The Viable Application of Renewable Microgrids: A Case Study

R. Styles, Business Development Manager
Norvento Energy UK
rstyles@norvento.com
111 Power Road, London W4 5PY

Introduction

Electrical distribution patterns have changed in recent years. At one time the only way to deliver energy at an affordable price was through a centralised network, however now the economics of distributed generation have changed with developments in the renewable energy industry. We now see the take up of smaller scale renewable generation, distributed and embedded throughout traditional electrical distribution networks.

Technological changes have driven this evolution. In the last 20 years, the cost of installing renewable generation has decreased by an order of magnitude. Solar PV is the most dramatic example of this and in addition, battery electricity storage has improved in both performance and cost-effectiveness, being a fraction of the cost compared with just a few years ago. With the correct system design, it is feasible to power a small network off-grid (disconnected from the main power network) with a renewables and battery storage focus and by burning minimal diesel. These systems must achieve a balance between electrical generation and demand and in so doing mimic large power grids in a much smaller fashion. Hence they are often termed microgrids.

Most of the developed world is already electrified through a centralised power grid. Despite the advances in distributed generation and storage technologies, the business case of a renewable off-grid system is not yet justified in every case, unless taking into consideration a more holistic view on advantages such as carbon footprint. However many small networks throughout the globe are isolated from a centralised power grid. This is often a consequence of their remoteness and such systems are likely to be powered by costly diesel generation. This happens in both developed and developing countries, being more frequent in the latter case.

It is in these more remote diesel-powered systems that renewable energy can make the biggest impact to the finances of an operation. Thanks to the virtual absence of economies-of-scale with solar and battery systems, these two technologies make it possible to power a system at a more cost-effective rate than with only diesel generators even for relatively small projects. It is important to point out that any renewable technology is only truly effective when located in an area with appropriate natural resources such as sun or wind. In an area with good wind resource, wind turbines may be more appropriate and vice versa with strong solar irradiation.
At Norvento we have developed the necessary skills to design, specify and install renewable-focused microgrids to suit the operational needs of our clients. The most comprehensive example of this is our HQ building, Cine. We also help businesses worldwide to transition towards a cleaner power source. For instance, we have recently provided assessment for a client involved in mining in South America. Our client currently addresses the lack of a local electrical distribution network by the use of diesel generation. However we have demonstrated the advantage of incorporating a renewable microgrid system to support the operation.

**Design Methodology**

We were approached by a client needing support in making an investment decision for their power system. The site facilities have been running for several years powered by diesel genets at a high cost of electricity. The client currently has a diesel price equivalent to £0.58 per litre, which includes the costs of delivery to its remote location. Now they face the requirement to either invest in a new energy system based on the same technology, or finding an alternative that may help them to save OPEX as well as help them comply with CSR targets.

At the start of the design process, we analysed the available renewable resources at the site, as well as collecting data on the typical electrical demand of the operation. Solar PV was considered the optimal primary generation source at the site due to the favourable solar irradiation conditions. In order to size the microgrid appropriately, data was collected on the typical daily electrical demand at the site. The client operates in two shifts 7 days a week, consuming electricity in an approximately constant pattern all year round (Fig 1).

**Fig 1. Electrical Demand and Generation throughout one day. Figures for generation shown for both summer and winter. Blue line shows site electricity demand, orange typical winter generation and grey typical summer generation**
Simulations allowed us to compare demand with generation across a range of solar PV systems of different sizes as well as a diverse set of storage capacities, taking into considerations the seasonality existing for this resource. Fig 1 shows a typical day of summer and winter, although simulations cover all year round.

The final specification that we arrived at for the microgrid sought to address the priorities of our client. The main priorities were to significantly reduce the operational cost of electricity generation on site, but also to achieve a relevant CO2 emissions reduction to comply with CSR targets.

In order to fairly assess the economics of two separate electrical generation systems, we use the levelised cost of electricity (LCOE) as a way to measure the cost of energy used by a client, regardless of the source it comes from. It is the net present value of the unit-cost of electricity over the lifetime of a generating asset, meaning that it considers not only the costs and the energy delivered but also when they happen. The formula is not presented here but is readily accessible in literature and online. LCOE was used to compare the current operational electrical generation for our client with a renewable-driven microgrid provided by Norvento.

We used a discount rate of 8% (which was indicated by our client) when calculating the LCOE over a 20 year period, which is meant to represent the cost of capital in real terms; neither inflation nor fuel price change have been accounted to calculate OPEX of the plant.

**Business case**

Initial assessment of the mining facility showed electrical needs to be met by two megawatt(MW) of old diesel generators with one backup generator of 1MW. These deliver 8500MWh of electricity each year at an operational cost of £42,134 for maintenance and £1,674,261 for diesel. The replacement of the existing generators required a CAPEX of £422,400. The diesel generators would consume a total of 2,880,658L of diesel per year, producing 7,736 tonnes of CO2. A lifetime of 10 years is predicted when utilising the generators to meet total electricity demand at the site, at which time they would need to be replaced.

Assessment by Norvento engineering arrived at an alternative option to the diesel- only system. We proposed a microgrid comprised of 5.3MWp of solar PV, 6MWh of battery storage, retaining the requirement for 2MW of diesel generator as a failsafe; maintaining the gensets makes sense as the CAPEX associated to the gensets is just a fraction of the total costs in their lifetime. The operation of the gensets in the microgrid will also be much less intense than in the base case, leading not only to a much lower diesel cost but also to an increased lifespan, as well as reduced maintenance and overhaul needs.

A comparison of the parameters of each system is shown in table 1 below. Figures are converted into GBP where appropriate.

| Table 1. Comparison of diesel generation vs a renewable microgrid with 75% renewable penetration over 20 year lifespan |
### Base case: 2MW installed diesel generation

**System Description:**
- 2 main gensets, 1 MW each for continuous operation
- 1 back up genset, 1 MW, for use during emergency and scheduled maintenance of main gensets
- Expected lifespan for gensets: 10 years, with overhaul after 5 years.

**Capital investment**
- 3 Gensets: £422,400
- Main gensets replacement (Y10): £281,800
- Main gensets overhaul (Y5 and Y15): £140,800 per overhaul
- Total: £985,600 (non-discounted)

**Operating costs**
- Fuel: £1,674,261/year (fuel)
- Maintenance costs: £42,134/year
- Total: £1,590,000

**Levelized cost of energy**: £210/MWh

**Environmental impact:**
- High CO2 emission of 7,736 tons/year
- Local pollution by NOx, SOx and particles

### Alternative case: 75% renewable penetration

**System Description:**
- 3 gensets as in Base case, to be used less than half of the hours used in the Base case
- 5.3MWp Solar PV
- 6MWh/2MW lithium ion battery storage system
- Expected lifespan for gensets: 20 years, with overhaul after 10 years.
- Expected lifespan for Solar PV and Batteries: 20 years

**Capital investment**
- 3 Gensets: £422,400
- Main gensets overhaul (Y10): £140,800
- 5.1MWp solar PV: £3,731,200
- 6MWh storage: £2,100,000
- Balance of system design: £88,000
- Total: £6,482,400 (non-discounted)

**Operating costs**
- Fuel: £448,159/year (fuel)
- Maintenance costs: £117,156/year
- Total: £548,802

**Levelized cost of energy**: £148/MWh

**Environmental impact:**
- CO2 emission down 73% to 2,070.81 tons/year
- Significantly reduced local pollution

### Findings

We have demonstrated the economic feasibility of a renewable microgrid as an alternative to diesel generation, especially in remote areas. It is important to comment...
on coverage of 75% of electrical demand with renewable generation, rather than 100%. The relationship between cost and renewable penetration is not linear.

For example, it may be feasible to cover 90% of a particular operation’s demand with renewables and battery storage, but to cover the final 10% may cause the system cost to increase by 3 or 4 times. In order to meet our client’s priorities, we have reached a balance between system costs and results, arriving at a 75% renewable penetration. It is for this reason that we combine renewable generation, storage and in the case study above retained the diesel generation. The optimal control of the system should also ensure that the generators are used in the most efficient manner possible with minimal diesel consumption and minimal wear of the equipment, by limiting the number of hours in operation and the number of start-ups required.

By switching to a renewable microgrid, we have demonstrated for our client that the economic benefits to the business could be more than £1M per year in operational costs and a LCOE that is 29% lower (Fig 2.). By utilising the generators as a backup in the microgrid system, their life can be greatly extended and operate with lower maintenance costs, as indicated in Table 1. As the LCOE calculation considers the initial capital expenditure in both projects it demonstrates that a renewable microgrid can deliver operational efficiencies, with a significantly lower cost of energy.

Clearly important also is the saving in CO2 emissions as a result of the transition to renewables; 5,665 tons/year (Fig. 3) of savings is significant and to be considered of high value.

The microgrid system also provides future flexibility to the business due to the simplicity of adding further generation or storage modules. In addition, relying on renewable
power generation and battery storage will allow the business to hedge against future volatility in diesel prices.

![Graph showing CO₂ emissions comparison]

**Fig 3. Difference in CO₂ Emissions between base case and Norvento designed microgrid**

The conclusions drawn from this case study will not be of equal relevance in the near future, as the prices of renewable technologies and fuels change. For many years we have witnessed a steep and consistent fall in solar PV and battery prices; a trend which is set to continue. The likely LCOE of microgrid projects are even likely to be comparable with main grid power in the close future. Assuming the above project was connected to the UK power grid rather than powered purely by diesel, the LCOE would be around £0.11p/kWh (data from Department of Business, Energy and Industrial Strategy published in 2018, excluding taxes and levies). It is clear to see that the proposed system in this case study is not far away from this reality; grid parity will soon arrive for microgrid systems.

**Where we stand on Microgrids**

At Norvento Enerxia, we have established a microgrid demonstrator project to showcase the possibilities of owning and operating a microgrid. The CIne (or Norvento Enerxia Innovation Centre) serves as the company headquarters and is located in Galicia, Spain. The building operates independently of electrical and gas networks and runs on renewable resources. As a renewable energy engineering and technology company, we have designed and specified the energy system, including a unique microgrid control system that allows optimal use of renewable resources. Further details on the project can be seen [here](#). Whilst the building stands as an operational example of Norvento’s engineering capabilities, it also takes steps towards fulfilling the company’s goal of aiding decarbonisation of the energy system.