PV-GENERATOR LINKED TO A PISTON-TYPE STEAM ENGINE WITH COMBINED HEAT AND POWER AS A HYBRIDSYSTEM FOR A COMPLETELY SELF-SUFFICIENT ENERGY-SUPPLY

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ABSTRACT: To build up a completely self-sufficient energy-supply-system for summer/winter or mixed conditions including a photovoltaic system, an additional equipment for periods with low insolation is necessary, especially also for heating.
Aim of this research project is the development of a Power-Supply-System which enables a maximum exploitation of available primary energy with a highest possible portion of renewable energy.
One possible system to provide private households or interdepartmental industrial consumers with heat and electrical energy is a hybridsystem consisting of a photovoltaic with combined heat and power. Inherent to these applications is an annual average ratio of electrical and heat energy of nearly one to ten. Therefore the combined heat and power can be implemented by a piston-type steam engine.
Keywords: Stand-alone PV Systems - 1 : Hybrid - 2 : High-Efficiency - 3

1. INTRODUCTION

Aim of this paper is the presentation of a new hybridsystem with photovoltaic and combined heat and power realised by a piston-type steam engine (Fig. 1), which enables a completely self-sufficient energy supply for summer as well as for winter or mixed conditions. This method combines the advantages of the PV to produce electric energy without CO_2-production with the well known principle of combined heat and power with its high possible total efficiency.

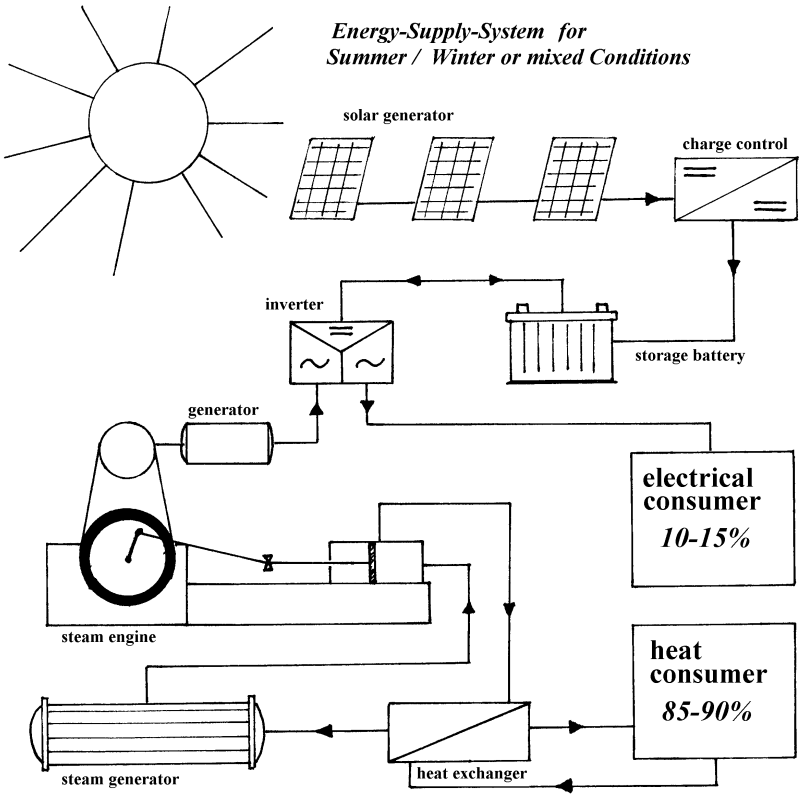

Figure 1: Simplified schematic diagram of the Hybridsystem

Theoretical and experimental investigations demonstrate the possibility to provide private households or interdepartmental industrial consumers with heat and electrical energy with this hybridsystem.
This could be done with a maximum exploitation of the available primary energy with a highest possible portion of renewable energy.
So it may be possible to achieve minimum CO_2-emissions.

2. APPROACH

To reach these aims, with the help of computational simulations, all necessary components of this system were defined and coordinated to each other to build up a process scheme. In advance of this, it was necessary to correlate the effects of the three stochastic parameters current consumption, heat consumption and insolation. Therefore extensive long-term measurements in addition to available publications concerning these parameters for average values as well as for the dynamic behaviour were made and systematically examined regarding seasonal variations. A control concept was developed to provide a gap free energy supply and to adjust the actually required ratio of electrical energy and heat with respect to the insolation.

FernUniversität building or to a 2.5 kW PV-Generator-Simulator. For piston-type steam engines the efficiency is nearly independent of the rotational speed at fixed steam temperature and pressure. So there is no significant change in physical conditions for partial load operation. The used steam generator supplies the steam engine with 6 bar saturated steam at 159°C.
One of the most important advantages of the piston-type steam engine is the highest possible degree of individual freedom for the choice of the fuel for the separated steam generator.
With respect to the mechanical efficiency (Fig. 2) of the steam engine of 10 -15%, this system is predestinated for energy consumer with an annual average ratio of electrical and heat energy of nearly one to ten.
The experimental experiences with the old machine together with modern mechanical engineering calculations with regard to the task of combined heat and power will finally result in helpful development tools for constructing an optimal machine for this purpose.
With a 3-5kWp photovoltaic linked to a piston-type steam engine for 5kW electrical energy for combined heat and power it is possible to provide an average private household completely self-sufficient with energy.
The photovoltaic is the main supply for electrical energy

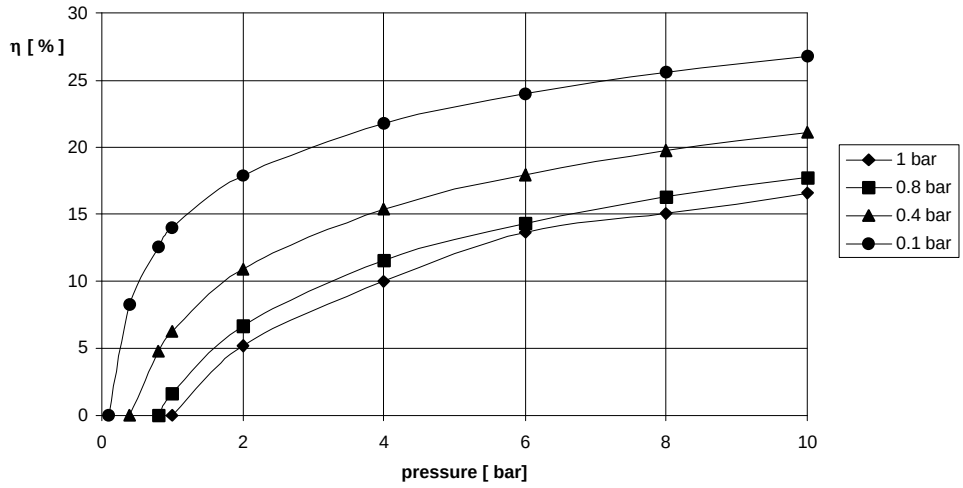

Figure 2: Thermodynamic efficiency dependent on steam and condenser pressure

A pilot plant of a hybridsystem consisting of photovoltaic linked to a combined heat and power with a piston-type steam engine was realised. Unfortunately nowadays it seems that there exists no manufactory for modern smaller piston-type steam engines up to 5 kW (only engines above 25kW).

3. THE HYBRIDSYSTEM

For experimental investigations, a pilot plant was built up with an old piston-type steam engine from the beginning of this century for approximately max. 2.5 kW, alternatively linked to the photovoltaic plant of the

in periods of high insolation whereas the combined heat and power system has the priority during heating periods.
A great advantage in the usage of steam for energy transfer is the possibility to use fuels from renewable resources with a maximum degree of freedom in choice. In comparison to the usual production of electrical energy with the usual efficiency of nearly 35% independent of the season, this hybridsystem could reduce the CO_2-emissions drastically. A grid-connected version is also possible. With respect to the average annual ratio of electrical power to heat of one to ten the achievable mechanical efficiency of the piston-type steam engine of 10-15% is advantageous for the developed energy management control system.

For the speed control of the shaft rotation, a regulated valve is implemented to throttle the inlet steam pressure. This influences the mechanical power as well as the momentary efficiency (Fig 3.). If the amount of heat passing through the engine would be lower than the consumption, a bypass is opened to connect the steam generator to the heat exchangers directly. In the contrary case a heat storage could help to equalise the deviations between heat production and consumption similar to the storage of the electrical energy.
The developed control system for this hybridsystem considers the three stochastic parameters current consumption, heat consumption and insolation and guarantees a gap free energy supply with the actually required ratio of electrical energy and heat with respect to the insolation.

Summarised it can be established, that this hybridsystem shows a good natured behaviour.
If this hybridsystem is optimised for a completely self-sufficient energy-supply it would not be difficult to prepare this also for a grid-connected operation mode.

4. CONCLUSIONS

This work shows the possibility to build up a completely self-sufficient energy-supply system with a photovoltaic plant linked to a combined heat an power with a piston-type steam engine. Theoretical as well as experimental investigations were done to determine all the necessary physical and technical parameters and their interactions which would be important for a successful practical realisation of such a hybridsystem by manufacturers. Inherent for the implementation in private households or for industrial consumers is an annual average ratio of electrical and heat energy of nearly one to ten or smaller.

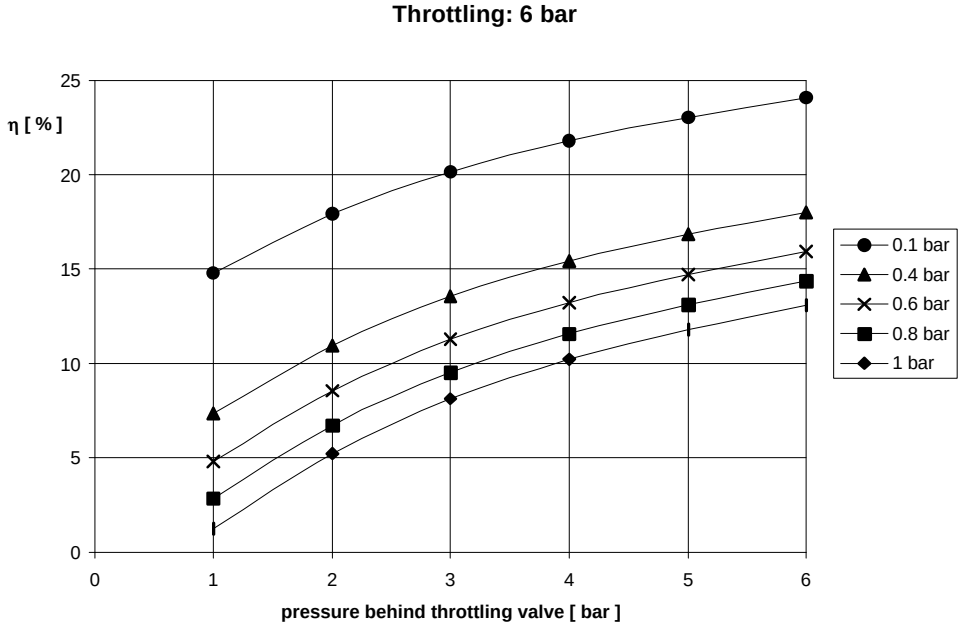

Figure 3: Influence of throttling on thermodynamic efficiency regarding condenser pressure

It could be shown, that it is possible to provide an average private household completely self-sufficient with heat and power by means of a 3-5kWp PV linked to a steam engine for 5kW with heat exchangers for hot water and radiation.
This system enables us to build up a standard system which includes all components with exception of the steam generator. The steam generator allows an individual freedom for the choice of the fuel with respect to the availability. It is desirable to use fuels from renewable resources.
Extensive measurements and investigations were made and are still necessary to optimise this system.
With these experiences it would finally be possible to give valuable development tools for a mechanical engineering manufactory to construct a modern steam engine for this purpose.
In comparison to a combined heat and power with an internal-combustion engine a great advantage of such a steam engine is also the nearly noiseless mode of operation.

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