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Development of Energy Monitoring System for a Typical Micro-grid

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Abstract— Energy monitoring system is developed for a microgrid consisting of Utility Electricity supply, DG sets, solar generation etc. Smart metering with developed data logger and software is adopted to monitor, measure, and control the electrical loads. This is used to control devices employed in HVAC and lighting systems across multiple locations in the campus considered as microgrid. Energy Management System (EMS) using SCADA is implemented at the Institute to monitor, control, and optimize the performance of the entire electrical network. The usage of the system would be for viewing the real time energy data for monitoring and control of electrical system performance like dash board, device communication status, Meter status, Line diagrams, and historical data for analyzing the past performance of the electrical system. Based on the analysis, preventive measures can be taken to avoid fault occurrence, addition of loads, phase balancing, planning for future loads etc in the network.

Keywords—Energy monitoring, Micro-grid, Smart meters, Control, phase balancing

I. INTRODUCTION

Energy management system (EMS) is an enabler towards a new, sustainable and flexible system as it creates new advantages in the energy value chain through integrated load management architecture. For example, it can decrease the need to invest in higher rating components to accommodate peaks in power demand; the consumer load can be re-allocated to different time of day [1]. Another, reason to improve the grid is the need for improved reliability and security. Smart metering, sensor networks, embedded technologies and IoT are required to realize many of these aspects.

Energy management is an interdisciplinary subject which requires products and concepts from various fields to make the system to function. For example, generation topologies integrating solar thermal, solar PV, grid and batteries (thermal, mechanical, electrical, material and chemical engineering), new monitoring and control mechanisms are required including new tools for planning electricity generation. This leads to several research areas viz. (a) Solar PV with grid integration (b) Solar thermal with grid integration (c) Battery-less grid integration (d) Grid failure detection, islanding (e) Load management (f) Real time monitoring and Control involving Wide area Measurements, Distributed and remote controlled actuators, Power line communication for monitoring and supervisory control.

The objective of the present work is to build a multimodal system towards saving energy, and thereby reduce carbon-footprint, at a personal level and also at the community level. This demand transforming way of life without compromising the quality. EMS envisages obtaining information by developing an intelligent sensor and power network that employs energy harvesting. This network should have recursive architecture and should help in balancing the demand and response. The decisions are to be made with distributed processing in real time and availing context information based on sensing with important objectives:

II. POWER AND COMMUNICATION NETWORK

A. Power and Communication Architecture planning

Figure 1 shows the design and build of a fractal of recursive power cum communication architecture adopted at the Institute. A fractal unit at a given hierarchical level consists of several nodal units connected to sinks on one side and to a master nodal unit on the source side. The master nodal units have several power cum communication ports that connects to the nodal units and a single port that connects to a source or act as a higher level hierarchical nodal unit. Every nodal unit will be composed of power electronic systems, embedded systems and IoT systems that will integrate power flow and information flow.

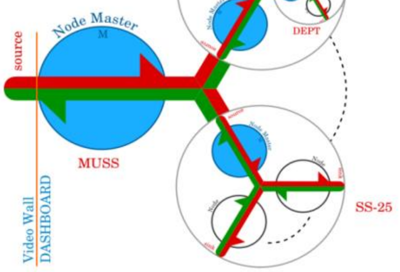

Figure 1. Recursive power & Communication network

B. Estimation of Roof top Solar PV Installation

Indian Institute of Science (IISc) campus at Bangalore, India is considered as EMS in the present context. The campus electrical system is considered as a microgrid, the topology of which is as shown in figure 1, the campus is spread of about 400 Acers. Various departments are connected to substations (SS-1 to SS-25). There is a single master unit substation (MUSS) 66/11kV where grid power enters the campus. The substations act as nodal points for the MUSS level. At one hierarchical level below, the topology recurses wherein various departments connect to a substation which acts as the node master at this level.

Further at lower level, the departmental sub-microgrid appears in the same architecture to handle power and information. This architecture can recurse up to each individual load as the lowest level sinks. At the other end, the same nodal architecture can scale upto many neighborhood, extensions.

Figure 2 shows the satellite image of Indian Institute of Campus at Bangalore, India. The green foliage portions of the campus have been greyed-out in order to highlight the roof top areas. The dark (reddish) portions are the roof tops that are visible from satellite. It can be observed that the campus can be classified into grid block zones as indicated in the figure. Not all zones have roof tops available. As the PV panels need to be located at a south facing angle only those roof tops that have slopes in the north-south directions have been considered as viable. This study being a preliminary estimation, the satellite image accuracy may be enough.

However, for a more accurate estimate, manual measurement of the roof tops is conducted along with the estimate of the effective angle of incidence of sun rays over a day on each roof top. After an exhaustive field study, the total estimated solar power which could be available is about 7500kW from the available open roof tops of various buildings in the campus. The roof tops can be used to collect solar energy through PV panels and deliver them at various sub-microgrids within the campus. Design and implementation of such renewable energy generation and integration to campus grid using the recursive power cum communication architecture is a key objective and is being carried out in phases, presently about 600kWof solar PV is being installed and fed to the local grid.

C. Microgrid Optimization

Fig.3 gives the electrical power consumption for last three years at the institute; it is observed that an average of 38lakh units is being consumed. Hence, it is planned to understand the daily and seasonal variations, together with the intermittency of Renewable Energy (RE) sources this necessitate hybridization and energy storage in order to obtain continuous power output. On the demand side, the variation in load pattern adds further complication to the overall performance of an RE power plant. Choice of the RE Sources mainly depends on the location while the capacity also plays an important role. Type and size of storage system depends on the RE Source and the time period over which the loads are to be catered. Type and pattern of loads can vary depending on the applications.

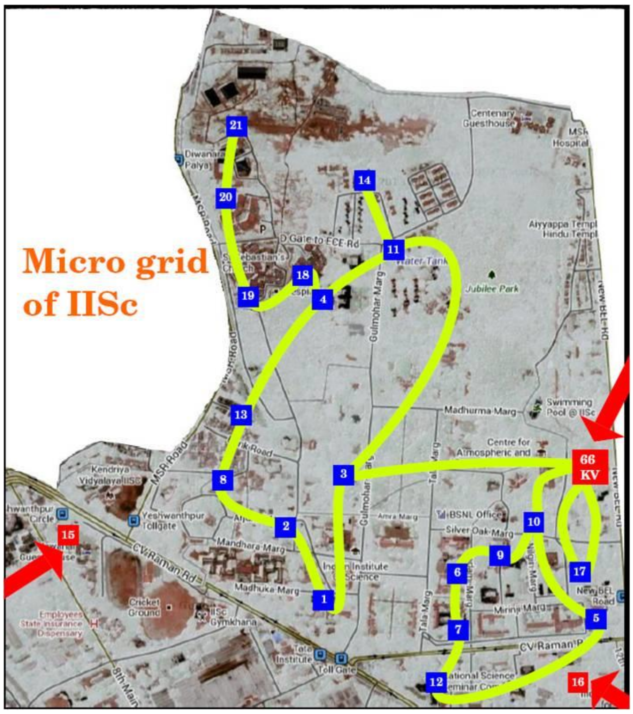

Figure.2 Google map of IISc microgrid

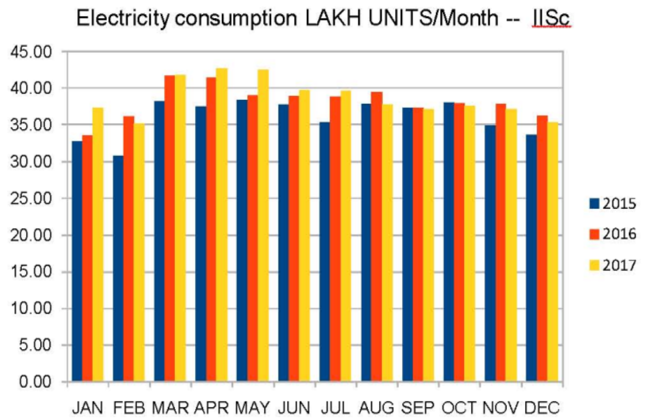

Figure.3 Electricity consumption for last three years

In general, a large variety of combinations are possible for a given application. Hence, rigorous dynamic simulation of the integrated system is essential to arrive at an optimized configuration especially in the design of a Stand-Alone RE Power Plant. Modeling and optimization feature will look at: (1) Development of methodology to capture multiple value streams of RE Sources and storage, for improving flexibility in off-grid integrated systems. (2) Analyzing the impact of high solar penetration in the system through integrated short-term and long-term modeling approaches including various energy storage options [2-5] (3) Arriving at optimal hybrid energy storage options for different system configurations, generation mix, capacities, load patterns, locations, etc.

In the present work a study is undertaken for a typical micro grid which consists of multiple generation technologies including solar PV and building integrated PV, Diesel generating sets etc. Schematic diagram of the proposed micro grid is shown in Figure.2. The micro grid will operate both in grid connected and isolated mode. Focus will be on investigating the impact of variation in storage size and technology selection, considering the availability of generating resources and load fluctuations. In order to realize the objectives mentioned, the entire campus is considered as the micro grid, wherein the EMS concept has been developed, tested and implemented. Detailed load analysis is also being performed. Roof tops of campus buildings will be used for solar energy collection [6-8]. The power electronic grid interfaces is being developed to operate seamlessly with or without grid. The recursive power cum communication network architecture is recently developed and implemented for modularity and scalability. A video wall energy dashboard has been installed, this act as the eye of the campus Energy Management System.

III. Smart Metering Implementation

The typical components required for a smart metering include: CTs and PTs, Energy meter, Data logger, Server, application software etc. Figure 4 shows the schematic of the components for a smart meter and Figure 5 and 6 presents few of the smart meter and a data logger installed at few locations at the campus. There are several advantages of using smart meters: to measure power, energy, phase and line voltages/currents, power factor, phase imbalance, peak demands, power down periods, harmonic distortions etc along with these weekly/monthly power demand, fault alerts etc are also embedded in the present developed software.

Smart meters are installed across the campus micro-grid at more than 250 nodes; Current, voltage and power data is monitored using smart meters with SCADA network. A web browser-based GUI is developed, wherein prediction of energy usage to make appropriate control decisions for maintenance and actuation is done. Django based interface is developed for viewing, monitoring and analysing data. Django is a Python-based free open-source web framework, which follows the model-view-template (MVT) architectural pattern, it also provides an optional administrative create, read, update and delete interface that is generated dynamically through introspection and configured through admin models, also a browser based video wall /interface is commissioned as shown in Figure7.

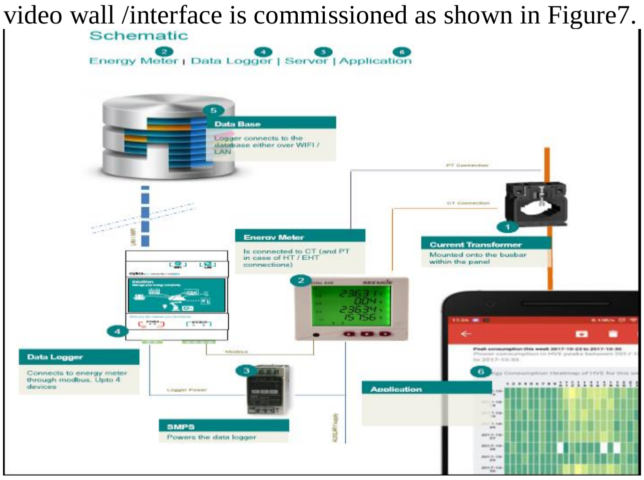

Figure 4: Schematic of the smart meter installation

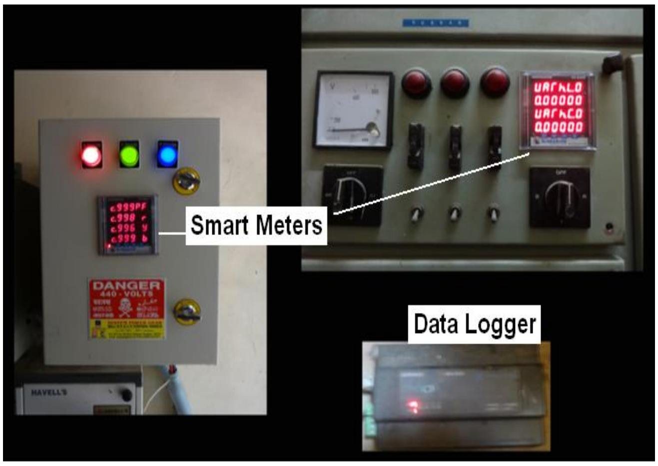

Figure 5. Installation of a Smart meter and Data logger


Figure.6. Typical smart meter installation (at 66/11kV SS)

IV. Energy Monitoring and Control

Energy management system with smart metering is developed to monitor, measure, and control the electrical loads. This is used to control devices used in HVAC and lighting systems across multiple locations in the campus.

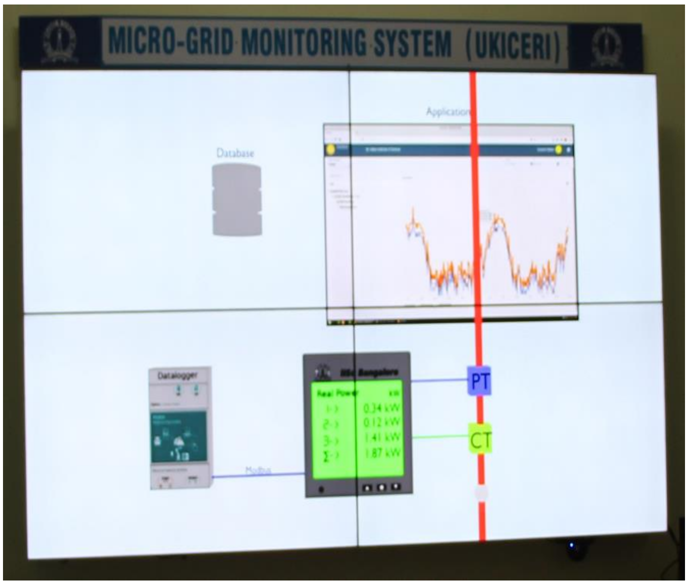

Figure 7. Browser based Video wall for monitoring

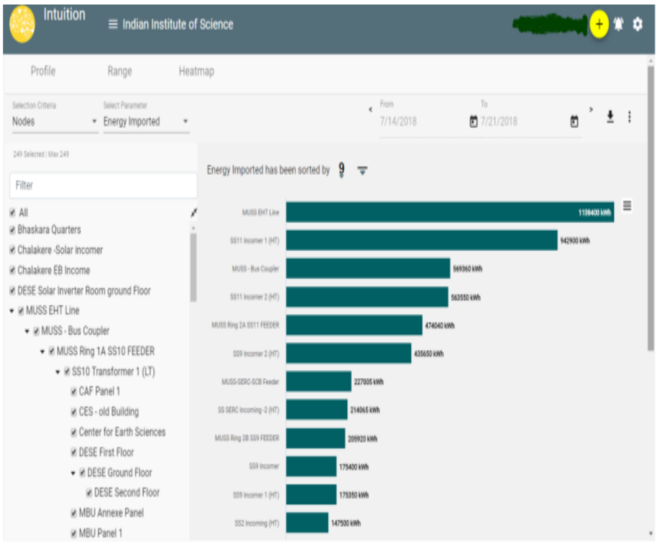

Figure 8. Energy at typical selected nodes

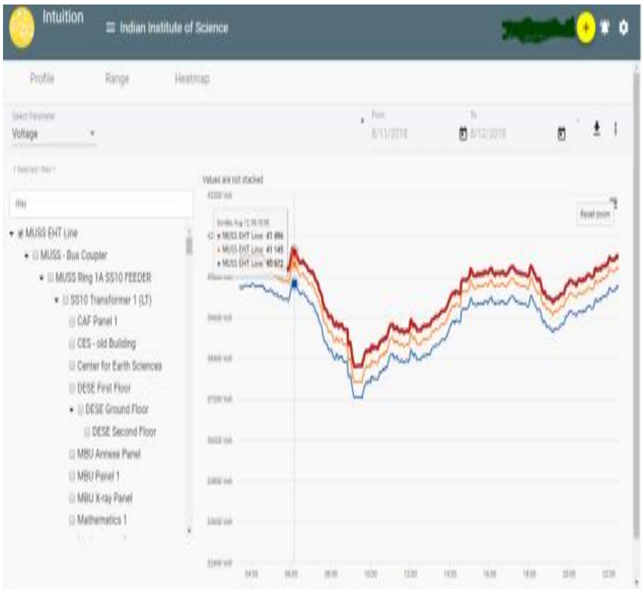

Figure 9. Voltage at typical selected nodes

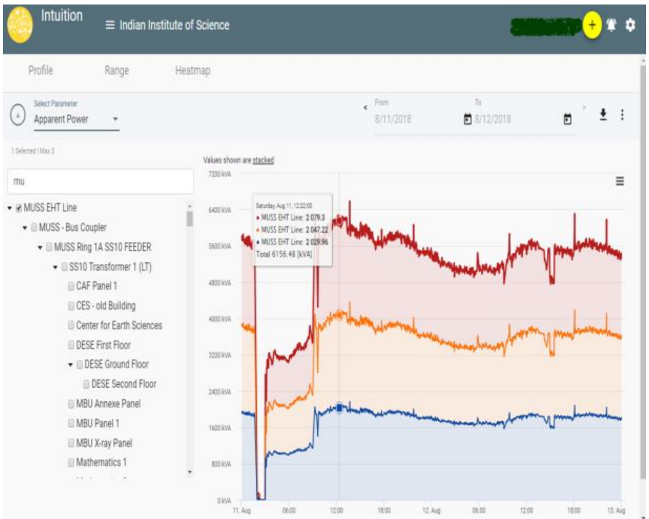

Figure 10. Apparent power at typical selected nodes

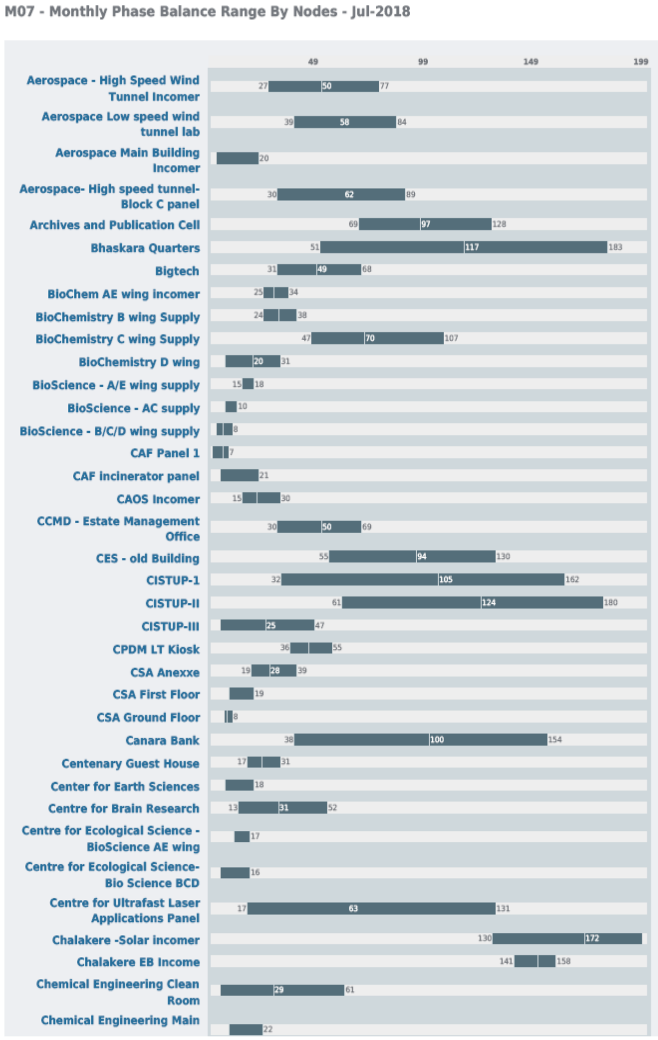

Figure 11. Phase balance at typical selected nodes

Figure 12. Heat map for 66kV SS Apparent power

INDIAN INSTITUTE OF SCIENCE

CV Raman road, Bangalore, Karntaka, India - 560012

Bill for July,2019
Invoice Date - 07 August 2019
Invoice Number -
I.IISC.1000813

MUSS
ATTENTION: POWER CCMD
power.ccmd@iisc.ac.in
8022932018

ENERGY CONSUMPTION PERIOD 01, Jul 19 - 31, Jul 19
NET ENERGY CONSUMPTION 3987200 Units
BESCOM MAIN TARIFF Revision 1

Energy consumption

# DESCRIPTION	PREVIOUS READING	CURRENT READING	UNITS
1 MUSS EHT Line	275821408	279808608	3987200

NET ENERGY CONSUMPTION 3987200 Units

# SLAB	RATE	CONSUMPTION	CHARGES
1 1-100000 Units	6.9 Rs/Unit	100000 Units	690000 Rs
2 100001-3987200 Units	7.2 Rs/Unit	3887200 Units	27987840 Rs

B.1 TOTAL ENERGY CONSUMPTION CHARGES 28677840 Rs
B.2 FIXED CHARGES 1870000 Rs

Net Amount :30547840

Last 3 months consumption history

# BILL MONTH	CONSUMPTION
1 June,2019	140305312.0
2 May,2019	3976448.0
3 April,2019	3935000.0

Figure 13. Developed billing format

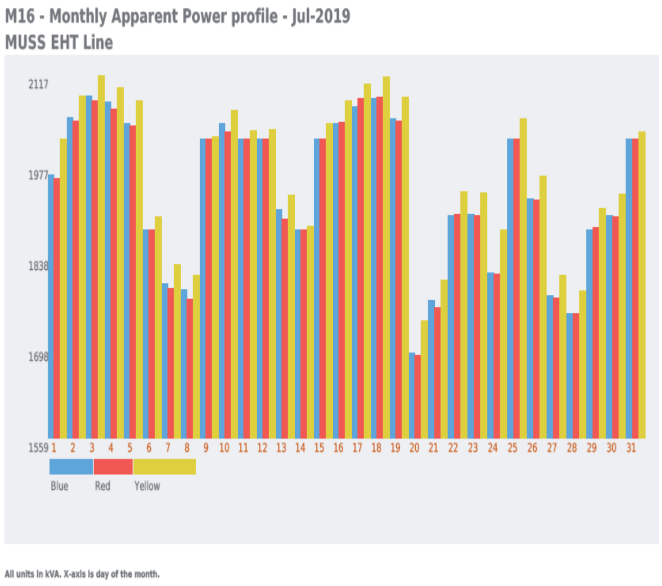

Figure 14. Apparent power profile of the 66kV MUSS

Figure 8 to 12 presents the sample information for the energy, voltage levels, apparent power, phase balance for different departments along with the heat map/power information for the 66kV substation at the selected nodes.

The smart metering applications have been extended to the fault detection and diagnosis, information about distribution network status, billing management shown in Figure 13, sample of monthly apparent power profile shown in Figure 14, further apparent prediction of load characteristics, energy conservation planning, reporting and personalized role-based access are developed in the present work.

V. Conclusions

The primary objective of the work is to propose a multimodal system towards saving energy, and thereby reduce carbon-footprint, at a personal level and at the community level.

Implementation of a typical micro grid consisting of multiple generation technologies including solar PV and building integrated PV, Diesel generating sets etc is in progress.

Smart energy management system is developed and implemented for the campus electrical network, presently more than 260 nodes are connected with smart metering.

A video wall energy dashboard is established to monitor, control the entire locations, this acts as the eye of the campus energy management system.

Acknowledgment

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