Development of a Solar Smoleniec/Stirling Hybrid Thermo-Mechanical Generator

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The Thermo-Mechanical Generator was invented by E.H. Cooke-Yarborough in 1967 and is an ingeniously simple and elegant heat engine operating on a Stirling thermodynamic cycle that can yield cogenerated electrical and thermal energy from moderately hot heat sources (200-500°C).

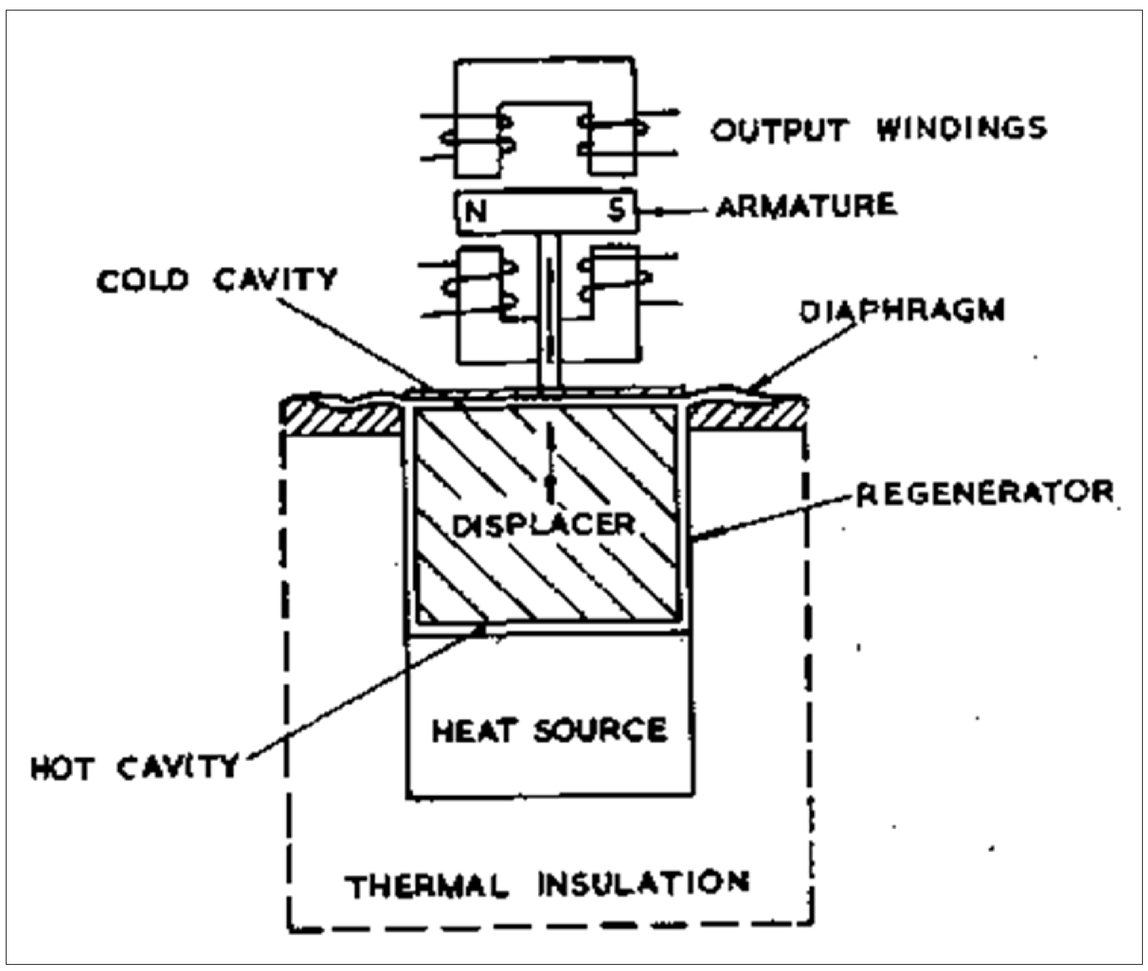
A new version of this heat engine has been invented by the Principal Investigator that is capable of operating off concentrated solar energy provided by inexpensive, acrylic Fresnel lenses. A key innovation in the technology is the use of a digital thermodynamic Smoleniec/Stirling cycle to optimize the performance of the heat engine in real time.

With an anticipated overall cogenerated (thermal and electrical) efficiency of at least 60% and a net cost of $1-2000 / cogenerated kW, the engine offers the potential of better performance than current hybrid solar photovoltaic/thermal collectors at a 3-fold or more reduction in cost.

This project is aimed at developing the invented technology into a prototype design that can be built and tested to determine whether its anticipated performance and cost advantages can be realized in practice. If realized, this hybrid solar thermal/electrical device offers the potential of a significant increment in the use of renewable solar energy in the building sector in particular.

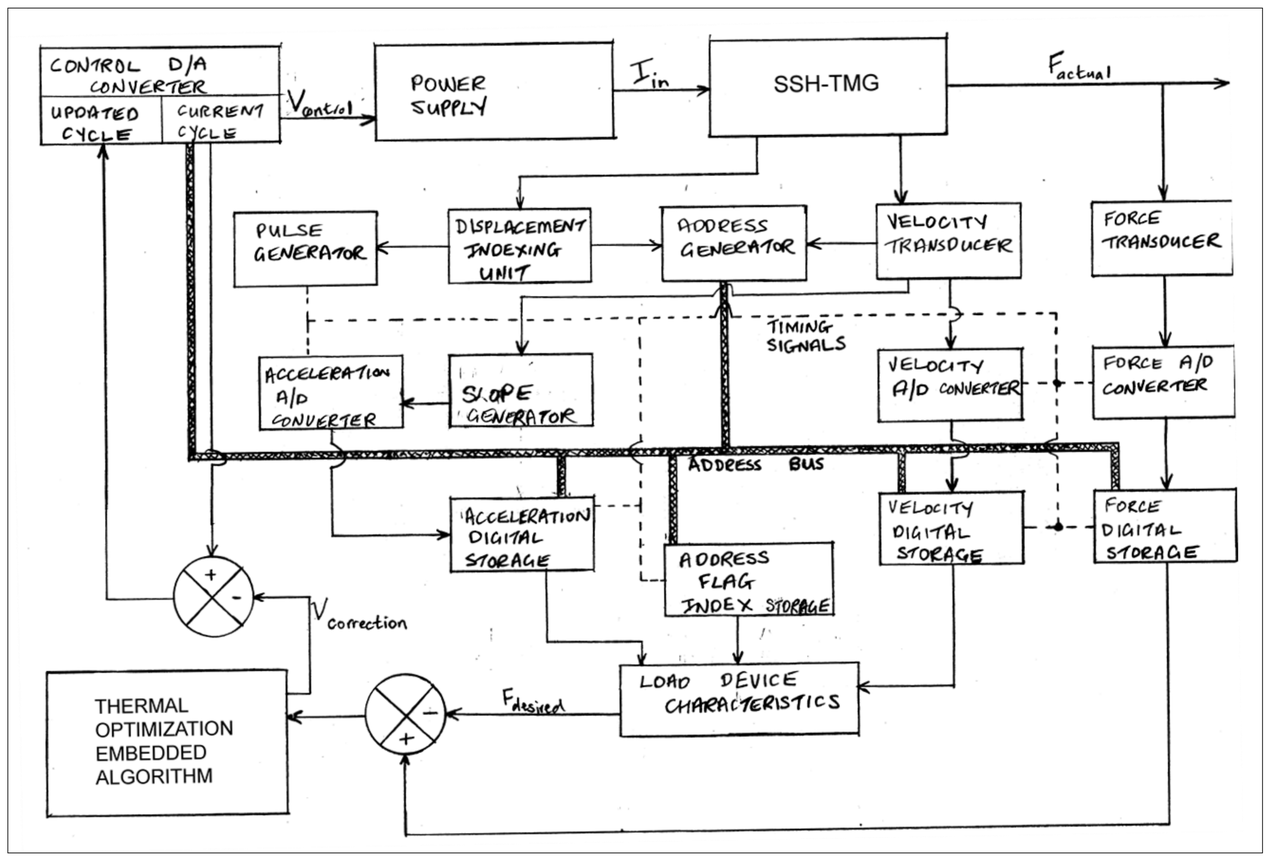
A prototype engine providing electrical power output via a linear alternator has been designed using a State-Space analysis technique that yields a closed-form solution ideal for establishing the overall engine power and operating characteristics. This solution has been exercised to establish the basic engine geometry and characteristics and to conduct an operating performance sensitivity analysis.

The design analysis has confirmed the technical viability of the invention as well as the existence of tractable control profile saddle-points. The analysis shows that the engine can achieve the target 1-2 kW electrical power output at physically reasonable piston and displacer strokes.



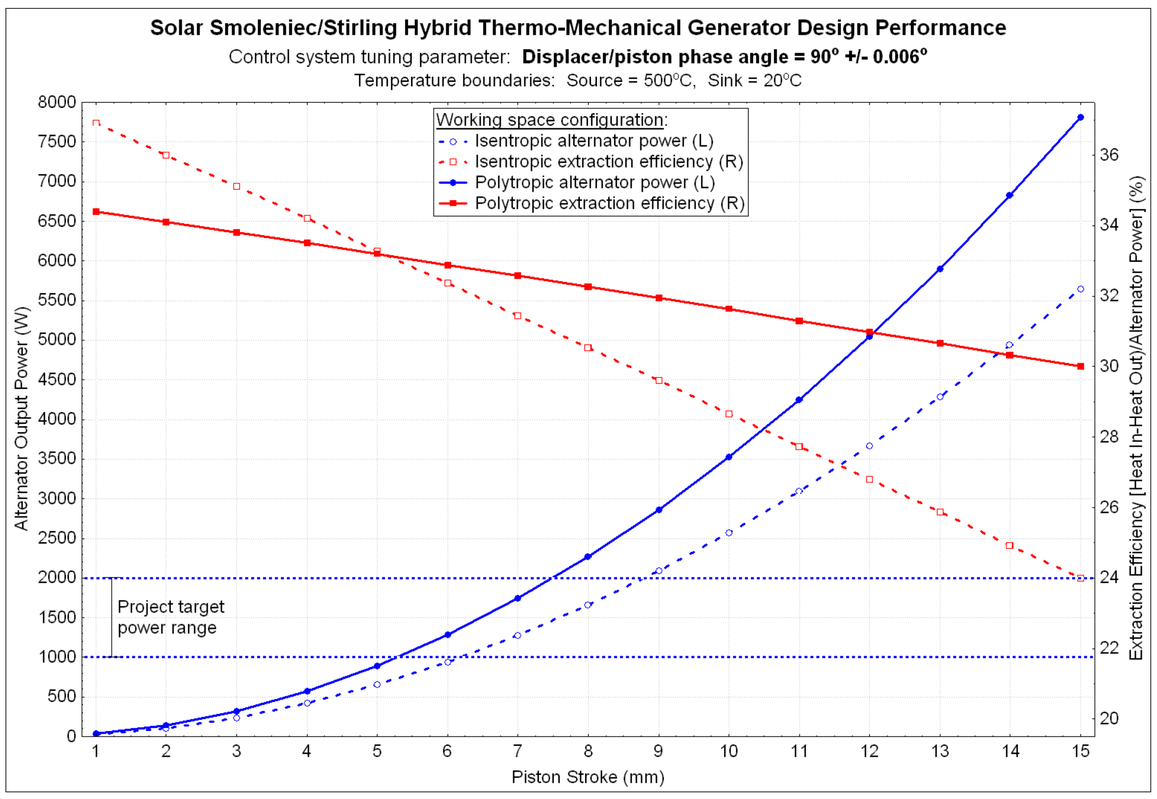
Classical Thermo-Mechanical Generator
(Cooke-Yarborough, 1975)

Preliminary control schematic
(based on Goldberg, 1985)

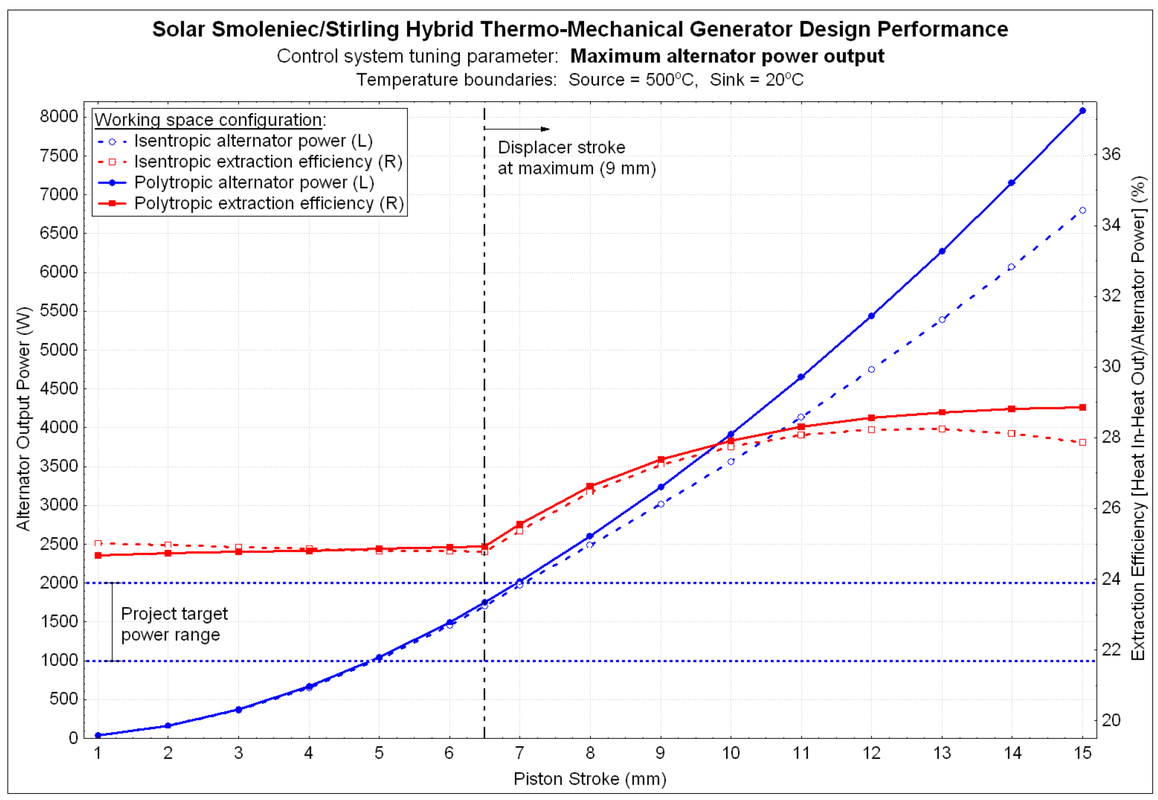


Solar Smoleniec/Stirling Hybrid Thermo-Mechanical Generator Design Performance

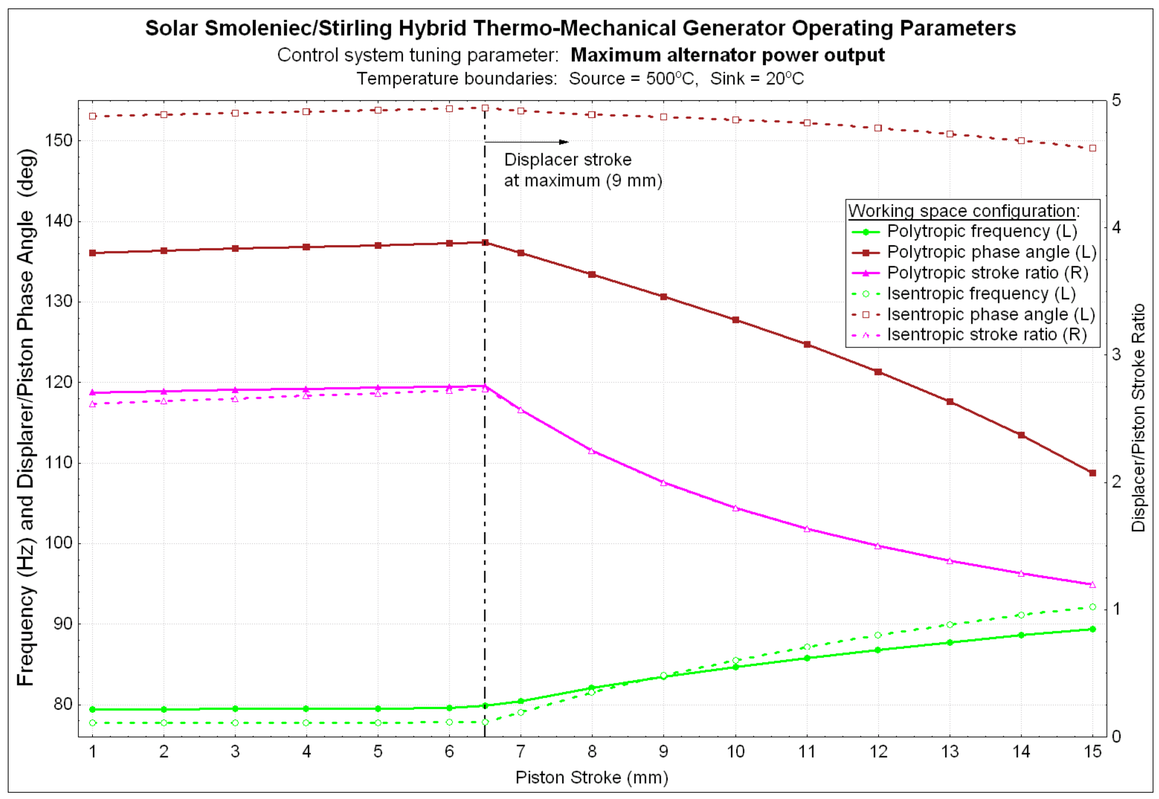
Engine controlled for maximum efficiency



Engine controlled for maximum power output



Note: The isentropic and polytropic profiles bound the performance of an actual engine.



Outline schematic of engine in solar tracking housing