Ensuring Reliable Power for Commercial and Industrial (C&I) Sites

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***Abstract*— Commercial and industrial (C&I) sites having grid outages are suffering from associated losses. These industries have onsite generation as diesel units to avoid any power outages and related costs. Microgrid solution including battery energy storage systems (BESS) and solar Photovoltaics (PVs) can provide reliable source of power to C&I sites. This paper shows the business case for a typical glass factory in India experiencing frequent outages. Four scenarios of different BESS and solar PV configurations have been simulated and related econometric metrics are discussed. The microgrid solution with BESS and solar PV has the lowest fuel consumption and Levelized Cost of Energy (LCOE) among other scenarios. The sensitivity analysis shows that the main drivers for LCOE reduction are outage costs and installed PV prices.**

Keywords-component; Commercial and Industrial sites, Outage Costs, microgrids, battery energy storage systems.

I. INTRODUCTION

In many parts of the world regular outages to the grid are a way of life. There are many different reasons for a grid to become unreliable, such as energy supply issues, weak infrastructure or extreme weather. Yet, the challenges for Commercial and Industrial (C&I) sites are usually the same: lost production, lower workforce efficiency and potential damage to their process equipment and products. To resolve the issue of poor grid power, C&I customers typically use some form of backup power, with diesel generators. A microgrid consists of distributed energy resources and loads that can be operated in a controlled, coordinated way either connected to the main power grid or in islanded modes. Given the immediate concern of outage-related costs and lost business potential, it may make sense to consider a BESS as the first step without additional renewable energy capacity. Blackouts are a significant cost burden for even the most developed countries, with a recent Navigant study highlighting 2016 US annual power outage related costs of ~150 BUSD, with 90% of corporations impacted by at least 1 major outage1 [1]. Unsurprisingly, developing countries are impacted by significantly more outages and associated costs. The World Bank cites numerous regions with revenue impacts above 4% (Table I).

To limit these impacts, C&I plant owners often use diesel generators to provide back-up power. This enables their site to work in an islanded state during an outage as well as benefiting from relatively low capital costs and the capability of the generator to run without stopping for long periods of time. Unfortunately, generators also suffer from a number of well-known issues: high fuel and maintenance costs, significant environmental impacts such as CO2, air quality, and noise, and a slow start-up time, typically of ~15 seconds, resulting in the shutdown and resetting of sensitive manufacturing and IT related equipment. Further, they depend on reliable fuel supply.

Microgrids offer businesses an alternative to mitigate the power disruptions that negatively affect their operations. Furthermore, thanks to rapidly decreasing battery and renewable energy costs, they have the potential to drive down overall energy costs and reduce carbon emissions. To assess the true potential offered by microgrids, ABB has developed a business case for a glass factory located in India with recurrent outages. This analysis considers the costs and benefits of implementing a microgrid for the glass factory's critical loads only, providing an opportunity for further incremental expansion at a later date. These loads relate to the critical glass manufacturing process itself, where even a short power outage stops production, requiring the removal and clean-up of the Work in Progress glass products. In this case, the scrap glass products can be recycled back into the process.

TABLE I. POWER OUTAGE ISSUES FOR GLOBAL REGIONS [2]

Region	Shares of firms experiencing outage (%)	Annual total outage duration (hours)	Associated losses (% of annual sales)	Firms owning / sharing a generator (%)
Middle East & North Africa	57	1,832	7	41
South Asia	66	1,615	11	45
Sub-Saharan Africa	80	570	8	52
India	55	331	4	47
East Asia & Pacific	46	253	3	33
LatAm & Caribbean	61	66	3	26
High income : OECD	28	15	1	11

Four Scenarios are analyzed to evaluate the microgrid solution for the C&I customer. The business case is described in section II, then the results and sensitivity analysis are discussed in section III, and conclusion is stated in section IV.

II. BUSSINESS CASE STUDY

The business case is built around a glass factory in India, however it would apply equally to any industrial operation of a similar size and with similar grid issues. While the whole factory has an average load of 15 MW with 24/7 operation, we have modeled the critical load only with a peak load of 1 MW and average of 0.5 MW with hourly (but no seasonal) variations. The plant is modeled with 260 outages per year, with each outage lasting an average of 1 hour. This outage frequency and duration is representative of businesses in other developing regions of the world such as Middle East, Africa and Asia according to the World Bank Enterprise Survey7. Cost assumptions related to an outage includes $350 for idle workers, $350 for value of lost product, and $100 for lost efficiency, totaling $800 per outage, or $208,000 per year. Power quality provided by a battery energy storage systems (BESS) is effective in resolving outage related costs.

The minimum operating reserve of the power system is set to vary as a function of load and PV output. The two generators supporting the critical loads are a standard model benchmarked on a leading manufacturer. Each generator has a capacity of 0.6 MW and operates on diesel fuel. The minimum load ratio for the generator is 30% with no minimum run-time.

This case study only considers new investment costs for the hybrid system including ABB microgrid plus control system as the generators are already installed on-site. For comparing each scenario we use a grid price of $0.15/kWh, an all-in diesel fuel price of 1.0 USD/l, which is inclusive of transport, taxes etc., and a total CAPEX for the installed solar PV system, including inverter, of 1.0 USD/Wp. In the simulation, the assumption for the solar irradiation is 5.6 kWh/m2/day. To account for cloud cover 75% of the PV's power output must be collectively covered in the operating reserve by the grid, diesel generators, or BESS. The BESS uses Li-ion batteries and the roundtrip efficiency is assumed to be 90%.

To assess LCOE and annualized costs, a 15% nominal discount rate is applied and a project lifetime is assumed to be 10 years, after which the solar PV modules, BESS and inverters are assumed to have a salvage value worth a third of the original purchase price.

The following scenarios consider various options for upgrading a C&I plant with a BESS and / or solar PV generation. In total, four different scenarios are simulated and optimized to provide the lowest LCOE while achieving a minimum 15% IRR. As presented in Table II, these include:

Base case – Grid + Diesel: The grid supplies all the required energy, and pre-existing back-up diesel generators only supply energy during an outage.

Grid + Diesel + BESS: BESS utilized to reduce grid costs, improve power quality, provide seamless transition to islanded operation, as well as to optimize the efficiency of the generators.

Grid + Diesel + solar PV: Solar PV plant without energy storage used to reduce grid costs and fuel costs.

Grid + Diesel + BESS + solar PV: BESS combined with solar PV effectively minimizes outage related costs while also benefitting from cost competitive solar energy.

The scenarios are simulated in Homer Pro and results are shown in Table II. The sensitivity analysis for different drivers are shown in Table III and Table IV.

III. RESULTS AND DISCUSSION

The base case refers to continuing to rely on the grid for all its energy needs, and only running the existing diesel generators as backup. During an outage, depending on the load and spinning reserve requirements, one or two diesel generators with a 0.6 MW nominal rating each may be required to serve the load. If both generators are online, they would operate in proportional load sharing which means each generator has the same capacity factor. The sum of spinning reserve9 carried by the first generator may allow the second generator to trip or the load to instantly increase without the need for load shedding. This operation leads to additional O&M costs from the second generator runtime as well as lower fuel efficiency due to a lower capacity factor.

At a grid price of $0.15/kWh, and diesel fuel price of 1.0 USD/L, the base case has annual grid power costs of 0.62 MUSD, and fuel and maintenance costs of 0.04 MUSD, resulting in an average annual operating cost 0.66 MUSD. However, if we include the outage related annual costs into the equation this leads to total electricity related expense of 0.87 MUSD with an associated LCOE of 203 USD/MWh. The following scenarios are benchmarked to this base case.

TABLE II. SIMULATION RESULTS FOR FOUR SCENARIOS

	Base case-Diesel + Grid	Grid + Diesel + BESS	Grid + Diesel + PV	Grid + Diesel + BESS + PV
Fuel Consumption (kL)	44.5	43.6	28.5	24.5
Investment ($M)	-	0.55	0.97	1.53
IRR (%)	-	35	20	26
LCOE ($/MWh)	203	177	190	163
Payback (years)	-	2.7	4.5	3.6

TABLE III. SENSITIVITY ANALYSIS FOR KEY DRIVER OF LCOE SAVINGS

Driver	Low Case	Base Case	High Case	Low Case LCOE impact (%)	High Case LCOE impact (%)
Outage Cost (k$/year)	104	208	416	-10.3	14.4
Installed PV price ($/Wp)	0.5	1	1.5	10.3	-10.4
Grid energy price ($/kWh)	0.1	0.15	0.2	-4.3	3.0
Diesel price ($/L)	0.5	1.0	1.5	-0.5	0.5
Installed battery price excl. converter ($/kWh)	300	400	500	0.5	-0.5

TABLE IV. MICROGRID LCOE REDUCTION SENSITIVITY TO ELECTRICITY AND PV PRICES

Electricity price ($/kWh) \ Solar PV price ($/Wp)	0.5	1.0	1.5
0.20	30.6%	22.7%	14.3%
0.175	30.3%	21.1%	12.3%
0.15	30.0%	19.7%	9.3%
0.125	29.0%	17.8%	6.1%
0.10	28.3%	15.4%	1.9%

The BESS for this business case must be able to provide seamless transition to the islanded state, which is enabled in ABB PowerStore solution. This seamless transmission capability can improve overall power quality, reduce grid costs by smoothing load demand peaks, and help delay or avoid the start of a generator. Total investment costs for a BESS solution meeting the modelled size requirements of 1.125 MW/0.25 MWh are estimated to be 0.55 MUSD. The simulation economics are such that the BESS is mainly used for the transition to the islanded state, and to smooth any sudden changes in load, leading to a small reduction in generator usage. Results show annual grid power costs of 0.62 MUSD, and fuel costs of 0.04 MUSD which, together with maintenance and minimal outage-related costs, results in an average operating cost of 0.67 MUSD with payback period of 2.7 years and IRR of 35%. The LCOE is reduced from 203 to 177 USD/MW, mainly due to a reduction in outage-related costs.

This third scenario pursues an alternative path to hybridization initiated by a PV-only upgrade without energy storage. Here we replace grid purchases and diesel fuel by cost-competitive solar PV. Installing this 0.98 MWp PV system requires a CAPEX of 0.98 MUSD. Results show annual grid power costs of 0.42 MUSD, and fuel costs of 0.03 MUSD which, together with maintenance and outage-related costs, results in an average operating cost of 0.65 MUSD. As a result, the LCOE is reduced from 203 to 190 USD/MWh with grid cost savings, and fuel savings are the primary value-drivers for this scenario. The payback time is 4.5 years and the IRR is 20%, somewhat lower than the diesel + BESS scenario that had an IRR of 35%.

In the fourth scenario, the two technologies, BESS and Solar PV, are combined. An investment of 1.5 MUSD is required to add a solar PV system of 0.98 MW and a BESS of 1.125 MW/0.25 MWh. Results show an annual grid power cost of 0.40MUSD, plus fuel costs of 0.02 MUSD which, together with minimal outage and maintenance costs, results in an average operating cost of 0.43 MUSD. Savings come from the 0.20 MUSD reduction in outage related costs, 0.02 MUSD of fuel cost, and 0.22 MUSD of grid cost reduction annually. This solution offers maximum value stacking from the storage component as it almost eliminates outage costs, reduces grid power costs, and reduces diesel fuel costs, substitute diesel generators as operating reserve and smooths demand peaks. The investment returns an IRR of 26% with a payback period of 3.6 years and an LCOE of 163 USD/MWh, and is easily the best option from an LCOE perspective.

As presented in Table III, outage-related costs are found to have the highest impact on LCOE savings. By increasing the outage related costs from 208 to 416 $k/year, an increase in savings of 14.4 percentage points is possible on top of the standard 19.7% savings. From an installation cost perspective, a decrease in PV installed price from 1.0 to 0.5 USD/ Wp leads to an increase in savings of 10.3 percentage points versus the base case + microgrid scenario.

To further assess the impact of grid and solar PV prices, Table IV shows the impact of solar PV price and Electricity price of LCOE savings. In case of high solar PV price and low electricity price, the LCOE saving is the minimum as of 1.9%. On the other hand, if the PV price is cheap and electricity price is high, then the LCOE saving has its highest value of 30.6%.

The transformation to a solar PV + BESS microgrid can be achieved through incremental hybridization investments that lower investment risk and enable an effective response to changing market conditions such as increased grid energy prices, increased diesel fuel price or decreased solar PV price. Adding a BESS alone addresses the immediate concern of outage-related costs and provides the highest IRR. Alternatively investing in a solar PV + BESS solution leads to the lowest levelized cost of energy.

IV. CONCLUSION

Results show that the highest investment IRR (Internal Rate of Return) of 35% is possible by installing a Battery Energy Storage System (BESS) where the main benefit comes from the reduction in outage-related costs. Alternatively, by combining this with solar photovoltaic (PV) panels, the glass factory can substitute expensive diesel fuel with cost competitive solar energy thereby delivering the largest reduction in fuel consumption (45%) and LCOE4 (19%), while maintaining a healthy IRR (26%). This does not include the additional benefits provided by a BESS such as improved power quality and deferred cost of additional generators.

Relying on a weak grid and diesel generators can leave a C&I plant vulnerable to outage-related costs, lost revenue and lost business potential. It also fails to capitalize on the economic and operating benefits that BESS and solar PV offers today. In some cases, C&I plant owners may prefer the incremental hybridization route as it allows more gradual changes to their operating system and strategy. Given the immediate concern of outage-related costs and lost business potential, it may make sense to consider a BESS as the first step without additional renewable energy capacity. This business case is based on a BESS that has the functionality of seamless transition between grid connected and islanding mode. Ideally, the use of a BESS with advanced functionalities of providing seamless transition from grid connection to islanded mode and forming the grid, such as ABB's PowerStore™ would allow the storage capacity to be increased if renewable energy systems are later added.

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