CASE STUDY:

Professional Off-Grid Power Supply Microwave Radio Stations

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Fuel cell as the cheapest and cleanest off-grid power supply!

Today, off-grid power is usually thought of as photovoltaic, wind, diesel generators or, under extreme operating conditions, thermoelectric generators (TEG). Here, photovoltaic and wind turbines are the most cost-effective power generators, as they require no additional fuel and little maintenance during operation. In many cases, however, their greatest shortcoming is the volatility of solar radiation and wind supply, which necessitates the use of additional generators. Furthermore, depending on the available solar of the area (Arizona and Northern Canada have dramatically different solar insolation values) power loads of more than 100 W can require a significant footprint for the installation of solar panels, not to mention snow and dust covering as an additional challenge in some areas. Hence larger power requirements are frequently covered by diesel generators. These, in turn, are cheap to buy, but require frequent maintenance due to oil and filter changes and regular refueling. Generators are often oversized for the load requirement, resulting in an 'under-loaded' operating condition that can cause long term stress on the generator and can reduce its efficiency to less than 20 %. Legally prescribed emission limits will make the operation of these devices more difficult in the future. Thermoelectric generators, another alternative with an efficiency of approx. 3 % and the associated high emissions, are only used in special applications and especially at particularly low ambient temperatures.

Fuel cells are the sustainable alternative. Classic low-temperature hydrogen fuel cells based on PEM technology or methanol fuel cells are ideal for backup applications with a short runtime of a few thousand operating hours. They start relatively quickly, can bridge brief grid failures or recharge the batteries in photovoltaic hybrid systems as long as the insufficient irradiation periods are not too long. However, the service life of the stack, the core system of the fuel cell generator, of usually 3000 to 7000 operating hours significantly limits their usability in continuous operation. In addition, the volumetric power density of hydrogen, even when stored and transported in pressure vessels, is very low compared to liquid or liquefied fuels such as Diesel, Methanol, Propane or Ammonia.

The solid oxide fuel cells (SOFC) with ceramic electrolyte have been proven for use in stationary continuous operation for several years. These are based on the principle that many ceramics become conductive for oxygen ions at temperatures above 650 °C. These are therefore high-temperature fuel cells that are usually operated in the 700 °C to 850 °C range. In contrast to the aforementioned technologies, these fuel cells require little maintenance. Intervals of up to 10,000 operating hours are possible. The core of the SOFC fuel cells can achieve a service life of 20,000 to 30,000 operating hours in continuous operation. Sunfire Fuel Cells GmbH has been manufacturing and selling such fuel cell generators since 2014, and they are currently available for operation with natural gas or propane as a fuel. With the expanded availability of renewable ammonia or hydrogen, corresponding product variants will also be available in time. So, nothing stands in the way of switching to a highly efficient, clean, and sustainable solution.

Fig. 1: Off-grid Microwave Radio Station with SOFC-PV Hybrid Configuration in Alaska – Sunfire-Remote 400 installed 2019

The question is: How do the different energy generation technologies for off-grid power supply rank? For this purpose, the total costs of acquisition, operation and maintenance of different off-grid generators were determined and compared as total cost of ownership (TCO) for a microwave radio station with an average power consumption of 220 W. Furthermore, the carbon dioxide emissions were calculated assuming the use of fuel from fossil sources compared to those from non-fossil sources. The moderate climate zone of the northern hemisphere was chosen as the region.

The following technical solutions were considered:

1. SOFC fuel cell stand alone

The fuel cell, in this case a Sunfire-Remote 400, is combined with a small to medium-sized battery bank. This supplies energy for starting the fuel cell and is able to cover temporary load peaks while the fuel cell is operated continuously.

2. SOFC fuel cell in a PV hybrid system

According to the energy demand of the load, a photovoltaic generator and a rather large battery bank with several days of power reserve are combined to cover the energy demand of the application during the months with good radiation availability (typically April to October in the northern hemisphere). As the days get shorter and the weather gets worse, the Sunfire-Remote 400 fuel cell is activated and provides energy during the low-radiation winter season.

3. Diesel generator with battery storage

Diesel generators can also supply a load directly, but in this case, they usually operate in the inefficient under-loaded condition and quickly reach a high number of operating hours. For this reason, these generators are often hybridised with batteries in off-grid applications to run as few operating hours as possible in full-load operation.

4. Methanol fuel cell stand alone

Equivalent to 1. the same case is considered for comparison with a 500 W methanol fuel cell.

5. Thermoelectric generator

Thermoelectric generators produce electrical energy from combustion heat and are usually combined with batteries in off-grid applications.

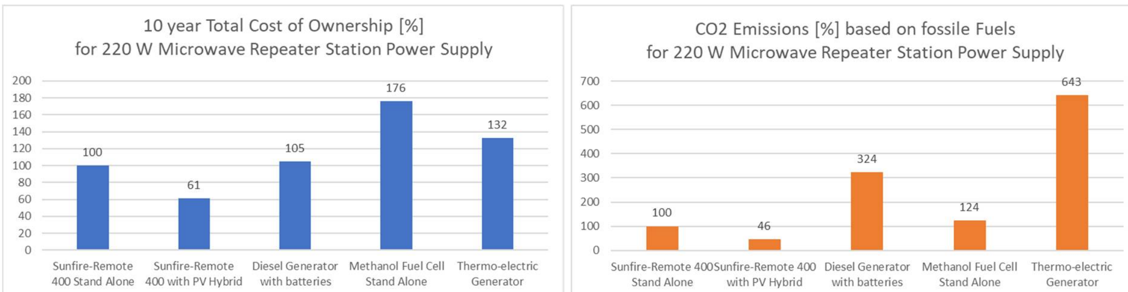

Fig. 2: Comparison of 10-year TCO and CO_2-Emissions of the different Solutions

The investigations carried out give the following picture: In terms of costs and CO_2 emissions when using fossil fuels, the combination of SOFC fuel cell in winter operation and photovoltaics in the summer half-year is unbeatable. In case there is not enough space for a PV generator with corresponding battery storage, the Sunfire-Remote fuel cell can also be used in stand-alone operation. A further reduction of CO_2 emissions by up to 90 % is already possible today using BioLPG from bio-residues available in Central Europe or also future electricity-based e-propane. Diesel generators have low efficiencies in this power range. Fuel costs and maintenance costs eat up the comparatively low investment costs. In the case of methanol fuel cells, on the other hand, the relatively high price of methanol combined with a shorter service life of the fuel cell stacks has the greatest influence on the total costs. Thermoelectric generators eventually hold the negative emissions record due to their low efficiency.

In summary, the SOFC fuel cell, such as the Sunfire-Remote 400 considered here in this practical example from Alaska, offers the optimal solution in terms of security of supply, total cost and emissions. Ultimately, however, it is recommended that a project-specific cost estimation will be carried out. External factors such as available space, frequency of travel to the installation site and its seasonal inaccessibility can also be further factors in opting for a low-maintenance, robust and proven solution.