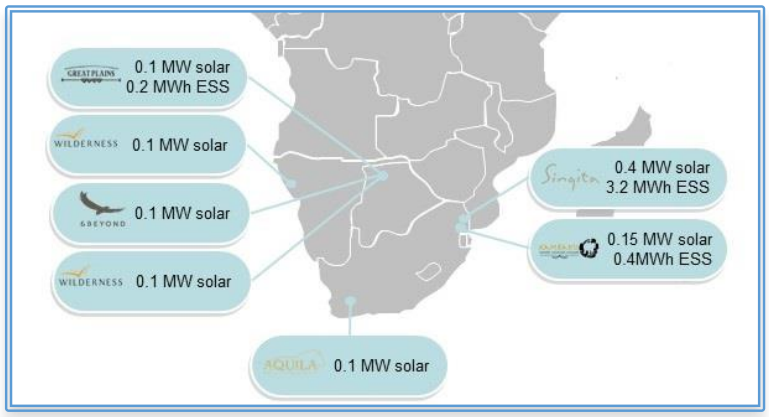
THEnergy-IPS Report

Hybrid Solar Mini-grids for Remote Safari Lodges in Africa



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1 Introduction

In many ways, safari lodges are different from other types of accommodation. Typically, they are located remotely in an environment that is extremely sensitive to human impact. For safari lodges, it is key to be able to keep the surrounding nature intact for visitors to enjoy. The lodges themselves have significant impact on nature. For safari lodges, it is a desirable objective to minimize any additional impact on their surroundings.

Studies show that tourists use even greater amounts of energy in tourism destinations than at home.[1] Power generation is one field that can be optimized to minimize the environmental footprint. Traditionally, safari lodges have been powered by fossil fuels that cause significant global impact in the form of CO2-emissions and local impact in the form of noise and hazardous emissions from the exhaust gas. All this might be minimized by adding solar power as a source of energy. More and more safari lodges have decided to do just this in the last years, ensuring that these pristine places remain treasures for everyone to enjoy.

Figure 1 shows various examples of safari lodges in Southern Africa that have shifted their energy mix from pure fossil fuel toward renewable energy.

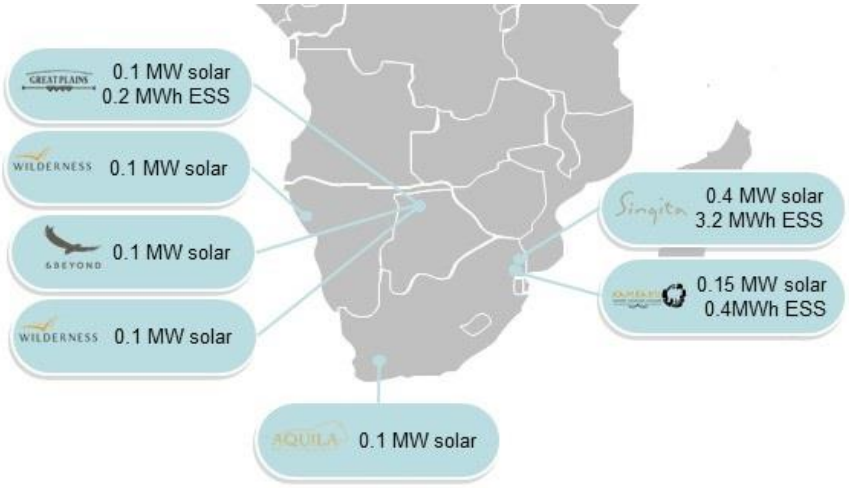

Figure 1: Project examples of solar installations at safari lodges in Southern Africa.

Due to the falling prices of solar components and energy storage, safari lodges will profit economically by reducing their electricity generation costs.

Environmental impact is not only relevant for flora and fauna but also for guests and employees who are also exposed to noise and exhaust gas emissions. Studies indicate that the core business of hotels, in general, is positively affected by green efforts such as the integration of renewable energy.[2]

We also see complementary efforts in the safari sector such as pilots for CO2 emission-free silent electric game-viewers and safari boats. These efforts only make sense if the electricity that charges the batteries to power such vehicles and boats comes from a renewable source.

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[1] Tang, Z.; Shi, C.B. and Liu, Z. (2011). Sustainable development of tourism industry in China under the low-carbon economy. Energy Procedia, Irandu, E.M. (2006). Sustainable tourism development on Kenya's coast: a hospitality sector view. International Journal of Tourism and Hospitality Research, 17, Saarinen, J. (2006). Traditions of sustainability in tourism studies. Annals of Tourism Research, 33.

[2] Robinot, E., Giannelloni, J.L. (2010). Do hotels' 'green' attributes contribute to customer satisfaction? Journal of Services Marketing, 24 and McGraw-Hill Construction (2013), Green Retail and Hospitality Report - Waste Management.

Finally, guests expect more and more the switch to renewable energy to be made. The situation is similar for exclusive island hotels which often attract a similar clientele and have to deal with high electricity costs due to their remoteness. In recent years, an increasing number of exclusive island hotels is powered by solar and wind energy.

2 Power Requirements for Remote Safari Lodges

2.1 Consumption patterns

Safari lodges often host a wealthy clientele that is demanding in terms of power supply. Power outages could significantly affect the satisfaction rate which could result in bad ratings on booking and travel portals such as Booking.com, Hotels.com, Priceline.com, HRS, Agoda, Expedia, Hotelscombined, or Tripadvisor.

In lodges, we often find appliances that run throughout the day such as air conditioning units, fans, freezers and fridges. The consumption of these offtakers mainly forms the base load.

Major sources of energy consumption include guest rooms, kitchens, and laundries as well as leisure facilities such as swimming pools, saunas, etc. These are typically:

- Bedrooms: air conditioning/fans, lights, kettles, minibar fridges, hair dryers, and the charging of low consumption devices such as mobiles, laptops, and cameras
- Kitchen: Fridges, freezers, ovens, fans/air conditioners, kitchen lights, dish washers, and ice machines
- Laundry: washing machines, and dryers

There are also pumps: pool pumps, heating pumps, and pumps in workshop-areas. Sometimes, water is purified on-site, and for that, additional electricity is required.

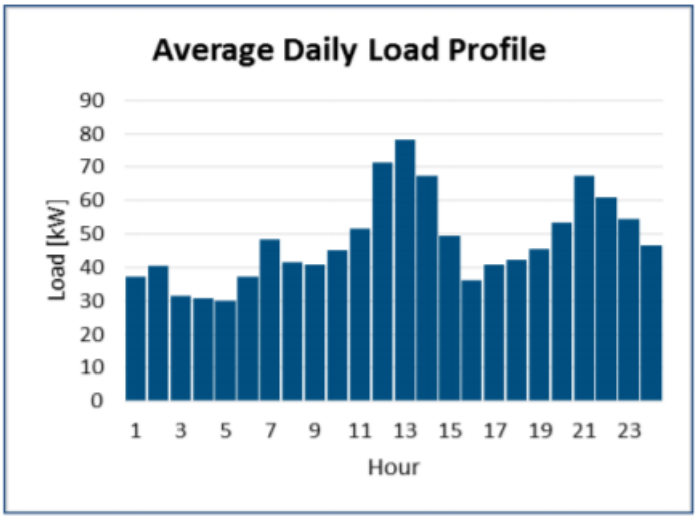

Figure 2: Example of a safari lodge's average daily load profile.[3]

Daily load peaks during the middle of the day: Guests typically leave their lodge at this time, but high energy consumption can be observed in kitchens and laundries. Also, air conditioning in common areas has a natural peak due to high ambient temperatures.

There are also many ways of reducing the energy off-take. Some of the measures will not be noticed by guests, while others result in restrictions.

[3] GIZ (2015). Project Factsheet Load measurement and Solar PV system design at a Tourism Lodge in Tanzania.

2.2 Challenges

Studies show that many guests feel that specific environmental practices may reduce the level of satisfaction and comfort at a hotel. We observe the paradox that customers generally support green efforts, but are not really willing to accept restrictions. This is especially critical at a time when dissatisfaction can easily be expressed on booking platforms on the Internet such as Booking.com, Hotels.com, Priceline.com, HRS, Agoda, Expedia, Hotelscombined or travel sites such as Tripadvisor.

In the study, guests cited low-flow showers (56.6%), low flow taps (50.1%) and the re-use of towels (49.1%) as environmental practices that may reduce their level of satisfaction and comfort at a hotel. Guests also cited the restricted use of air conditioning (55.8%) as having a negative effect on quality and satisfaction at a hotel.[4]

	Agree	Neutral	Disagree
Dimming of lights in public areas	46.5	11.5	42.0
Low-flow showers	56.6	13.8	29.6
Low-flow taps	50.1	13.0	36.9
Re-use of towels	49.1	11.3	39.6
Re-use of linen	48.1	14.3	37.6
Restricted use of air-conditioning	55.8	22.0	22.2
Use of showers instead of baths	31.0	20.8	48.2
Use of local goods and service	25.0	19.3	55.7
Use of recycling bins	17.3	12.8	69.9

Figure 3: Guest opinions regarding green efforts of hotels[5].

Solar, in combination with energy storage, does not have the inconvenience of such restrictions. In addition, it is a clear visual sign that green efforts have been undertaken. The use of solar energy at a lodge would impact the attitude of those clients that are environmentally and socially responsible. It could also make them select a safari lodge based on this characteristic, namely its conservation policy.

2.3 Requirements for powering safari lodges in Africa

As a summary, several requirements for powering safari lodges in Africa can be derived. These are particularly valid for new solutions that will compete with existing systems.

(1) Costs

Power generation needs to be cost-efficient. Traditional diesel gensets provide power at relatively high costs. The main cost factors for diesel gensets besides the power plant itself are fuel costs, transport, theft, storage, and operating and maintenance of the diesel generators.

(2) Reliability

Safari lodges typically are active in the luxury segment. Reliable power supply is a basic requirement for many guests. Outages are not accepted - restrictions on the availability of electricity might lead to lower customer satisfaction rates.

(3) Flexibility

The power demand of safari lodges might vary in the future. An extension of the lodge or the introduction of electric safari vehicles are just two examples that might lead to an increased power

[4] Sucheran, R. (2013). Environmental Management in the Hotel and Lodge Sector in KwaZulu-Natal, South Africa.
[5] Sucheran, R. (2013). Environmental Management in the Hotel and Lodge Sector in KwaZulu-Natal, South Africa.

demand in the future. The power generation system must provide flexibility to reflect future demand changes.

(4) Ecological

Safari lodges are strongly interested in limiting the ecological footprint of their power generation. Some national park regulations do not accept permanent structures and prohibit the usage of concrete. Emissions and noise are other aspects that might impact on nature or scare away animals.

(5) *Social aspects*

Power generation can also provide work for locals. Local technicians will be able to perform almost any work on easy-to-use systems.

2.4 Traditional approaches to power generation

In many cases, remote safari lodges are powered by diesel gensets. Sometimes the grid is extended, which also represents a significant impact. Normally, this is not feasible for remote lodges due to the regulations of national parks.

Diesel generators allow for relatively reliable on-site power generation. Generators convert fuel into AC electricity which is suitable for all the appliances that are utilized in safari lodges. The availability of diesel as a fuel is very good in most of the countries in which safari lodges are located. However, diesel has to be transported from central storage facilities. In the case of very remote lodges, transport will be an important cost factor. As diesel is also suitable for private usage, theft is often a severe problem and adds to the electricity bill.

One liter of diesel generates approximately 3-4 kWh of electricity. The efficiency of diesel generators is much lower than the efficiency of large-scale power plants. This results typically in significantly higher CO2 emissions per kWh. In addition, large-scale power plants have much better emission control systems than diesel generators. Electricity generation with diesel generators has negative side effects such as local emissions of hazardous off-gases and can generate considerable noise levels - two aspects that do not fit very well with the image of luxury that safari lodges wish to project. In the past, these disadvantages were accepted due to a lack of alternatives. This is changing, because with solar power, a clean energy alternative is available that is also often superior regarding costs. In addition, it should be kept in mind that visitors to safari lodges are typically people who love nature and would support preserving it and keeping it clean. The idea of renewable generation often overlaps with the typical mindset of the clientele of safari lodges.

3 Solar for reducing diesel consumption in remote applications

3.1 The concept of solar-diesel hybrid approaches

The cost of solar electricity has decreased significantly in the last few years. The costs of solar energy mainly depend on the location in question and its specific irradiation. That means that the costs of solar electricity vary from one safari lodge to another. The costs of electricity also depend on a number of factors such as diesel price, generator conversion efficiency, transport costs and losses / theft. In most cases, solar electricity will be significantly less expensive than electricity from diesel. Often, solar electricity is in the range of 25-50% cheaper than electricity from diesel generators in safari applications. In solar-diesel hybrid approaches, expensive diesel power is at least partly replaced by rather inexpensive solar power.

Solar electricity also has some downsides, the main ones being intermittency and relatively high investment costs (but almost no operating costs).

The intermittencies of solar energy have several dimensions:

- Short-term: fluctuations due to shading of the solar array (clouds, mist)
- Mid-term: fluctuations due to time of day (day vs. night)
- Long-term: seasonal fluctuations (summer vs. winter; dry vs. rain period)

These fluctuations might be compensated by using intelligent energy conversion technologies in combination with an energy storage system. We see a similar development for energy storage today as could be observed for solar several years ago. The prices are coming down considerably. In addition, new technologies are evolving. While several years ago, lead-acid based battery solutions were the only preferred solution in off-grid applications, today technologies such as lithium-ion and redox flow batteries gain traction. The various battery types have different advantages and disadvantages. The decision regarding which battery to use will in the end depend on the specific application. In any case, batteries will add costs to a project.

The idea of a solar-diesel hybrid is to combine rather inexpensive, but inflexible, solar power with rather expensive, but flexible, diesel power. Diesel power is partly replaced by solar to an extent that still allows for a stable power supply. Nowadays, there are innovative energy conversion technologies that could manage the use of diesel and solar input sources, and in combination with energy storage, achieve the combined effect of flexibility plus lower operating cost.

Depending on how much diesel power is replaced by solar power, different “penetration rates” can be distinguished. In a low penetration system, diesel generators provide a so-called spinning reserve that might compensate for short-term fluctuations, e.g. when clouds pass through and shade the PV array. For this reason, gensets are run at lower loads when the solar system achieves a high energy yield. Decreases in solar generation can then be made up when the output of the diesel generators is increased. In this concept, the diesel gensets are always grid-forming, i.e. they cannot be switched off. The solar system is often designed to cover around 70% of the peak power generation, while the diesel generator covers the remaining 30%.

3.2 Optimizing diesel usage with solar and storage

In more advanced systems, short-term fluctuations are compensated by battery energy storage systems (BESS). During sunny days, the diesel gensets can be switched off during daytime. To achieve this, special solar inverters are required that are grid-forming. Batteries adapt the profile of solar production to the load-profile.

In high penetration systems, batteries are also used for powering safari lodges during night-time. Diesel generators are only used as back-up, e.g. for longer periods of bad weather when the solar energy yield during the day is not enough for charging the batteries sufficiently, the diesel generators are automatically switched on. Battery, generator, power and load management all complement each other to provide a comprehensive system management. The system should also optimize the runtime of the diesel generator so that wear and maintenance of the generators are decreased. Increasing the solar energy penetration rate requires larger batteries which translates into higher capital expenditures. Higher solar energy penetration means at the same time, higher potential savings in operating costs, less emissions and noise.

3.3 Energy conversion units for intelligently integrating different power sources

The integration of different energy sources and synchronization of generation and load are a particular challenge. Additional equipment is needed for these tasks: rectifiers, solar charge controllers, inverters, and DCDC converters. Communication and connection of components from different manufacturers is not always easy. In many cases, the integration is not very user-friendly and requires expert assistance from manufacturers. So-called energy conversion units provide a modular solution. There is only one unit (MCU – Main Control Unit) that monitors and controls all system modules (i.e., rectifiers, solar charge controllers, inverters, and DCDC converters). A Bulgarian manufacturer released the EXERON, a plug & play, hot

swappable energy conversion system that won the Intersolar world innovation award for EES (Electrical Energy Storage) in Germany in 2014.[6]

Figure 4: The EXERON system as an example of energy conversion units

The system structure is based on power modules of 2kW or 4kW, and due to a proprietary communication protocol, the systems can address up to 16,300 modules simultaneously, which means 16,300 modules x 2kW or 4 kW - corresponding to 65MW of power. The modular system structure offers great scalability and flexibility. The power capacity extension for any power system component is easily done by simply adding new plug & play power modules. The system provides redundancy: if one module fails, the other will not be affected. Therefore, an outage in one or more modules will not lead to a full system stop. EXERON is easy to install and maintain with a small footprint and light architecture. The system was developed for military applications and is used in the telecom industry, two sectors that even have higher requirements than safari lodges.

3.4 Efficiently powering safari lodges with energy conversion unit based hybrid mini-grids

Modular energy conversion units in conjunction with solar and energy storage solutions perfectly fulfill the requirements that safari lodges have for power generation.

(1) Costs

In many cases, solar power is more cost efficient than diesel power. The integration challenge can be overcome by energy conservation units that optimize the use of different energy sources.

(2) Reliability

Solar power in combination with energy storage is extremely reliable. Irradiation fluctuations can be compensated by energy storage and / or diesel power. Energy conservation units that are proven in military and telecom applications will ensure a reliable power supply for safari lodges. The system

[6] The awarded committee stated the following: "*International Power Supply from Sofia, Bulgaria, showcased an optimal system for off-grid use in the form of the Exeron MX, which fulfils all requirements surrounding energy management, communication and modularity. Optimized controller designs enable different energy sources to be combined. The jury was won over by the stringent modular design, easy-to-maintain hot plug technology, advanced lead battery management as well as the increased availability thanks to the excellent system redundancy.*"

availability is extremely high and robustness of power generation is guaranteed. EXERON is certified and used by NATO in the harshest of conditions. The high quality and build specifications ensure maximum durability of the system, operation at high ambient conditions with high temperatures of up to 55°C and humidity of up to 98%.

(3) Flexibility

Solar power and energy storage can be scaled up rather easily. It is important that also the energy conversion unit allows for scaling up, e.g. the EXERON solution allows for scaling up easily as 2 kW or 4 kW modules are used.

Figure 5: Energy conversion unit and energy storage system at safari lodge in South Africa.

(4) Ecological

The use of solar power will decrease negative environmental impact by avoiding the greenhouse gas emissions associated with conventional power generation. There are multiple secondary effects as a result of the renewable energy use related to the decrease in local hazardous exhaust gas emissions and noise of traditional diesel gensets. An environmentally friendly technology which decreases the use of a diesel generator and the associated noise from it can also attract animals to areas closer to the lodges and make them even more attractive to tourists. Solar power plants can be also mounted on structures that do not use concrete so that potential national park regulations can be fulfilled.

(5) *Social aspects*

The user-friendliness of energy conversion units ensures that no extensive expert skills are required. To a large extent, operations and maintenance tasks can be performed by local technicians.

(6) Transparency

EXERON includes real-time monitoring capabilities which enable lodges to optimize their power system and intervene when problems occur. This feature can also be provided to end-customers which could further increase their involvement and raise their consciousness for clean electricity generation.

4 Conclusions and outlook

This report shows that safari lodges in game reserves and solar energy installations are an excellent fit. Due to the falling prices of solar and energy storage solutions, cost savings are the main driver for this development. Safari lodges can significantly reduce their electricity costs by integrating renewable energy solutions.

However, there are many factors beyond pure cost savings. In remote locations, it is very important that the solutions are easy to use and robust. Guests of safari lodges have high expectations regarding power supply reliability. Redundancy is needed. If a part fails, it is not acceptable to wait several days until spare parts arrive from manufacturers. The control and monitoring units must be easy to install and operate. If experts from the manufacturers are needed for long time-periods during installations and commissioning, a significant influence regarding costs is to be expected. Similarly, there are many advantages when local technicians can do the maintenance on their own if the existing personnel from the diesel power plant is able to operate the hybrid power plant.

It can be observed that more and more safari lodges integrate renewable energy solutions such as solar as part of their conservation policy. There are also examples in which solar and storage fully power safari lodges and diesel generators are only used for back-up purposes. This is pursued on the one hand for economic reasons but on the other hand to be in line with eco-friendly environmental policies. The installations that have been built recently will demonstrate the advantages of solar energy to lodge owners and operators. The confidence in solar installations for electricity self-consumption at safari lodge sites will become more popular with the increasing number of owners using them. This will further increase the confidence in solar solutions. In the mid-term, solar will be a firm component of almost all power plants at remote safari lodges.

About IPS

IPS is a company with 28 years of experience in developing and manufacturing power electronics and energy conversion technologies. Its award-winning technology – EXERON (www.exeron.com) is a fully integrated modular system applicable in multiple sectors some of which are mini-grids, telecom, residential, military, oil and gas and industrial. The technology can combine power from different energy sources like solar panels, wind turbines, diesel gensets and the grid, store unused energy in a battery and offer a consistent power supply and energy independence for areas with limited or no grid.

All the system's modules are plug & play, hot swap and built to work as integral parts of a whole. This allows for higher overall efficiency and more intelligent management of the system. Initially designed as an off-grid power solution for the defense sector, EXERON has unrivalled reliability and quality. EXERON is without an analogue as a technology on the market, military approved (AQAP 2110 certified) and patent pending in the USA. IPS's products are operated currently in 56 countries worldwide.

About Dr. Thomas Hillig Energy Consulting ("THEnergy")

THEnergy assists companies in dealing with energy-related challenges. Renewable energy companies are offered strategy, marketing and sales consulting services. For industrial companies, THEnergy develops energy concepts and shows how they can become more sustainable – combining experience from conventional and renewable energy with industry knowledge in consulting. In addition to business consulting, THEnergy advises investors regarding renewable energy investments in changing markets. www.th-energy.net

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