Micro-Grid Campus Concept from Data to Design: Case Study Malta

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***Abstract*— This paper aims to highlight the endeavors of a micro-grid campus development from data to design stage that is under development at the Malta College of Arts, Science and Technology (MCAST), Malta. Malta is an island in the middle of the Mediterranean Sea having an area of 316km2 and receives the highest EU solar irradiance. The MCAST micro-grid is the first living laboratory for training and research on the island with one-third of the campus fully development in state-of-the-art facilities. In this case study, the loads consumption, photovoltaic (PV) generation and potential Electric Vehicles (EVs), that may support the campus when necessary are analysed for further designs supported by over 2 years of campus data. This analysis would provide the understanding of integrating future EVs on campus and higher penetration of PVs while keeping high consumption loads at watch. In addition, reliability and cost factors of the MCAST micro-grid are considered and recommendations are given on the infrastructure to complete campus wide transformation.**

Keywords—PV, EV, Microgrid

I. INTRODUCTION

Micro-grids have been used to describe a campus wide intelligent network whether connected or not to the main electricity grid. Micro-grid demonstration projects on universities campuses are implemented for various purposes for example to improving grid performance, reliability and efficiency [1], [2]; integrate renewable energy sources (RES) and storage options [3], [4]; engage users students, faculty and staff to improve energy efficiency on campus [5], [6]; and facilitate research and education [7], [8]. Data is important to design a future-proof microgrid.

This paper aims to highlight the endeavors of a micro-grid campus development from data to design stage that is under development at the Malta College of Arts, Science and Technology (MCAST), Malta. The goal is to provide understanding of integrating future EVs on campus and higher penetration of PVs while keeping high consumption loads at watch.

The paper is structured as follows: first, in Section II, the case study is introduced. Afterwards, in Section III, the

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respective results are investigated. Later, in Section IV, the main conclusions and future work are given.

II. THE CASE STUDY

A. MCAST Microgrid Model

Malta is an island in the middle of the Mediterranean Sea having an area of 316km_2 and receives the highest EU solar irradiance. The MCAST micro-grid, shown in Fig. 1, is the first living laboratory for training and research on the island with one-third of the campus fully development in state-of-the-art facilities. However currently only 64kWp PV systems are integrated leaving a large gap of power demand from around 440kW maximum demand and a base load of 70kW.

The data is collected remotely through a centralized controller monitoring of the low voltage feeders, heating and ventilation systems, a major load, as well as lighting and PVs with the installation of smart meters at the end of each feeder. Some of the key performance indicators (KPIs) have been evaluated from the real data as given in Table I. These parameters are used to determine the performance of the microgrid.

Moreover, on campus there is a large vehicle underground parking facility that reaches its peak during the peak demand profiles. The carpark is estimated to accommodate up to 600cars once that works in the campus are completed by end of 2020. It is estimated that in 5 years, 15% of the cars in Malta will be Electric Vehicles. The total load demand at MCAST campus in kilowatts is given in (1),

$$P_{LOAD} = P_{ESS} + P_{NE} \tag{1}$$

where P_{ESS} and P_{NE} are the essential loads and non-essential loads respectively while P_{GEN} is the total power generated on campus. The input power from the grid, P_{GRID} is given as stated in (2)

$$P_{GRID} = P_{GEN} - P_{LOAD} \tag{2}$$

where P_{GEN} is the total power generated on campus. To the present, the P_{GEN} is equal to the power generated by the PV system installed (P_{PV}). Therefore, essential load demand is calculated by (3),

$$P_{ESS}\,(kW) = P_{D\_ESS} + P_{F\_ESS},\ P_{J\_ESS} + P_{PR1\_ESS} + P_{PR2\_ESS} + P_{SR\_ESS} + P_{CP\_ESS} \tag{3}$$

TABLE I

KEY PERFORMANCE INDICATORS

Name	Value
Reduction of GHG Emissions	66,628 ton CO_2
Voltage Standard Deviation	3.72 V
Frequency Standard Deviation	0.51 Hz

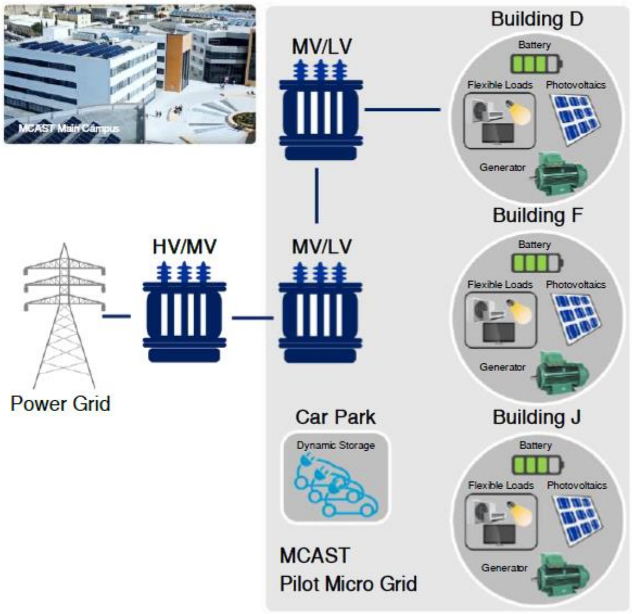

Fig. 1. The Case Study Illustration [9]

where P_{D_ESS}, P_{F_ESS}, P_{J_ESS}, are the essential loads of Buildings D, F, and J respectively, P_{PR1_ESS}, P_{PR2_ESS} are the essential loads of Pump Room 1 and 2 while P_{SR_ESS} and P_{CP_ESS} are loads of the switchgear room essential loads and carpark essential loads respectively. Similarly, P_{NE} is defined by (4)

$$P_{NE} = P_{D\_NE} + P_{F\_NE} + P_{J\_NE} + P_{D\_AC} + P_{F\_AC} + P_{J\_AC} \tag{4}$$

where P_{D_NE}, P_{F_NE} and P_{J_NE} refers to the non-essential loads of the proposed buildings while P_{D_AC}, P_{F_AC} and P_{J_AC} are the feeders of the HVAC systems of each building.

A. Formalization of Microgrid Components

The size of energy storage system is formalized depending on the essential loads. Therefore, the energy storage capacity, C, can be calculated using (5),

$$C_{BAT}(kWh) = \frac{P_{ESS} * h}{DOD * \eta_{BAT}} \tag{5}$$

where *h* is the number of hours that the battery should supply, DOD is the Depth of Discharge, and η_{BAT} is the efficiency of the battery. The DOD results to be,

$$DOD\,(t) = 1 - SOC(t) \tag{6}$$

where SOC refers to the state of charge of the battery at time *t*. Similarly, the rating of the generator is defined by

$$S_{GEN}\,(kVA) = \frac{P_{ESS}(kW)}{PF} \tag{7}$$

where the S_{GEN} is the Apparent Power of the Generator while PF refers to its power factor.

III. RESULTS

In this section, the cases are presented from the data readings of the MCAST microgrid. Fig. 2 shows the essential load demand curve for one month in August. From the initial analysis, the peak essential load demand is almost 120kW for a relatively short period of time while the baseload demand is less than 20kW for 50% of the month. From the real-time data gathered, the essential load demand is similar throughout all months of the year. The sizing of the energy storage and/or electrical generator required by the system are further discussed in this paper results including monthly typical results.

The scope of this analysis is to provide designated methodology to convert the studied buildings into a microgrid based localized energy generation. A localized diesel generator and lithium-ion (Li-on) battery are proposed to be integrated to improve the electrical network reliability and maximize the energy reliability to the current system. This will enhance the microgrid network with an energy storage system and a dispatchable source which is controlled by the main controller [13].

The methodology of this study is to propose an energy storage system as a backup energy system in case of power failure from the main grid. The energy storage system should be able to supply electrical power to essential loads for two hours, thus shedding the non-essential loads if needed. The energy storage system consists of both fixed and mobile storage: lithium-ion battery and electric vehicles (EVs).

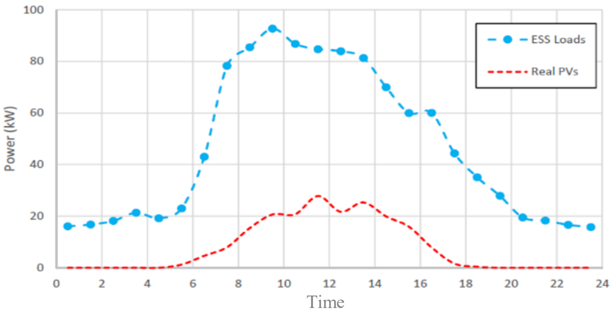

Fig. 2. Daily essential demand v/s PV generated

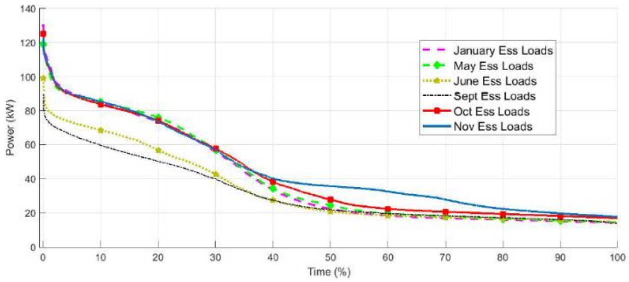

Fig. 3. Load demand curve for various months

Fig. 3 illustrates the difference between the essential load demand and the power generated from the PV system on a typical weekday at MCAST campus. These curves were plotted using real data obtained from the smart meters where the essential loads between 8AM and 2PM are found to be above 80kW.

The peak power consumption of the buildings being monitored occurs when there is a maximum population on campus. At the peak times, it was estimated that 90 cars out of 600 are electric vehicles, from which 45 cars can be used for Vehicle-to-Grid (V2G) concept when necessary.

Since there is a large gap between the peak power (100kW) and the baseload demand (20kW), a compromise for the energy capacitance of the fixed batteries was proposed to minimize the costs while still keeping sufficient power to supply for the most of the essential load. The rest of the power can be obtained using bi-directional charging points for Vehicle-to-Grid (V2G) concept from EVs since the peak consumption occur when the carpark is fully utilized.

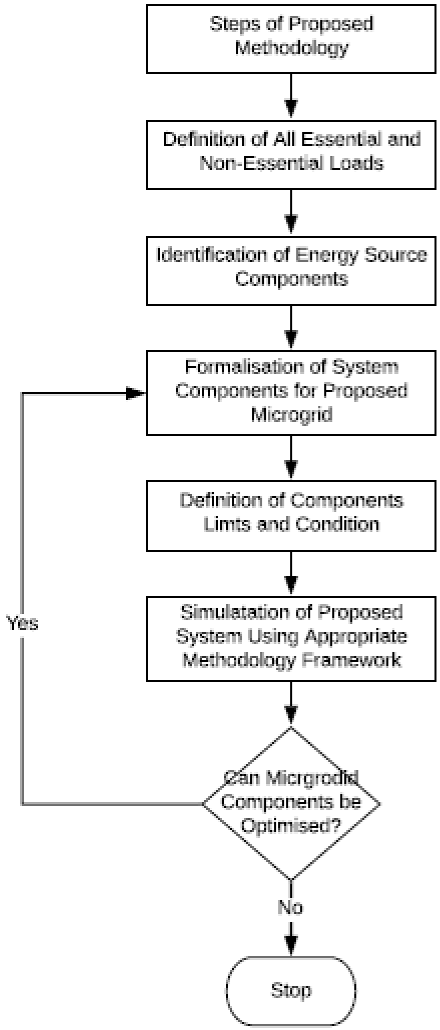

Fig. 4. Proposed Methodology Flowchart

Therefore, the lithium battery capacitance is rated 150kWh. This was implemented in a methodology framework and results shown that this size of the battery lasts longer than 2 hours. The Li-on Battery SOC should not go under 30% while the EVs' SOC should remain above 50%. Beyond these battery states, a 150kVA generator starts if the power is not restored from the main grid. These values are projected in the worst case scenario of the PVs, therefore when they are not generating any power. After the first simulation on the framework, the system was further modified that the Li-on battery should supply all system (including non-essential loads) until its SOC is above 50%. Once its SOC reaches 50%, the non-essential loads are shed.

Fig. 4 describes the steps of the proposed methodology for identifying the ideal components for the campus microgrid. Once the components are calculated from the relevant loads and generation data, these are implemented in the framework. The optimal solution for improvement in system reliable can be simulated.

IV. CONCLUSIONS

A data driven analysis of the MCAST microgrid was presented in this paper. It was emphasized that with the help of the proper data generation, the yearly behavior of the microgrid can be envisaged. The planning of the exact storage requirement was also formulated in the paper. With the help of the data, several key performance indicators were revealed, which included the CO_2 emissions, as well as the voltage and frequency standard deviations. Therefore, it can be concluded in the paper that real data is indispensable in planning a futuristic and efficient microgrid.

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