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Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

Title of the research project: Organic Trilateral Flash Cycle for Efficient Conversion of Solar Heat to Power

Principal Investigator: Dr.-Ing Dimitris Manolakos, *Assistant Professor, Department of Natural Resources Management & Agricultural Engineering*

Reader-friendly title: SOL-art

Scientific Area: Energy and Environment

Institution and Country: Agricultural University of Athens (AUA), Greece

Host Institution: AUA, *Department of Natural Resources Management & Agricultural Engineering, Laboratory Of Farm Machine Systems*

Collaborating Institution: Ghent University (UGent), *Applied Thermodynamics and Heat Transfer (ATHT) Research Group*

Budget: 164000 €

Duration: 36 months

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Research Project Synopsis

The target of the project is the development of a small-scale (2-3 KW) thermal engine applying the Trilateral Flash Cycle (TFC) for power production by exploitation of the solar energy. The TFC is a promising alternative to the traditional Organic Rankine Cycle (ORC) for low-grade heat recovery. However, the complexity of, and the knowledge gap in the, inherent in the TFC, two-phase expansion is a limiting factor for its wide scale applicability.

In the context of the Research Project an in-depth computational analysis of the two-phase expansion will be performed. Simulation tools will be developed for the analysis of the two-phase expansion phenomenon, as well as the integrated thermal engine with solar energy as the heat source. Organic fluids and mixtures with negligible Global Warming Potential (GWP) and Ozone Depleting Potential (ODP) will be considered in the simulations. Moreover, the effect of the intermittence of solar energy on the efficiency of the TFC will be studied.

The computational analysis will provide design specifications for the manufacturing of a novel non-conventional two-phase expander, capable to handle two-phase flow and with a target value for the isentropic efficiency in the range 65%-70%.

The manufactured two-phase expander will be tested at the experimental facility of Ugent in order to acquire a detailed performance map under various operating conditions. Finally, the expander will be integrated into the existing Concentrated PhotoVoltaic-Thermal (CPV-T) test rig of the AUA. The solar collectors and the TFC technologies will be combined by the development of a control system aiming at the maximization of the integrated system efficiency for solar heat source at 80^0- 90^0 C.

Project originality

The novelty of the Research Project lies in the investigation, theoretical and computational, of the TFC, and the development of an integrated system combining the TFC with solar energy for efficient power generation.

Traditionally, the ORC has been implemented as a standard technology for low-grade heat recovery. However, the thermal efficiency of the ORC lies in the range 5-6% for heat supply in the order of 100^0 C, which is about 30% of Carnot efficiency. The TFC has been indicated as a promising alternative, because its implementation minimizes the irreversibilities generated during heat transfer from the heat source to the working fluid. The working fluid enters the expander in saturated liquid state and a sudden depressurization results in vapor generation and, subsequently, volumetric expansion.

Despite its promising prospect, the TFC has not been applied widely due to the lack of knowledge concerning the underlying physics of the two-phase expansion phenomenon in the volumetric expander, and the thermodynamic non-equilibrium associated with phase change. Moreover, experimental data about two-phase expansion in volumetric expanders are scarce.

In the Research Project, the two-phase expansion in volumetric expanders will be thoroughly investigated and computationally modeled, providing state of the art data. Moreover, the simulations will provide valuable input for the design and manufacturing of an efficient non-conventional two-phase expander. The experimental testing of the manufactured two-phase expander will also provide invaluable data to the scientific community.

Another novelty of the Research Project is the integration of the manufactured expander with a combined CPV-T system for the efficient production of power from solar energy as a heat source, a technology which has not been implemented so far.

Expected results & Research Project Impact

The anticipated impact of the Research Project on science is expected to be high, since a new research field, that of the full investigation of the TFC and its potential commercial implementation, will be initiated.

Concerning the economy, environment and society, the efficient utilization of solar energy mitigates the use of fossil fuels, thus leading to the reduction of harmful emissions and CO2. The achievement of more competitive electricity costs will boost the expansion of solar thermal systems; thus creation of new jobs is expected indirectly.

Even though the focus of the Research Project will be mainly on the combination of the TFC with solar energy as a heat source, the gained expertise on the specifics of two-phase volumetric expanders and their performance under varying operating conditions will provide valuable insight about the potential application of the TFC in various fields, such as:

- ***Rural electrification***
- ***Power supply in buildings***
- ***Industrial waste heat recovery***
- ***Solid biomass exploitation***

The importance of this funding

H.F.R.I. funding supports with adequate resources our research activities. It gives also the opportunity to young researchers to gain expertise in specific scientific fields, as those of Renewable Energy Technologies and Energy Efficiency, while doing their PhD thesis at the same time.

The 3 years project duration represents a time period adequate for researchers to get deeply into new disciplines and answer effectively relevant scientific questions.

H.F.R.I. funding will also give us the opportunity of upgrading our experimental infrastructure and produce a number of papers to be presented in high level international conferences and peer reviewed journals.

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