A Novel Approach to the Microgrid Lifecycle:From Design to Operation

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***Abstract*—This paper deals with a new approach being developed by Enerwhere named Enlite that is intended to make the process of setting up microgrids easier. The different aspects of setting up a microgrid from data collection to final operation are described and the proposed solution is expected to make the process easier for the relevant personnel. The current process for setting up microgrids is described in detail followed by the new approach wherein a single portal is used as the interface to measure, design and operate microgrids. The proposed approach ensures that the load curves generated for simulation process is accurate using historic data and AI based approach. The simulation engine proposed here ensures that operational data from real sites are constantly fed back and used to reduce the error percentage of the simulation results. Finally, a microgrid controller that is a continuation of the simulation tool is proposed that uses the same control algorithms that were simulated. The proposed controller constantly runs a digital twin of the operating site highlighting differences between simulation and operation to the operations team. Sample screenshots of the proposed portal and simulation tool are shown along with some examples of real sites operating on the proposed controller.**

Keywords-component; microgrid, simulation, measurement, operation, data

I. Introduction

Independent power systems running their own power generation equipment are common around the world. These systems have traditionally been powered by conventional sources of power that are fossil fuel based. The global diesel generator market is valued at USD 16.4 billion and expected to increase at a CAGR of 8% from 2020-2027 [1].

Over the last decade the cost of renewable power especially solar has dropped dramatically with prices dropping by 82% since 2010 [2]. Considering this, the economics of integrating renewables with isolated grids running on diesel or other fuels has become more and more attractive. Independent power systems running different sources of generation have been named microgrids and research into the stability and operation of these microgrids has been steadily increasing over the past decade with different areas of focus. A large batch of research focusses on the dynamic stability of microgrids [3]-[6]. In [7]-[10],

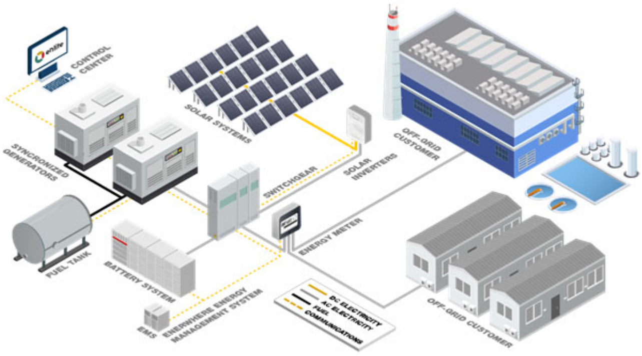


Fig.1. Typical microgrid setup

optimization techniques for the dispatch of microgrids are discussed. While most of the work addresses the technical challenges of microgrids and the optimization of diesel cost, there isn't a lot of attention on the commercial aspect and challenges of setting up a microgrid. A large part of the global power supply still depends on small to medium scale independent grids and a large percentage of them still operate with minimal renewable penetration. At the small and medium scale, the bankability of microgrids from an investment perspective is lacking due to the complexity of the current process to set up microgrids and the expert engineering required.

This paper focusses more on providing a viable solution to help ease the process of developing microgrids. Section II discusses the three main steps to setting up a microgrid and some of the solutions currently on the market. Section III of this paper presents the concept of an integrated microgrid development tool being proposed that provides a single portal for design and operation of microgrids. Examples and screenshots of some of the tools are shown and the feedback between different steps of the development process is highlighted. In Section IV, some of the results from the different components of the proposed tool are shown with real examples of operations from different microgrids being designed and operated on the platform.

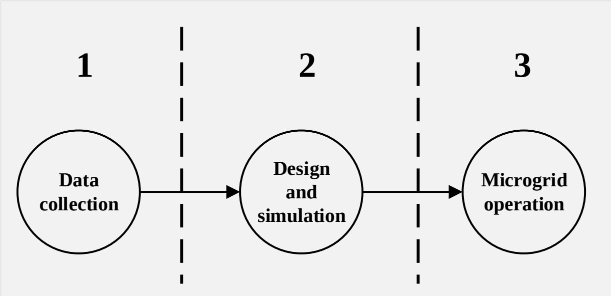


Fig.2 Steps to microgrid development

II. Steps to a functioning microgrid

A. Data collection

The first step to ensuring that the microgrid is designed correctly is to ensure that the loads and energy consumption patterns of the system are understood correctly. Poor data on microgrids used particularly for backup power across the developing world has been identified as a key issue in the energy transition [11]. Changes in load curves driven by weather and other elements are critical to understand to ensure that the final configuration of generation options chosen are optimal and also to make sure that the control algorithm for the operation of the microgrid is designed for all scenarios. Currently, most commercial simulation tools on the market require the load curves as an input and it is up to the designer to collect the load information. From experience in the market, these load curves are collected in a variety of ways.

a) Load curve supplied by the consumer which is sometimes available for more sophisticated consumers

b) Estimates carried out based on conversations with clients

c) Estimates derived from total connected load scehdules

In all of the above methods, there is a very high chance of the load that is modelled being inaccurate. The chances of error are very high in all techniques and correct estimation requires qualified engineers that can extract the right information from the client and with knowledge of the types of loads they are estimating. Further, for industrial loads, it is extremely difficult to estimate or predict starting currents and spinning reserve requirements. Without the correct understanding of the loads, the entire design process cannot be accurate and the gap between simulation and operation will inevitably be very wide. There aren't too many easy to access and commercially viable tools on the market to solve this problem currently and most available tools do not have a direct link from measurement to simulation requiring tedious steps along the way.

B. Design and Simulation

Once information regarding the load and the consumption patterns are available, the next step of the process is to run a simulation to understand the tradeoffs and the optimal generation configuration. Though there are tools currently available for simulation, there are a few drawbacks that need to be addressed.

a) Ease of use- Highly trained engineers are required to run simulations and the process is time consuming

b) There is no direct link between the simulation tool and data collection to make the process easier

c) Control algorithms on the simulation tools may not necessarily be the same once system is in operation

d) Operational constraints and feedback from operating microgrids is not taken into account

e) The ability to constantly compare simulations to operating microgrids as digital twins, measure error and correct for future projects is lacking

The lack of these features makes microgrid simulation less bankable and the differences between operating sites and simulations carried out is large. In combination with inaccurate data inputs described earlier, the entire process to arrive at a system design requires special expertise, is time consuming, inefficient and not always accurate.

C. Microgrid operation

The final step of realizing a microgrid once all the different components are installed is the controller for the system. There are different control techniques and optimization algorithms presented in literature and there are a few commercially available products that can essentially bring together different sources like diesel generators, renewables and energy storage devices. However, with so many different suppliers available for each of the components, providing a flexible controller that is technology and supplier agnostic is a major challenge. The ability of controllers to learn and optimize the operation of microgrids with changes in load patterns and behavior of different components is lacking. Further, there is a need to make controllers smarter providing them with AI based techniques to learn and improve from the experience of multiple operating microgrids with specific features that may vary based on load type and geographical location. Providing microgrid operators with a smart control system that ensures reliability while minimizing operational costs and enabling the integration of a wide array of technologies with ease is important to progress the adoption of microgrids without hurdles.

D. Hurdles to adoption of microgrids

Considering the three different steps to setting up a microgrid, in order to convert a power system currently operating on conventional generation to a smart microgrid, there are multiple challenges in each step of the process with multiple tools and personnel with different expertise required. Considering the large portions of the globe currently relying on off-grid power, there is a need to streamline the process and provide consumers with the right set of tools to design and operate microgrids reliably. In the following section, a solution is presented that provides a unified single smart portal to handle the entire process of setting up a microgrid.

III. Proposed Solution

In this paper, a unified portal is presented for the design and operation of microgrids that allows users to seamlessly

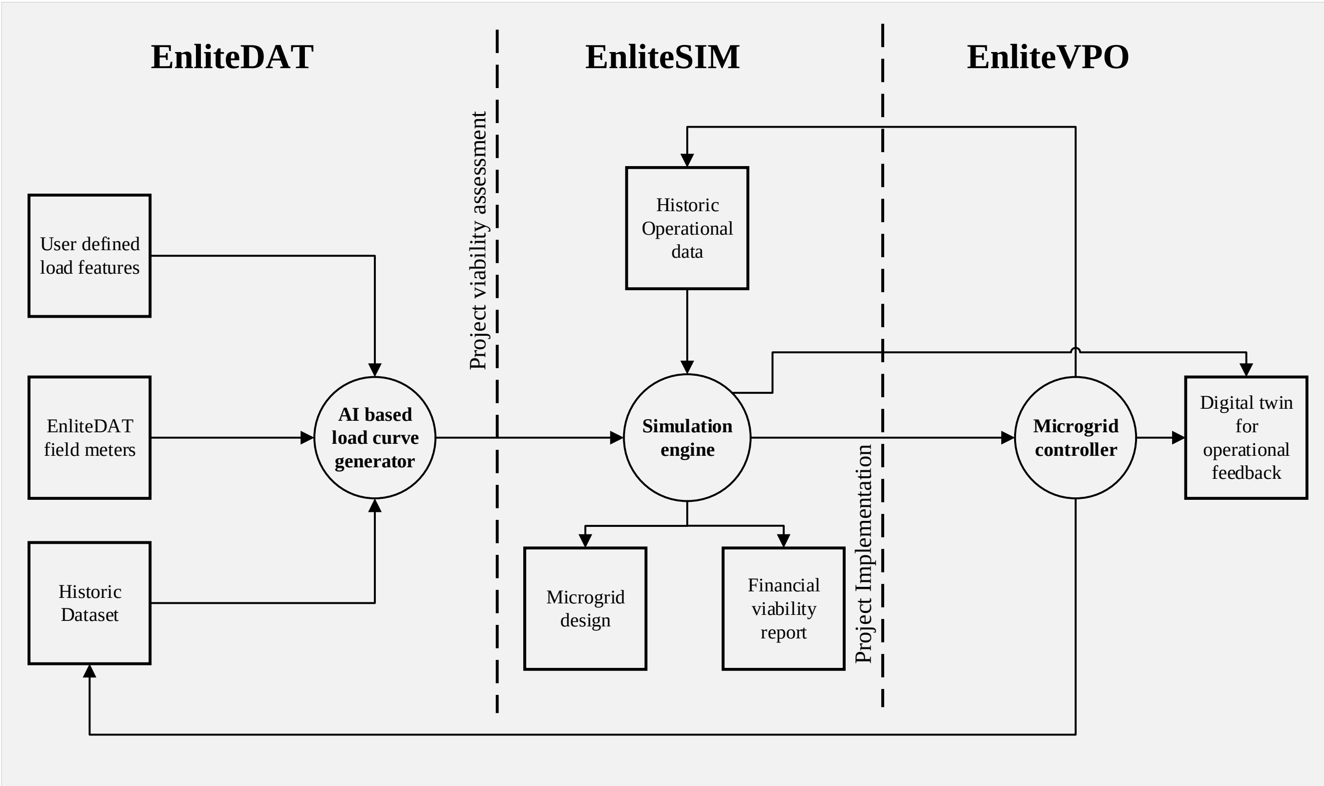


Fig.3 Proposed microgrid design process

go from identifying an independent power system to operating a smart microgrid that incorporates different technologies. The portal has been names as Enlite and will be referred to as such from here on. The proposed system looks to solve some of the major problems in the process identified earlier while making the development of microgrids easy and accessible to developers around the world. In Fig. 3 , an overview of the three steps is shown highlighting the closed loop nature of the process leading to better simulation and better operations. A detailed explanation of the proposed solution is given step by step below

A. Data collection (EnlitDAT)

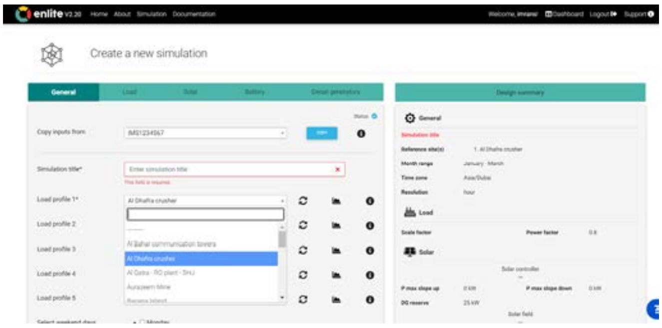
As identified earlier, understanding consumer data and the patterns are critical to the design process. In order to ensure that the data is collected and estimated correctly, an easy to use and rugged metering solution is proposed. The meter boxes are easy to install and upload data from any potential consumer to a central database. A picture of such a meter from the field is shown in Fig. 4.

The central database holds a collection of load curves from different geographies and load types that have been collected over years and continue to be updated based on new measurements and also from the different sites that are operated by the controller. Once a particular meter is installed on a specific load, a user enters certain key parameters regarding geographic location, type of loads and other key features. Using the provided information, an AI based load generation engine looks at historical data and develops a yearly load curve for the specific site based on limited measurements. The duration of measurements required depends on the type of load and location. The generated load curve and the live energy parameters are made available to the user on the Enlite portal.

Fig. 4 Enlite pre packaged meters

B. Design and simulation tool (EnlitSIM)

The simulation tool proposed here is a progression from the data collection module. Once load curves have been built based on measurements, these are made available to the user as an input. From here, the user has the option to define capacities for solar, diesel generators and energy storage or enter certain constraints like space availability or financial constraints based on which an optimal system configuration is presented based on an optimization engine that optimizes for a user defined objective which maybe financial or based on renewable penetration expected. An overview of the



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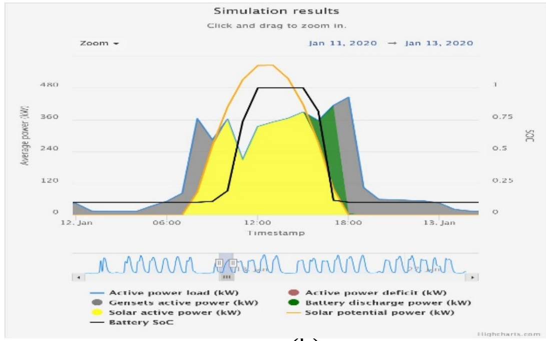

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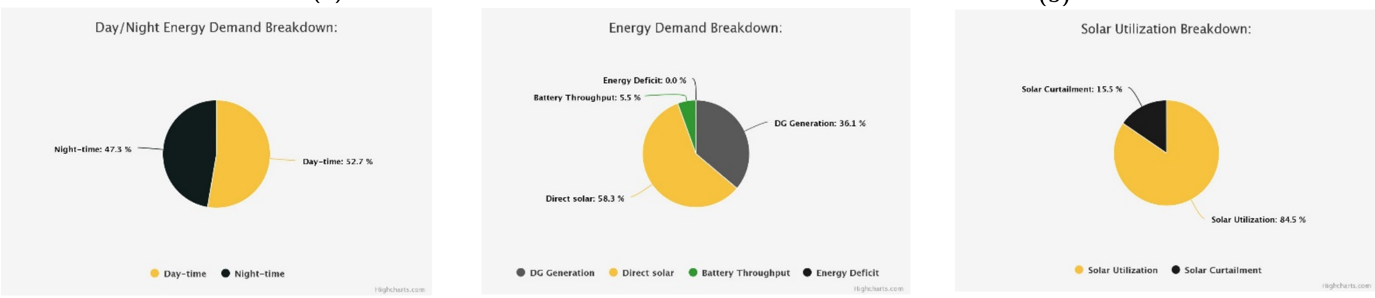


(c)

Fig. 5. (a) Load type and curve selection screen (b)High resolution daily operational result and (c) Energy demand and consumption breakdowns

different modules for the simulation and the key features of each are described below

a) Load curve selection

The load curves for the measured systems are made available to the user and the yearly load curved can be browsed through by the user to understand the system curves from different plants allowing users to pick and drop load

curves and combine them for simulation purposes patterns that can guide in solar and storage selection. Additionally, the tool allows users to combine different load

a) Solar capacity selection

In case the user decides to run their own configuration without allowing the system to simulate, PV capacities and orientation of the modules can be chosen here. Additionally, flexibility for taking into account operational constraints are added where based on location and cleaning schedule, using historical data from similar sites, soiling factors are decided

b) Energy storage selection

Certain key parameters of the energy storage system like capacities, c-rating, DOD and RTE are entered here to enable the correct simulation

c) Diesel generator selection

One of the key advantages of the proposed simulation tool is the use of real world efficiency data from diesel generators operating on site under different temperature and load conditions enabling a more accurate prediction of diesel consumption that is usually the key operational cost for a microgrid

d) Financial analysis

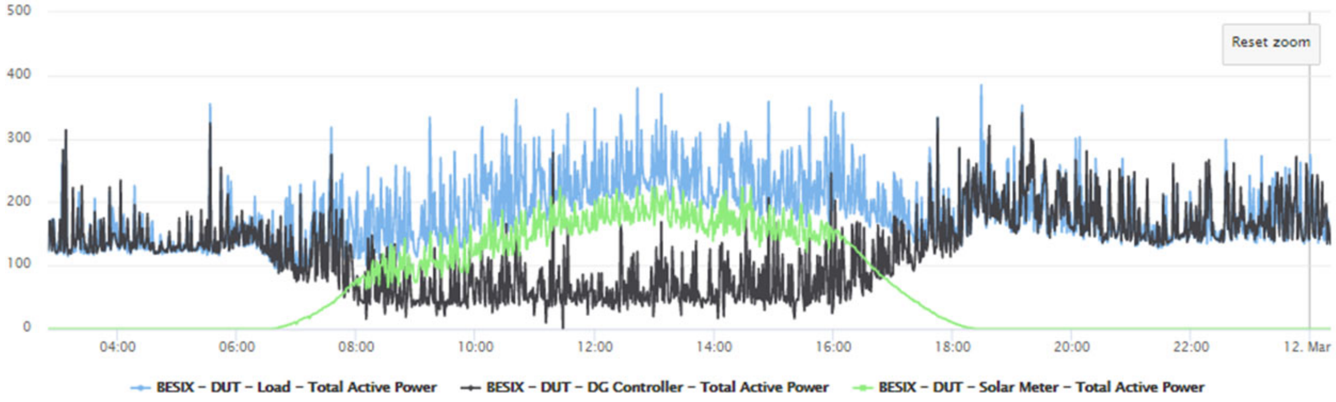
Based on the parameters entered and control algorithms that are defined and designed based on the multiple sites that are operated using the solution, a yearly high resolution simulation is carried out with the results primarily indicating the operational fuel costs on site. In addition, the user enters other cost parameters for the site like O&M costs and BOP costs. Based on the given information, a simple payback and an IRR are calculated for the different configurations simulated. In case of the optimization engine, a low CAPEX, high CAPEX and medium CAPEX scenarios are presented to the user enabling ease of decision making.

e) Constant feedback from operations

The design of the simulation tool is done with the ability to learn as an increasing number of sites are run using the Enlite suite of services. Operational data from sites operated using the controller is fed back to the simulation engine, that then constantly updates key parameters like efficiency of generators used, solar production estimates based on region, battery performance and aging, parasitic loads and observed round trip efficiency values of batteries for the location. This key feature ensures that the more the tool is used, the better the simulation experience and the accuracy of results.

C. Microgrid controller (EnlitVPO)

The final part of the microgrid setup is the controller that is responsible for controlling the different elements of the microgrid like the diesel generators, energy storage systems and the solar inverters. Most of the commercially available controllers are linked to equipment suppliers and there are very few technology or supplier agnostic controllers available. The proposed controller is a flexible, technology and supplier agnostic controller that has the following main features:



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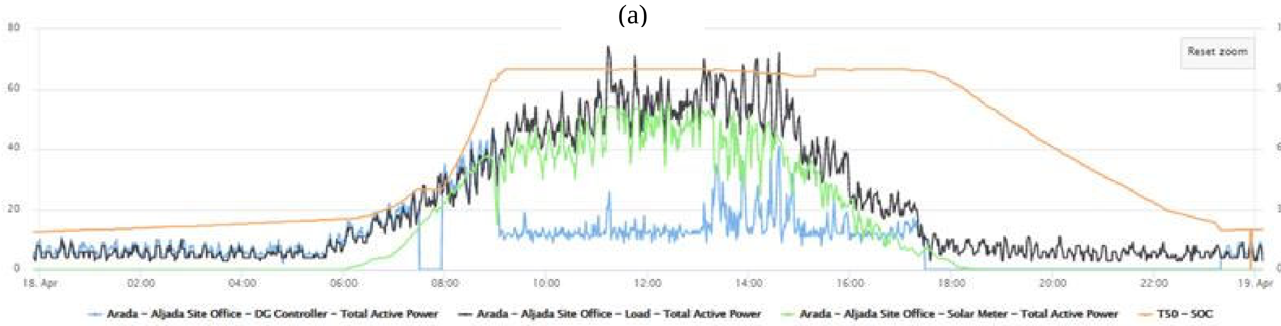

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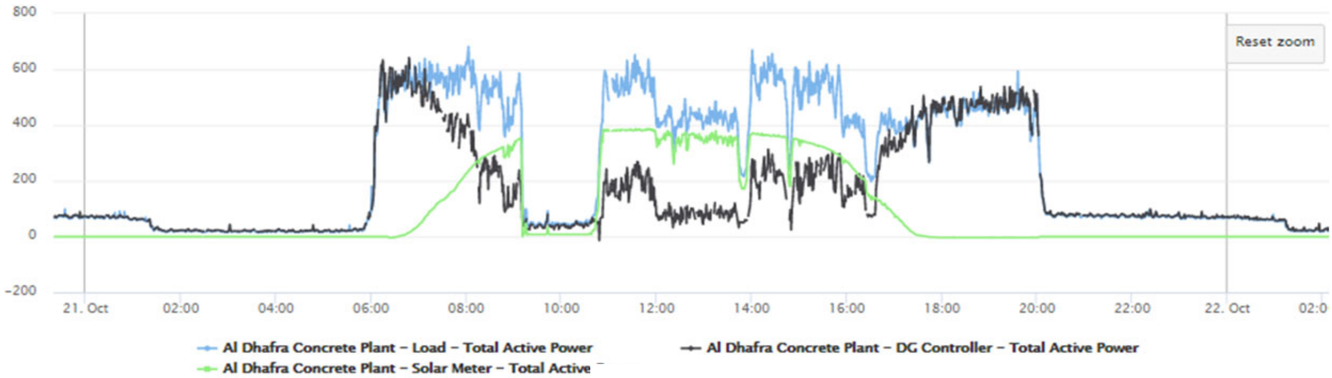

(c)

Fig. 6 . (a) Operation of EnliteVPO on a high peak industrial load (b) Operation of EnliteVPO with solar, batteries and DG on a site office (c) Operation of EnliteVPO on a high penetration industrial grid with sudden load drops and increases

a) Enables high penetration of solar on microgrids even with industrial peaks that are managed with solar

b) Integrates seamlessly with different solar and storage inverters available on the market

c) Links back to the simulation tool, constantly sharing data from the real world to improve simulation accuracy

d) Compares simulation results with ongoing operation and raises alrets on deviations

e) simulations performed. Diesel consumption figures were Identifies the source of deviation from simulation (unlcean panels, inefficient generators etc.) and enables the operations team to rectify

f) Adds load specific information to the central database constantly, improving load estimations for new simulations

IV. RESULTS

In this section, some of the results and operational samples from the simulation and control tools proposed in this paper are shown.

A. EnliteSIM

The simulation tool developed links to the data portal using a dropdown menu from which the data source is chosen. A series of images from the tool are shown in Fig. 5 highlighting different aspects of the tool.

Further, data from various operating microgrid sites was fed into the simulation tools and the results were compared to real data from the site to check for accuracy of the
used as a reference to validate the accuracy since the biggest operational spend on a specific microgrid is usually the diesel consumption. The results for two sample sites are shown in Table I.

TABLE I

Project	*Simulated Fuel efficiency (L/kWh)*	*Real Fuel Efficiency (L/kWh)*	*Fuel consumption error (%)*
Site office load	0.43	0.42	6
Industrial load	0.30	0.30	1

As seen in Table-I, the simulation tool predicted the efficiency obtained on site accurately. The error in absolute fuel consumption is below 10 %. The model is currently being updated to learn from the many different factors that impact the error obtained here from solar cleaning schedules to diesel generator breakdowns. The novelty of the approach where the data is constantly fed back lies in the fact that these error percentages are expected to continuously lower as more sites are operated and more lessons are learnt by the simulation engine.

B. *EnliteVPO*

The proposed controller is currently operating on more than 20 microgrids across the UAE ranging from mines to construction sites. A sample shot of two applications are shown in Fig. 6. In Fig. 6 (a), the operation of the controller on a site that has a mix of site offices and high power tower cranes leading to the peaks that is shown. Around 500 kW of solar was installed on this site along with diesel generators and controlled with high precision to follow the peaks and dips of the tower crane operation maximizing solar penetration and minimizing diesel consumption. In Fig. 6 (b), the controller is running on a system with generators, solar and Lithium based battery systems. The use case here is to ensure maximum penetration of solar, reduce diesel generator running hours and diesel consumption while ensuring reliability. Further, the controller used on this project communicates independently to the battery management system (BMS), the power conversion system (PCS) and the diesel generator controller to ensure smooth and reliable transitions between different sources. In Fig. 6 (c), the operation of the controller is shown on an industrial load with sudden drops and increase in loads with the solar having to follow closely.

V. CONCLUSION

The current process of setting up a microgrids complex and disjointed with different tools and expertise required for each stage. The disjointed nature makes accurate modelling of microgrids difficult and more often than not the difference between expected results and actual operation is high. In this paper a unique approach to microgrid design is presented that enables developers and end users to hybridize their power systems. Making sure that there constant feedback and learning from live sites reflected in the load curve generation and simulation process ensures that the proposed system is accurate and the gap between operation and simulation is narrowed. The proposed system only gets better the more the number of sites measured, simulated and operated. Finally, the results from the simulation tool and some real examples of the controller operating are showcased for reference.

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