Technical description

Hybrid drive of a heat pump with Stirling generator

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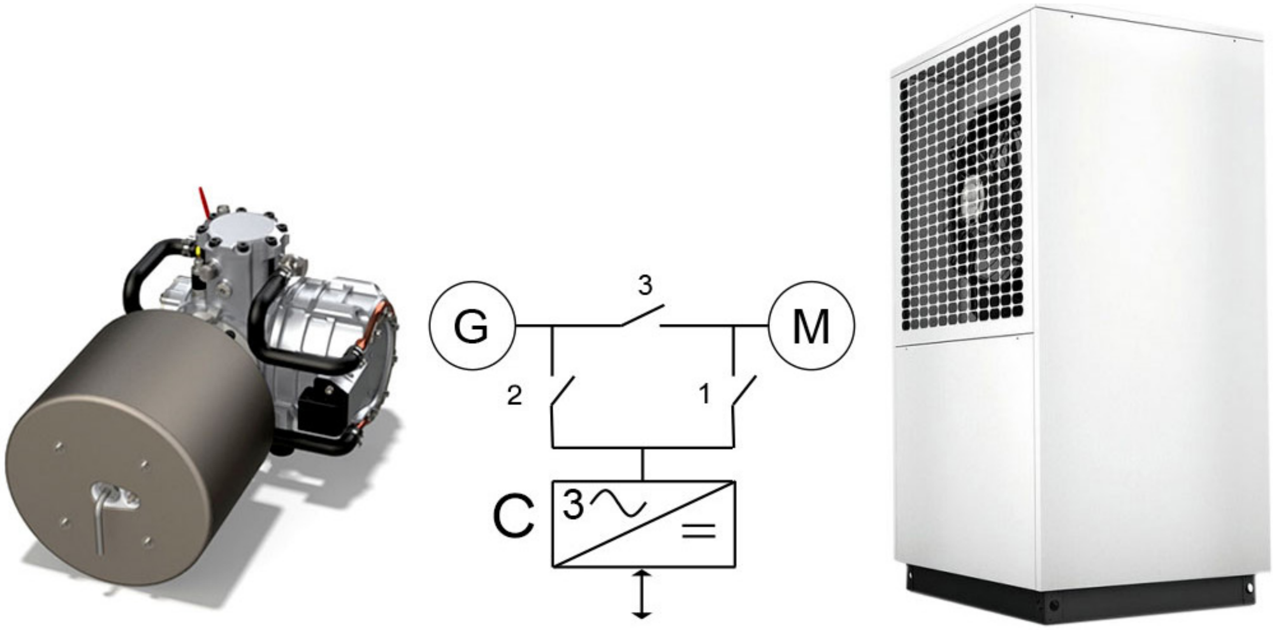


Hybrid drive for heat pumps: secured power supply and more

The heat pump is a remarkable machine: it is able to convert the energy input up to 6 times into heating energy. However, there is a small downside to the otherwise very sophisticated and quiet mode of operation: on the coldest days, its efficiency (COP = coefficient of performance) drops considerably, especially in the case of air-to-water units, which are the most widespread in terms of numbers; this drop is accompanied by high consumption of electricity, the origin of which can hardly be covered from renewable sources during these periods. This is undoubtedly one reason why, in extreme weather conditions, the heat pump is often supported by another heating source, such as electric heating rods, gas boilers, oil or pellet boilers. However, these additional devices do not make full use of the advantages of the heat pump and reduce the use of primary energy sources only to a manageable extent. A common feature of all these solutions is the loss of heat production in the event of a power failure, with all the consequences this entails.

What has been known for a long time in the larger output range will also work in the future for smaller heating systems for flats and single-family houses: the optional drive of a heat pump with electrical energy as before and alternatively with our innovative Gen70G(L) unit, that is operated with natural gas, liquid petroleum gas (LPG) or biogenic fuels. In addition to the mechanical power for the compressor, the unit also provides thermal power from its cooling circuit and thus supports the heat pump in terms of a smaller temperature spread. This operating mode provides up to 60% more heat from the fuel used. The fact that the same unit can supply power not only to the heating system itself, but also to electrical consumers in the house, delivers the prospect of a new quality in heating technology. Now every homeowner can look forward to the dreaded blackout scenarios without stress.

Fuel heat effectively supports environmental heat

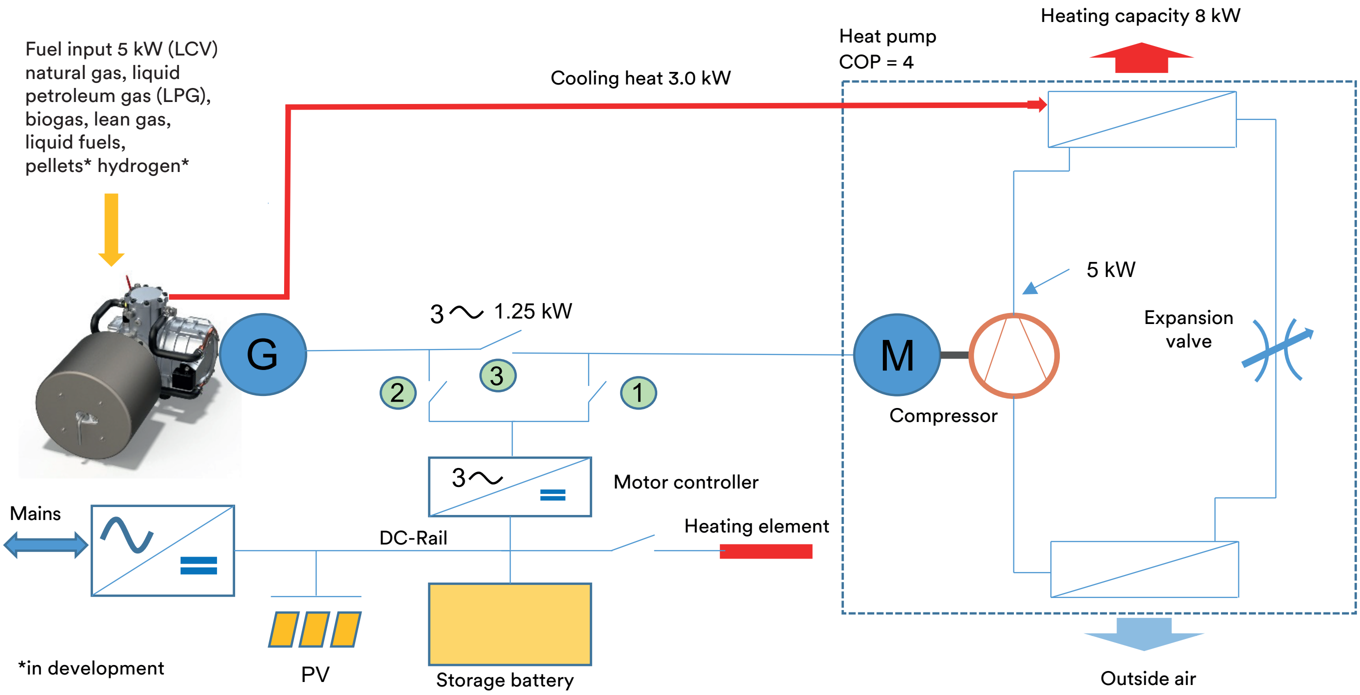
The synergy effect between the heat pump and the new unit is easily explained. Heat pumps achieve high efficiency at small temperature differences, but this efficiency drops rapidly at outdoor temperatures below 0°C. In this respect, it makes sense to feed the heat pump from the electricity grid during frost-free periods or, even better, with support from a PV system that may be present. At low outdoor temperatures, the Stirling engine can be coupled with the heat pump's compressor. In this operation, the heat of the engine cooling is added to the output of the heat pump, whereupon up to 160% heating output can be harvested from 100% fuel input. For example, a fuel output of 5 kW for the operation of the Stirling engine increases to a heating output of 8 kW. This value is sufficient for heating low-energy houses or multi-storey flats. The fact that the same heat pump can also be used to cool the rooms is state of the art and certainly a strong argument for fully air-conditioned solutions.

However, the robust Stirling continuous runner has another advantage. During heating breaks, its integrated power generator is able to charge a buffer battery to supply the entire heating system and other sensitive consumers. This operating mode is invaluable, especially in the event of a mains failure, and also creates a wide range of possible applications for off-grid stand-alone solutions. This also includes mobile applications, such as supplying parked transit trucks with heat, cooling and electricity.

Rapid readiness for series production after coordination of the interfaces

Frauscher Motors has specialised in the development and manufacture of Stirling generators modules Further research steps in the field of heat pumps or air-conditioning compressors in-house would be completely inappropriate in view of the current high level of product maturity in many companies. Since the interface between the Stirling generator and the compressor unit consists only of a switchable electrical connection, once the performance parameters have been tuned, commercially available components can be used, for example scroll compressors driven by brushless synchronous motors. For coupling an air-conditioning compressor to the Stirling machine.

Functional diagram using the example of a building heating system



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Detailed description of the operating modes:

For the coupling of an air-conditioning compressor to the Stirling engine, Frauscher uses a process developed in-house that does without couplings and shaft feedthroughs. This is very important for sustainable operation, as both the Stirling engine and a compressor module are under high gas pressure, which can hardly be kept tight in the long termwith shaft feedthroughs. In addition, low-loss transmission is guaranteed. Above figure shows the function and the energy flows in simplified form. The indicated individual contacts 1-3 each have 3 contacts for switching a 3-phase AC voltage.

Condition: the generator -G- of the Stirling machine and the electric motor of the compressor -M- are identical and coordinated permanent magnet excited 3-phase synchronous machines.

The possible operating modes can be represented as follows:

A) Standard heating mode

The motor of the heat pump is operated via the motor controller and contact 1 from the DC Rail. Depending on the operating state, the DC voltage comes from the storage battery, the PV system or from the mains or from parts of these sources.

B) Starting the Stirling engine

When contact 2 is closed, the Stirling engine starts after fuel heat has been supplied. The generator -G- acts as a starter motor.

C) Operation of the Stirling engine

After ramping up, the electrical generator power is routed via the motor controller to the DC Rail, where it is routed to the battery charging or to the house grid according to demand. Contacts 1 and 3 are open.

D) Synchronisation Stirling engine - heat pump

Contact 2 opens, contact 1 closes and brings the motor of the heat pump to approximately the same speed as the generator of the Stirling machine.
Contact 3 then closes, the Stirling generator drives the motor of the heat pump directly via the 3-phase link with low losses and avoids losses via the diversions of a direct and alternating direction.

E) Heating operation by the Stirling engine and power modulation

There are two variants; heating has operating priority.

Variant 1)

The heat pump is driven by the Stirling engine at full speed (output). As soon as the heat demand of the heating system switches off, the Stirling engine – heat pump connection is disconnected by opening contact 3 an the connection to DC-Rail is activated by closing contact 2. A state as described under C) is established. When heat is demanded, the states D) and E) are run through again.

Variant 2)

Since the Stirling engine delivers a constant torque, the output of the heat pump can be regulated via a speed control - starting from the throttle position of the expansion valve. A reduced speed automatically leads to less fuel demand, as the internal heat consumption of the Stirling machine decreases. The fuel supply for the Stirling machine's burner is automatically adjusted. This operating mode is advantageously selected in heating operation at low outside temperatures, as the best possible efficiency of the heating system is achieved.
During heating pauses, the Stirling generator takes over the battery charging again by disconnecting the 3-phase link (contact 3) and connecting contact 2. A state as described under C) is established.

F) Lack of mains supply - power failure

In this phase, the electrical supply has priority. The Stirling machine is started - if it is not already in operation - as described in B) and subsequently operates as described in C). The cooling heat is used entirely for the heating circuit to prevent the building installation from freezing. If there is no heating demand, the cooling heat is dissipated to the domestic water or to the outdoor environment. Should the battery be charged, the heat pump can start as described under E) or the electrical excess power is discharged to the heating system or domestic hot water via an E-heater. Advantageously, a PWM control can be used, which ensures a controlled charging regulation of the battery.

Summary:

The hybrid drive for heat pumps represents a new quality in heating technology. In addition to supplying heat with considerable fuel savings, the device also provides electrical energy from the fuel store or fuel network. This means that, in addition to heating operation, important consumers can be kept in operation if the electrical mains supply fails.