low efficiency results in high fuel consumption during combined cycle start procedure.

Proposed new technology:

Preliminary gradual heating-up of HRSG and steam turbine before the gas turbine ignition provides a significant reduction of the thermal fatigue damage during combined cycle start procedure.
Preliminary heating-up of HRSG shortens gas turbine start procedure, specifically operation on minimum load, and thus reduces fuel consumption during combined cycle start procedure.
The preliminary heating-up is provided by in-duct burners, which are installed upstream of HRSG and use the air flow provided by the gas turbine operating on crank speed.

The project implementation steps:

1. Survey of start-up procedures of single-shaft and multi-shaft combined cycles
2. Survey of thermal fatigue correlation to metal temperature fluctuations.
3. Development of flue gas turbine exhaust flow-temperature model during combined cycle start procedure.
4. Development of HRSG heat transfer model during combined cycle start procedure using finite element method and performing subsequent thermal stress analysis.
5. Assessment of HRSG thermal fatigue damage during combined cycle start procedure
6. Comparative analysis of the existing and proposed combined cycle start-up procedures
7. Development of conceptual design of the system for preliminary heating-up of HRSG.

Minimum requirements for graduate students:

1. Solid knowledge of thermodynamics and heat transfer.
2. Basic knowledge of thermal fatigue principles
3. Familiarity with design and operation principles of Heat Recovery Steam Generator
4. Basic knowledge of cost - benefit analysis (engineering economics)

7. Integration of Liquefied Air Energy Storage (LAES) with Gas Turbine Combined Cycle as a Tool for Cost-Effective Stabilization of Electrical System under Large Scale Renewable Energy Implementation.

Background: The economics of contemporary power generation dictates the necessity of fast response on the part of electrical utility to changes in demand for power. Peaking gas turbines operating most of the time in spinning reserve at minimum capacity could provide that, but their thermal efficiency is fairly low, also the cost of operating these turbines in spinning reserve is also very high and should be avoided whenever is possible. Combine cycles in spite of optimistic expectations, demonstrated limited capability of providing fast response to sharp changes in power demand. Also, when combine cycle operates on partial load, its efficiency significantly deteriorates. The operating experience of the last 15 to 20 years proved that combined cycles are much more effective and reliable in the base load operation than in the peaking or semi-peaking regimes. More rapid and cost-effective response to fast increase in power demand can be provided by liquefied air thermal energy storage (LAES).

Liquefied air thermal storage consists of quasi-isothermal compression train of several compressors and intercoolers assembled in sequence. This train compresses ambient air during the charging mode of operation. Compressed air flows to a series of packed bed towers containing small mineral solids that extract thermal energy from compressed air and store it. The last in the sequence of packed bed towers is kept initially at cryogenic temperature. When compressed air flows through cryogenic packed bed, its temperature steadily drops to the point of liquefaction (-186 C at 50 bar). Air exits cryogenic packed bed as a liquid at 50 bar and - 188 C. It is further expanded in cryogenic turbo-expander to the pressure level of 1.9 bars and temperature -193 C, and then directed to an insulated storage tank. During the discharge mode of operation liquid air exits the tanks, passes through the pump and the same sequence of packed beds in opposite direction, gains additional heat in the heat exchanger that uses waste heat from external source and finally enters the gas turbine - generator set that provides electric power back to the grid.

Proposed new technology: Integration of liquefied air energy storage (LAES) with gas turbine combined cycle (GTCC)

Integration of large scale energy storage with existing or new gas turbine combined cycle (GTCC) plant provides a proper loading of GTCC without shut downs for the periods of low demand for power or excessive load modulation during the day time and evenings. During the period of low demand for power energy storage accumulates energy produced by GTCC and stores it until demand for electricity in the grid sharply rises. At that moment energy storage discharges power back to the grid in parallel with the GTCC.

LAES should be sized in such way that in addition to its major function of energy charging and discharging device it could provide enough cold liquid air for cooling compressor inlet air (for GT power augmentation purposes) and condensing process in a bottoming cycle condenser. The latter will boost the efficiency of GTCC. This is additional feature of LAES - GTCC integration.

Due to strict environmental regulations the increase in solar and wind power production usually comes at the expense of fossil power production (from burning gas and coal). So, if power generating system includes significant solar or wind power capacity the latter will always get higher priority when power authority decides which power plant shall supply electricity to the grid first. This means that when high demand for power coincides with the period of solar or wind power availability, natural gas fired combined cycles and coal fired units must reduce their power production accordingly. It brings fossil power plants of all types into ineffective partial load operation or shut downs dictated by economic consideration. It increases the cost of power production from conventional power plants and reduces their reliability as well as time intervals between costly inspections of major equipment (increased O&M cost).

The presence of the integral LAES in the power generating system can alleviate this problem. When demand for fossil power substantially drops GTCC and coal fired units can supply part of their power output to LAES. That will keep their operating load at a relatively higher level with all the benefits of operation at high loads. Again, when demand for electricity rises toward the peak level, LAES will discharge electric power back to the grid at prices significantly higher than those that existed during the period of LAES charging.

The project goals:

7. Development of computerized model simulating operation of power generation system (including start-ups and shutdowns) which consists of coal-fired units, combined cycles, solar power plants and LAES facilities. Power generation capacity of each plant and LAES is yet to be determined. The model shall be based on realistic annual electricity demand curve.
8. Development of mass-flow-energy-emissions model of GTCC unit during its start-up, partial-load operation and shut down.
9. Techno-economic study of integration of LAES and GTCC units in comparison with shifting operation of GTCC alone.

Full implementation of the project requires two students.

Additional student can be accepted for development of project goal # 1 when solar power is replaced with wind power.

For a single student the project scope can be scaled down to development of project goal # 1 + cost benefit analysis for use of LAES.

Minimum requirements for students:

1. Good knowledge of thermodynamics and heat transfer.
2. Familiarity with conventional power plant principles of operation and performance of major equipment (turbines, compressors, steam generators and etc.)
3. Basic knowledge of cost - benefit analysis (engineering economics)
4. Basic programming capabilities using one of the following codes: FORTRAN, C, C++, Visual Basic, MATLAB