Condition Monitoring and Control of a Campus Microgrid Elements

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Summary
Smart-grid concept in power system operation requires intelligent monitoring of network elements and quick response to the demand. A Microgrid (MG) that facilitate distributed generation including renewable sources can be a building block for smart grid technology if it adopts smart monitoring and intelligent control. We set up and run a campus MG with high efficiency combined heat and power (CHP) generation and renewable energy sources where load and generation management have been done remotely by implementing automation and distributed control. The loads connected to the MG are monitored by smart wireless sensors supporting internet access. A custom designed control system using distributed control system (DCS) is providing remote control and protection of MGs critical components. Multiple industry standard communication protocol (Modbus, Profibus etc.) have been used to provide control automation and monitoring. The study shows that the controlling of water flow to the CHP generator along with smart monitoring and distributed control provide energy savings. Condition monitoring of rotating load also provides early warning for preventive maintenance.

Key words:
Microgrid; internet of thing; smart sensor, condition monitoring.

1. Introduction

A Microgrid (MG) is defined as an autonomous grid having both load and generation [1-2]. MG provides one of the most viable infrastructures for the integration of distributed generation (DG). Energy delivery within the MG is monitored and controlled by its own control system which ensure consumer freedom at the demand side [1-3]. Sensors, switches, energy storage devices, generators, protection equipment, control systems, linear and nonlinear loads, smart metering etc. are some key functional components of a MG which need to be integrated to make it functional [2]. Available energy resources, existing grid infrastructure, and viable technology play a vital role in MG operation [1-2]. As an autonomous entity with automation and monitoring facility, a MG can be considered as a building block of the smart grid approach [1-4]. There are two major aspects of sustainable energy management: one is the integration of energy harvesting from renewable sources such as solar or wind energy to the energy infrastructure and the other is to save energy usage by demand management [1-5]. With renewable generation and control automation, MG provide a viable platform for energy harvesting and energy management at the load side, helping save energy consumption [1-2,4-6]. In this paper we will be investigating both aspects. Using an IoT enabled open sourced software (BEMOSSTM) we control the load connected to the MG and manage energy consumption [7]. Simultaneously we improve efficiency of the energy generation and consumption by deploying a monitoring based distributed control algorithm. Internet access of these technology provide convenience to the customer and grid operator to make smart decision regarding efficiency, preventive maintenance and sustainability.

To ensure economic, efficient and reliable operation of the network, smart monitoring of MG elements is essential [8-16]. Bruno [8] proposed a microcontroller-based power management system for an experimental low voltage microgrid equipped with a battery, fuel cell (FC) and a photovoltaic (PV) module emulator. They proposed the control of the battery state-of-charge, which is estimated by using an accurate algorithm developed for power management. Katiraei [9] and others investigates preplanned switching and fault events that lead to islanding of a distribution subsystem and formation of a micro-grid. Their studies show that an appropriate control strategy for the power electronically distributed generation unit can ensure stability and maintain voltage quality of the MG. Peças Lopes [10] define control strategies of islanded MG. Ubilla, [17] proposed MG as a solution for long term sustainable solution for rural electrification. Zamani [18,19] proposed some protection strategy for MG. However, to the best authors knowledge little work has been done monitor the condition of both the MG's generators present and predicted generation as well as load

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demand to make appropriate control decision. Certainly, it helps to manage optimum power delivery at the MG.
Here in this paper we are presenting the condition monitoring of critical components of a campus MG for preventive maintenance, efficient operation and protection. We deployed a smart network of sensors that gather status information of intelligent devices and provide input to protective switchgears [20-22]. A DCS from ABB Inc. (800-XA system) along with its human machine interface (HMI) is deployed for data acquisition and remote control of the MG [22]. With proper authentication and access control the acquired data are made available to the user.

2. Microgrid Setup

At McNeese State University in Lake Charles Louisiana a MG, with generation from two 65 KW of combined heat and power (CHP) generators manufactured by Capston Inc. USA and 15 KW of photo voltaic (PV) sources has been established and running. PV simulator with battery storage unites from Chroma Inc. USA feeding a smart inverter (Trio from ABB Inc.) [20-22]. Along with the CHP generator output the invertor is supplying loads connected to the MG. Several resistive and rotating loads are connected via a machine control center (MCC) at a 480 V level. A three phase Y-connected resistor bank with 0-200 KW was used to vary load, two motors are connected to MCC can be run by a variable speed drive and universal motor controller (UMC) respectively. MG single line diagram in Figure 1 shows connected components. As shown in figure building power can be disconnected by operating a manual/automatic switch and enable the MG run in islanded mode [11].

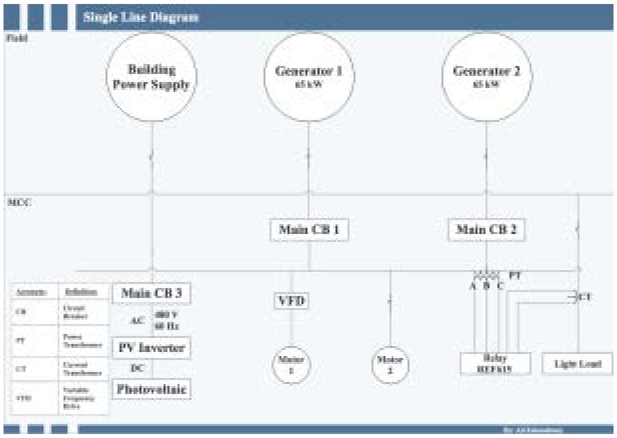
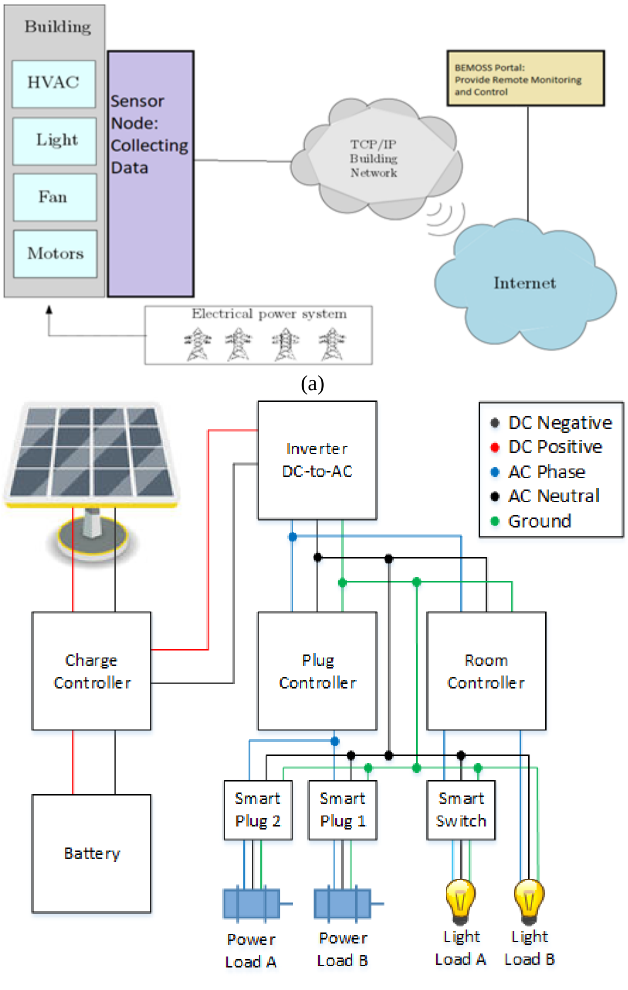


Fig. 1 Single line diagram of a campus MG

MG operation has been controlled by a DCS from ABB Inc. (800-XA system). All circuit breakers are enabled to operate manually by pressing the local switch as well as remotely by using the DCS. CHP Generator is protected by a microprocessor based protective relay system imbedded in the inverter electronics. Resistive load feeder is protected by using REF 615 relay from ABB Inc. On the other hand, REM 615 relay from the same supplier provide motor protection. Two real-time web-based motor condition monitoring systems from ABB Inc. are deployed to collect their status information [23] We conducted a rigorous simulation of our MG's different operation modes to study its loading behaviors and response to abnormal perturbation such as fault, arc flash etc. before taking real time measurement. Our licensed ETAP simulators were engaged to perform load flow, fault, and arc flash analysis and compare the test with experimental measurement.



(a)

(b)

Fig. 2(a): High level diagram of building energy management system (b): Conceptual diagram of prototype MG with renewable source and controllable load

We also developed another prototype MG at Islamic University of Madinah (IUM) with controllable loads feed by renewable sources as shown in Figure 2. Photovoltaic sources charge the battery which provide DC voltage input to an inverter (shown in fig. 3). Microprocessor based charge controller provide control of battery charging. The inverter provides 120 v ac to several rotating and lighting loads which are controlled by IoT smart switches. We customized an IoT based, open source software: BEMOSS for control [7] The software provide option to control overall, room light and air conditioning systems using room controller. Whereas group of all rotating loads and appliances can be controlled by using plug controllers and smart plugs.

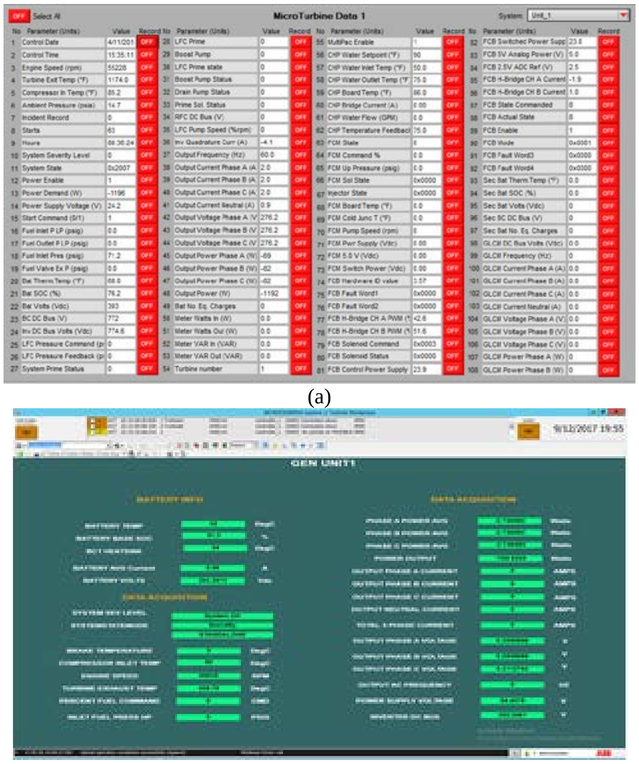
Fig. 3 Photograph of connected parts: solar panel, battery charger, light, Wi-Fi router, smart plug and switch.

3. Results and Discussion

3.1 Distributed control

DCS is proven to be effective to control and coordinate energy delivery of a MG. Control operation of our MG is performed by a DCS along with OLE for process control (OPC) server. We custom built an HMI for data acquisition and control action using proprietary software from ABB Inc. named “controlbuilder”. A set of sensors indicating the status of different components such as battery charge level, temperature, and output from each turbine in a multi-pack arrangement etc. is deployed for automation. Register at the DCS IO module receive this status information and HMI can visually display information in more user-friendly manner.

Alternatively, to do the same control operation, we also use remote monitoring and control systems provided by the turbine manufacturer Capston Inc.: proprietary software Capston Remote Monitoring (CRM) [11, 21]. It uses serial data port for data transmission. The CHP generator is equipped with multiple sensors. These outputs are available in local display as well as remote terminal through DCS with HMI capability. Modbus protocol is followed for communication between generator and DCS. Figure 4 displayed data acquired by CRM and DCS. This real-time data acquisition with archiving facility provide user the tools for smart monitoring, control and future network planning.



MicroTurbine Data 1

System: Unit_1

No	Parameter (Units)	Value	Record	No	Parameter (Units)	Value	Record	No	Parameter (Units)	Value	Record	No	Parameter (Units)	Value	Record
1	Control Date	4/11/201	OFF	28	LFC Prime	0	OFF	55	MultiPac Enable	1	OFF	82	FCB Switched Power Supp	23.8	OFF
2	Control Time	15:35:11	OFF	29	Boost Pump	0	OFF	56	CHP Water Setpoint (°F)	90	OFF	83	FCB 5V Analog Power (V)	5.0	OFF
3	Engine Speed (rpm)	55228	OFF	30	LFC Prime state	0	OFF	57	CHP Water Inlet Temp (°F)	50.0	OFF	84	FCB 2.5V ADC Ref (V)	2.5	OFF
4	Turbine Exit Temp (°F)	1174.0	OFF	31	Boost Pump Status	0	OFF	58	CHP Water Outlet Temp (°F	75.0	OFF	85	FCB H-Bridge CH A Current	-1.9	OFF
5	Compressor In Temp (°F)	85.2	OFF	32	Drain Pump Status	0	OFF	59	CHP Board Temp (°F)	86.0	OFF	86	FCB H-Bridge CH B Current	1.0	OFF
6	Ambient Pressure (psia)	14.7	OFF	33	Prime Sol. Status	0	OFF	60	CHP Bridge Current (A)	0.00	OFF	87	FCB State Commanded	8	OFF
7	Incident Record	0	OFF	34	RFC DC Bus (V)	0	OFF	61	CHP Water Flow (GPM)	0.0	OFF	88	FCB Actual State	8	OFF
8	Starts	63	OFF	35	LFC Pump Speed (%rpm)	0	OFF	62	CHP Temperature Feedback	75.0	OFF	89	FCB Enable	1	OFF
9	Hours	08:36:24	OFF	36	Inv Quadrature Curr (A)	-4.1	OFF	63	FCM State	8	OFF	90	FCB Mode	0x0001	OFF
10	System Severity Level	0	OFF	37	Output Frequency (Hz)	60.0	OFF	64	FCM Command %	0.0	OFF	91	FCB Fault Word3	0x0000	OFF
11	System State	0x2007	OFF	38	Output Current Phase A (A	2.0	OFF	65	FCM Up Pressure (psig)	0.0	OFF	92	FCB Fault Word4	0x0000	OFF
12	Power Enable	1	OFF	39	Output Current Phase B (A	2.0	OFF	66	FCM Sol State	0x0000	OFF	93	Sec Bat Therm.Temp (°F)	0.0	OFF
13	Power Demand (W)	-1196	OFF	40	Output Current Phase C (A	2.0	OFF	67	Injector State	0x0000	OFF	94	Sec Bat SOC (%)	0.0	OFF
14	Power Supply Voltage (V)	24.2	OFF	41	Output Current Neutral (A)	0.9	OFF	68	FCM Board Temp (°F)	0.0	OFF	95	Sec Bat Volts (Vdc)	0	OFF
15	Start Command (0/1)	1	OFF	42	Output Voltage Phase A (V	276.2	OFF	69	FCM Cold Junc T (°F)	0.0	OFF	96	Sec BC DC Bus (V)	0	OFF
16	Fuel Inlet P LP (psig)	0.0	OFF	43	Output Voltage Phase B (V	276.2	OFF	70	FCM Pump Speed (rpm)	0	OFF	97	Sec Bat No. Eq. Charges	0	OFF
17	Fuel Outlet P LP (psig)	0.0	OFF	44	Output Voltage Phase C (V	276.2	OFF	71	FCM Pwr Supply (Vdc)	0.00	OFF	98	GLCM DC Bus Volts (Vdc)	0.0	OFF
18	Fuel Inlet Pres (psig)	71.2	OFF	45	Output Power Phase A (W)	-69	OFF	72	FCM 5.0 V (Vdc)	0.00	OFF	99	GLCM Frequency (Hz)	0	OFF
19	Fuel Valve Ex P (psig)	0.0	OFF	46	Output Power Phase B (W)	-62	OFF	73	FCM Switch Power (Vdc)	0.00	OFF	100	GLCM Current Phase A (A)	0.0	OFF
20	Bat Therm Temp (°F)	68.0	OFF	47	Output Power Phase C (W)	-62	OFF	74	FCB Hardware ID value	3.57	OFF	101	GLCM Current Phase B (A)	0.0	OFF
21	Bat SOC (%)	76.2	OFF	48	Output Power (W)	-1192	OFF	75	FCB Fault Word1	0x0000	OFF	102	GLCM Current Phase C (A)	0.0	OFF
22	Bat Volts (Vdc)	383	OFF	49	Bat No. Eq. Charges	0	OFF	76	FCB Fault Word2	0x0000	OFF	103	GLCM Current Neutral (A)	0.0	OFF
23	BC DC Bus (V)	772	OFF	50	Meter Watts In (W)	0.0	OFF	77	FCB H-Bridge CH A PWM (%	42.6	OFF	104	GLCM Voltage Phase A (V)	0.0	OFF
24	Inv DC Bus Volts (Vdc)	774.6	OFF	51	Meter Watts Out (W)	0.0	OFF	78	FCB H-Bridge CH B PWM (%	51.6	OFF	105	GLCM Voltage Phase B (V)	0.0	OFF
25	LFC Pressure Command (p	0	OFF	52	Meter VAR In (VAR)	0.0	OFF	79	FCB Solenoid Command	0x0003	OFF	106	GLCM Voltage Phase C (V)	0.0	OFF
26	LFC Pressure Feedback (p	0	OFF	53	Meter VAR Out (VAR)	0.0	OFF	80	FCB Solenoid Status	0x0000	OFF	107	GLCM Power Phase A (W)	0	OFF
27	System Prime Status	0	OFF	54	Turbine number	1	OFF	81	FCB Control Power Supply	23.9	OFF	108	GLCM Power Phase B (W)	0	OFF

(a)

(b)

Fig. 4 Generator status information (a) CRM acquired data display and (b) acquired data by DCS displayed in HMI (graphic builder from ABB Inc.)

3.2 Thermal Recovery by CHP generator

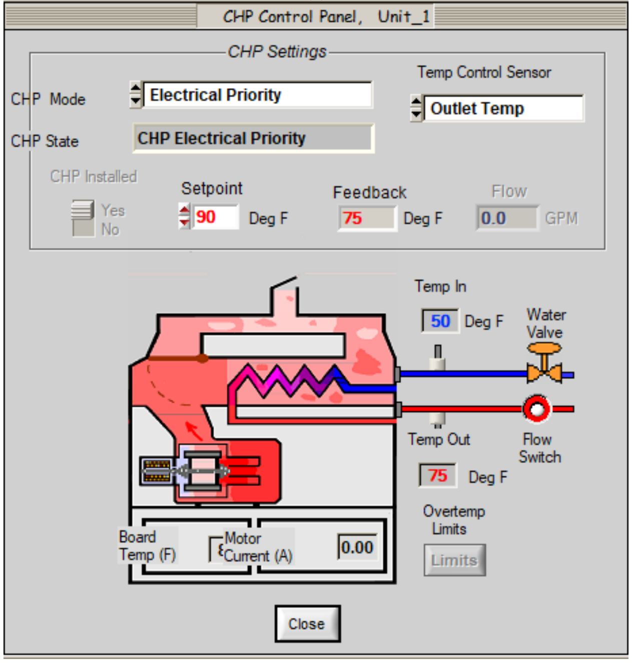
CHP generator connected to MG has thermal recovery unit to achieve higher overall efficiency. The circulating cold water recover unused heat from the flue gas and that can be used for space heating. Using condition monitoring and distributed control operator can decide the control operation of turbines: such as opening or closing of circuit breakers or keeping the turbine in standby mode based on acquired data. Based on the measured data such as inlet and outlet water temperature, water flow, system overall load etc., a software algorithm can be set to automate the control operation to achieve higher overall efficiency and peak shaving. The inlet water flow of the CHP generator can be controlled to achieve higher efficiency corresponding to the load. Figure 5 shows the heat recapture unit and the status information of different components of this heat recovery unit using proprietary Capston Remote Monitoring (CRM).

We monitor the inlet and outlet water temperature as T1 and T2 respectively in 0C. We monitor the water flow, Q in GPM either from local reading or by using DCS. The measured data from water flow meter enter the analog input of the DCS and display in HMI screen. Recovered Heat calculated as [4,6,11]:

$$P_{thermal} = 0.063Q(T_2 - T_1)C_p \qquad (1)$$

Cp is the heat capacity for water it is 4184 J/kg-^{0}C

(a)



CHP Control Panel, Unit_1

CHP Settings

CHP Mode: Electrical Priority

CHP State: CHP Electrical Priority

Temp Control Sensor: Outlet Temp

CHP Installed: Yes / No

Setpoint: 90 Deg F

Feedback: 75 Deg F

Flow: 0.0 GPM

Temp In: 50 Deg F

Temp Out: 75 Deg F

Motor Current (A): 0.00

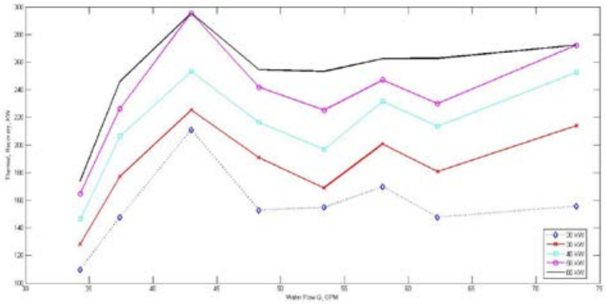
(b)

Fig. 5 Heat recapturing of CHP units: (a) Photograph of heat recovery unit and (b) CRM view of CHP operation monitoring

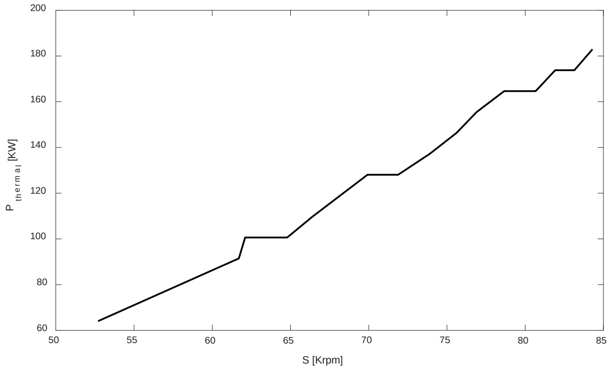
Figure 6 shows the thermal power recovered by the cold water flowing through the heat recovery unit of the micro turbine at different water flows. As observed from the figure the thermal power gain increases substantially as the electrical output increases. In brief, more load means more generation and eventually more heat recovery. However, the measurement show that the best thermal recovery was possible at a water flow rate of 43 gallons per minute (gpm). Also, a linear increase of thermal recovery is observed with respect to the mechanical speed of the generator. DCS allows remote recording and archiving of these sorts of data.

3.3 Condition Monitoring of MG loads using Internet of Thing (IoT) based smart sensor

Smart wireless and IoT technology provide consumer facility to operate and control connected loads by constantly monitoring them and operating remotely when required. Traditionally rotating machines are monitored and controlled by using local controller and data acquisition system which are currently been done using internet. Recent development of smart wired and wireless communication technology along with high signal processing power makes this activity into a reality. Motor condition monitoring by utilizing the IoT can bring any motor into the proper servicing before unwanted failure popularly known as preventive maintenance and makes it very economical for large operation.



(a)



(b)

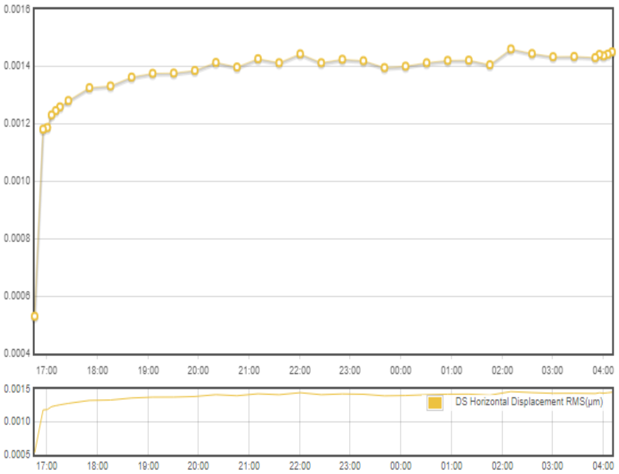
Fig. 6 Thermal recovery of CHP generator at different loading and water flow condition

In our MG, we used two different types of motor condition monitoring systems. In the first system, an induction motor equipped with four sensors shown in Figure 7(a) collect line current, speed, vibration and other relevant data. The collected data then transmit to ABB Machsense server through a dedicated wireless channel and the ABB proprietary algorithm then processes the data and presents the report in the online portal [11, 22]. Figure 7(b) shows the value of an induction motor collected from the Machsense portal. To compare the processed value available in on line portal with locally measured value; we designed a measurement system to collect the vibration data: displacement with time. Figure 8(a) shows the testing arrangement. In the testing arrangement, four sensors are providing low intensity signal which then amplified and processed by a signal analyzer with the supporting LabVIEW measurement software from National Instrument Inc. The measurement provides time domain signal which is later transfer into the frequency domain signal using discrete Fourier Transform describe the equation 2 below

$$X[k]=\sum_{n=0}^{N-1} x[n]\,e^{-j2\pi kn/N} \qquad (2)$$

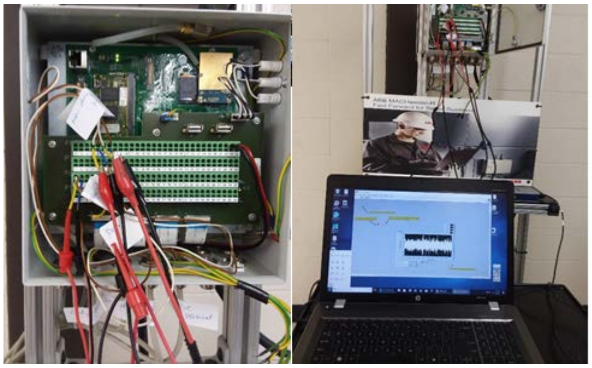
where x[n] is the positional value of the displacement of the motor. N is the number of samples. Velocity has been evaluated by taking the first derivative of x(t) with respect to time, t. A MATLAB code has been written for this conversion using First Fourier Transform (FFT) algorithm. Figure 8 shows the time domain and frequency domain signal of vibration.

(a)



(b)

Fig. 7 Motor supported by Machsense condition monitoring system: (a) Four sensors connected to the motor (b) web portal showing processed vibration data



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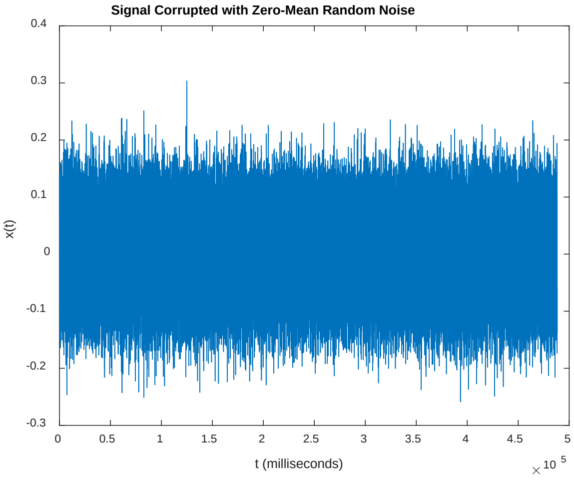

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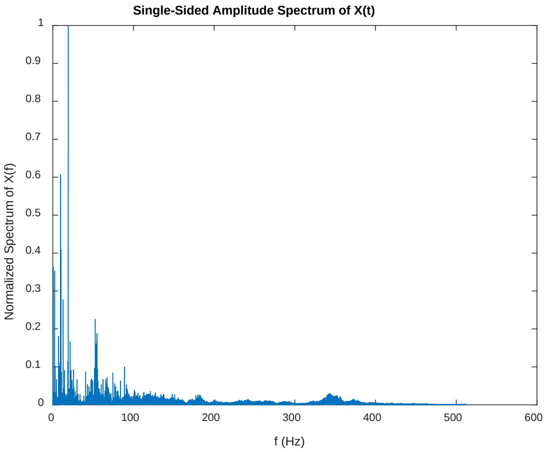
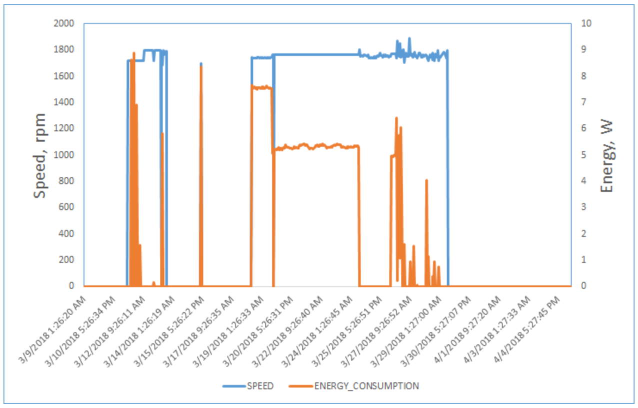


(c)

Fig. 8 Vibration measurement of a Motor: (a) measurement set up for sensor and time sampled vibration data displayed in local computer (b) displacement in time domain and (c) normalized frequency response of displacement

In the second system we use a smart sensor from ABB to record data at an hourly interval. A Bluetooth activated Mobile proprietary phone application allows the user to download data such as speed, vibration, energy usage, number of starts, etc. and send those to the cloud for later use [11, 16]. Users evaluate the desired quantity to determine health trends and necessary alert generation for preventive maintenance. Figure 9 shows the recorded motor data at different time and customizes it by comparing the relation between speed with energy consumption. It observed that energy may be consumed more even at lower speed. Vibration, skin temperature contributes to the overall consumption of energy.

(a)



(b)

Fig. 9 Condition of a running induction motor: (a) induction motor with smart sensor attached and (b) relation between speed and energy consumption.

Fig. 10(a) Snapshot of deployed camera images of MG critical assets (a) two CHP generator

In our microgrid we deployed an IP camera to visualize the operation of MG's critical resources such as generator, load and control module. Figure 10 shows snapshots of MG critical assets by using IP camera. We access the camera and take over its control by using internet. The technology is matured, economic as well as provide convenience to the customer. The operator can remotely pan and zoom camera, activate night vision as well as sound mode over the internet with proper authentication and administrative privilege.

Fig. 10(b) MCC connected IEDs for protection

Fig. 10(c) motor running with night vision on

4. Conclusion

IoT enable condition monitoring and distributed control of MG critical assets make its operation more viable by providing more accurate control decision. Smart sensor-based condition monitoring facilitates customer easily accessible assets health information and warn them for any possible failure so that they can make decision of preventive maintenance/replacement. The study shows that the controlling of water flow to the CHP generator by using distributed control provide higher thermal recovery. Also, the IoT based control of building electrical load provide energy savings.

Acknowledgment

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References

[1] F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, "Microgrids management," IEEE Power Energy Mag., vol. 6, no. 3, pp. 54–65, May 2008.

[2] Mini S. Thomas, John Douglas Mcdonald, "Power system SCADA and Smartgrid" Published by Apple Academic Press Inc., Canada (2015)

[3] Nikos Kiritsis, Kaisar Khan and Dinesh Sachdeva, "Preparing the Millennial Engineering Graduate to Join the Workforce," presented in ABB automation and power world (APW) digital conference at Houston, TX, March 2017.

[4] Kaisar R. Khan, Atiqur Rahman, Muhammad Shoaib Siddiqui "Condition Monitoring of a Campus Microgrid Elements using Smart Sensors" accepted in Jeddah, KSA, 2019.

[5] Kaisar R. Khan, Atiqur Rahman Adnan Nadeem, Muhammad Shoaib Siddiqui and Rafi Ahmad Khan "Remote Monitoring and Control of Microgrid using Smart Sensor Network and Internet of Thing" Presented ICAAIS Conference, Riyadh, KSA, April 2018.

[6] Kaisar R. Khan, Atiqur Rahman, Turki Alghamdi, Adnan Nadeem, Muhammad Shoaib Siddiqui and Rafi Ahmad Khan, "Smart Monitoring of Microgrid Critical Assets using Smart Sensors" accepted in MAGNT Research report, vol 2(2), 2018.

[7] http://www.bemoss.org/

[8] Belvedere, Bruno & Bianchi, M & Borghetti, Alberto & Nucci, Carlo Alberto & Paolone, Mario & Peretto, Antonio. (2012). A Microcontroller-Based Power Management System for Standalone Microgrids With Hybrid Power Supply. IEEE Transactions on Sustainable Energy. 3. 422-431. 10.1109/TSTE.2012.2188654.

[9] Katiraei, F & Iravani, Reza & Lehn, P.W. (2005). Micro-Grid Autonomous Operation During and Subsequent to Islanding Process. Power Delivery, IEEE Transactions on. 20. 248 - 257. 10.1109/TPWRD.2004.835051.

[10] J. A Peças Lopes, C. L. Moreira, and A. G. Madureira, "Defining control strategies for microgrids islanded operation," IEEE Trans. Power Syst., vol. 21, no. 2, pp. 916–924, May 2006.

[11] Kaisar R. Khan, Muhammad Shoaib Siddiqui, Yazed Al Saawy, Atiqur Rahman, and Nurul Islam, "Condition Monitoring of a Campus Microgrid Elements using Smart Sensors" to be presented in 16th International Learning and Technology Conference (LT 2019), Jeddah. KSA, 3-4, March 2019.

[12] K. Venkatraman, B. Dastagiri Reddy, M.P. Selvan, S. Moorthi, N. Kumaresan, N. Ammasai Gounden, "Online condition monitoring and power management system for standalone micro-grid using FPGAs" IET Gener. Transm. Distrib., 2016, Vol. 10, pp. 3875–3884

[13] Reza Pourramezan, Younes Seyedi, Houshang Karimi, Guchuan Zhu, and Michel Mont-Briant, "Design of an Advanced Phasor Data Concentrator for Monitoring of Distributed Energy Resources in Smart Microgrids" IEEE Transactions on Industrial Informatics, 2017, vol. 13, no. 6, pp3027-3036

[14] Diptak Pal, Rounak Meyur, Santhosh Menon, Maddikara Jaya Bharata Reddy, Dusmanta Kumar Mohanta, "Real-time condition monitoring of substation equipment using thermal

cameras" IET Gener. Transm. Distrib. 2018, Vol. 12 Issue. 4, pp. 895-902

[15] Md. Masud Rana, "Architecture of the Internet of Energy Network: An Application to Smart Grid Communications" IEEE Access Journal, 2017, Vol 5, pp 4704-4710

[16] L. H. Tsoukalas and R. Gao, ″From smart grids to an energy of internet: Assumptions, architectures and requirements, Conference Paper″, Conference Paper, Power and Energy, 2008.

[17] Ubilla, Karen & Jimenez-Estevez, Guillermo & Hernández, Roberto & Reyes, Lorenzo & Hernandez Irigoyen, Claudia & Severino, Bernardo & Palma-Behnke, Rodrigo. (2014). Smart Microgrids as a Solution for Rural Electrification: Ensuring Long-Term Sustainability Through Cadastre and Business Models. IEEE Transactions on Sustainable Energy. 5. 10.1109/TSTE.2014.2315651. Syst., vol. 21, no. 2, pp. 916–924, May 2006

[18] Zamani, M. Amin, Amirnaser Yazdani, and Tarlochan S. Sidhu. "A communication-assisted protection strategy for inverter-based medium-voltage microgrids." IEEE Transactions on Smart Grid 3, no. 4 (2012): 2088-2099.

[19] Zamani, M. Amin, Tarlochan S. Sidhu, and Amirnaser Yazdani. "A protection strategy and microprocessor-based relay for low-voltage microgrids." IEEE transactions on Power Delivery 26, no. 3 (2011): 1873-1883.

[20] ABB remote condition monitoring: http://new.abb.com/motors-generators/service/advanced-services/remote-condition-monitoring.

[21] Capston Inc. User Manual: https://www.capstoneturbine.com/products/c65

[22] ABB Machsense-R portal: https://machsense.abb.com/

[23] Internet of Things Global Standards Initiative. ITU. Retrieved 26 June 2015

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