Dynamic Simulation, Control, and Design of a Novel Solar Thermal Hybrid Power Plant

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ABSTRACT

Solar power is among the promising technologies leading towards cleaner fuel. However, there are still technological challenges regarding the reliability of power generation due to its intermittency. Concentrated solar power (CSP) technologies, such as parabolic trough, can be integrated with natural gas [1] to ensure a reliable power supply, while also increasing the efficiency of the overall plant [2]. This work demonstrates the synergies that exist in integrated hybrid systems, where a dispatchable fuel is used in conjunction with CSP. In this simulation-based study, Therminol VP 1 is used as the heat transfer medium and a parabolic trough solar concentrator is used to collect solar energy, which is then used to power a Rankine cycle. The system relies on natural gas combustion in the steam generator to generate supplemental steam when the solar intensity is reduced due to cloud cover or at night. Natural gas is also used for superheating the steam, which allows the system to produce higher temperatures, resulting in an increased cycle efficiency. This flexible design produces 87 MW_e nominally and demonstrates that by hybridizing the system using a dispatchable fuel increases the solar to electric efficiency by 11 percent.

METHODS

Two models were developed from scratch
- Solar Hybrid Model
- Stand alone solar plant with Thermal energy storage

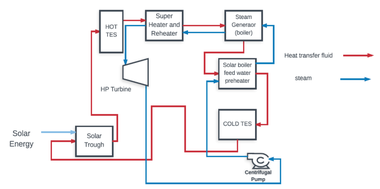
The basis of comparison were
- Therminol VP1 heat transfer fluid
- NREL solar data of Las Vegas (w/ m^2)
- Solar area 257250 m^2
- Typical day is chosen as May 30th
- Parabolic trough collector system
- Enough to power 3000 houses [4]

Figure : Solar trough systems[3]

HYPOTHESIS

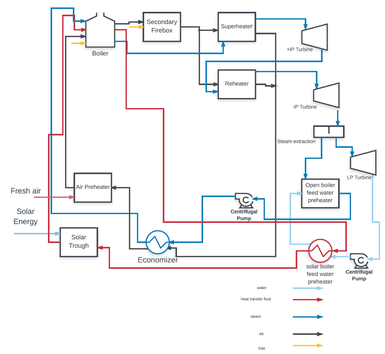
- Hybridizing the solar plant with gas gives the plant flexibility. Hence a hybrid design would increase the solar to electric efficiency

MODELLING



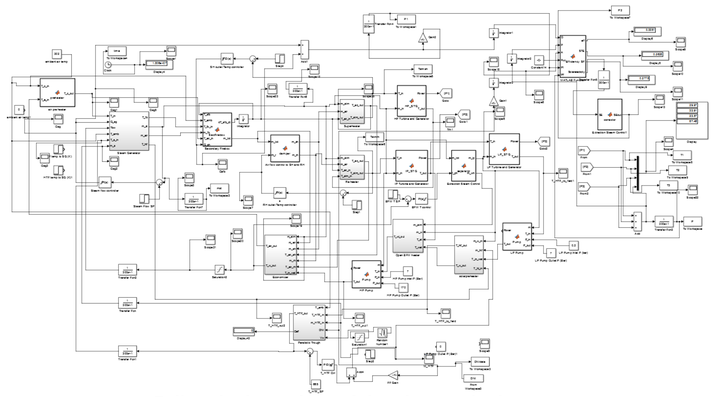
Stand-alone Solar Plant

Design:
- 8000 m^3 sized hot and cold thermal enegy storage is used
- One high pressure turbine is used for energy extraction.



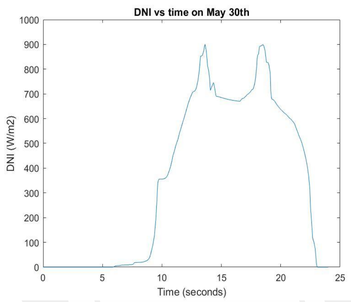
Process diagram of Solar Hybrid power plant

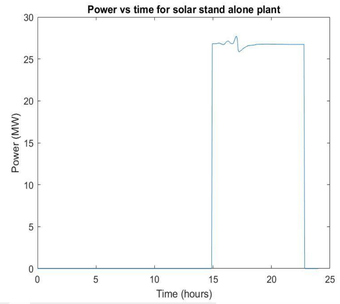
Design:
- Gas heating provides super heating potential of the steam
- Solar preheat to use the full potential heat from Therminol VP1
- Series of three turbines to extract energy.

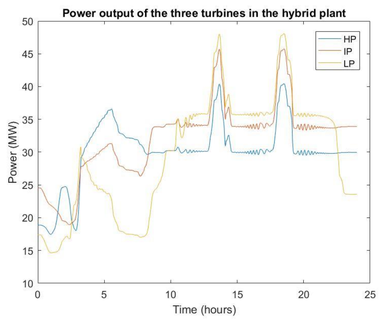


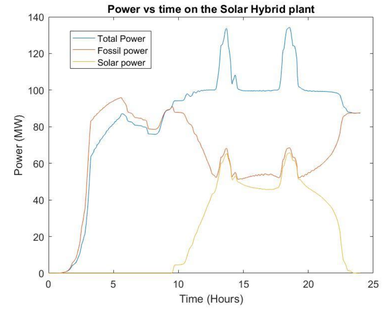
Full-scale dynamic model and control scheme

RESULTS/DISCUSSION









	Solar Fraction	Solar to electric efficiency (STE)	Overall Efficiency
Fuel Only	0%	0%	37%
Solar Only	100%	15%	15%
Hybrid System	13%	26%	34%

- Natural gas provides the ability for the reheater and super heater out put temperature at 824 k in the hybrid model
- The Solar stand alone plant produces around 25 MW for 7 hours when there's enough solar power available using thermal storage
- The super heated steam for the stand alone solar plant is maintained at 653 K which is significantly less compared to the hybrid plant
- DNI reaches a maximum of 900w/m2 on the particular day
- The Solar Hybrid plant provides around 87 MW continuously and excess at high output times

CONCLUSIONS

- Hybridization gives more reliable and efficient plant operation.
- The solar fraction of the energy produced in the hybrid plant is 13% of the total energy.
- Hybridization increased solar to electric efficiency. Efficiency increases from 0.15 to 0.26.
- The stand alone solar plant has a very low over all efficiency of the plant (15%)
- The efficiency of the hybrid system doesn't decrease much compared to the NG powered system alone.

REFERENCES

[1]J. H. Peterseim, S. White, A. Tadros, and U. Hellwig, “Concentrated solar power hybrid plants, which technologies are best suited for hybridisation?,” *Renew. Energy*, vol. 57, pp. 520–532, 2013.
[2]H. Hong, S. Peng, Y. Zhao, Q. Liu, and H. Jin, “A typical solar-coal hybrid power plant in China,” *Energy Procedia*, 2014.
[3] 1. https://prezi.com/bfvupaggrqcp/the-parabolic-trough/
[4] Source: http://www.slideshare.net/Ulsah1/biomass-supported-solar-thermal-hybrid-power-plant-59765804

ACKNOWLEDGEMENTS

- **Department of Chemical Engineering, University of Utah**