Remote Monitoring and Control of Microgrid using Smart Sensor Network and Internet of Thing

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Abstract— **A Microgrid (MG) is a viable and scalable approach to integrate distributed sources, ensure reliable and secure energy supply to the remote and the mission critical grid. Smarter monitoring, control and energy management is required to ensure economical and reliable operation of the MG. Equipping an MG with smarter sensor for monitoring along with reliable and secured communication among devices are some critical initial steps toward a smart grid approach. We implement a working MG which is controlled by an advance computer based distributed control system (DCS) from ABB Inc. (800-XA system). We deployed smart sensors and internet of things (IoT) for condition monitoring which is integrated with the DCS. Besides grid, automated operation, this state of the art (DCS) also provides data acquisition, accesses to the user friendly human machine interface (HMI) and supervisory control of all critical assets. Both physical and cyber security is provided by proper authentication and access control.**

***Keywords-** Mictro grid; distributed generation; remote monitoring & control; IoT, Human Machine Interface (HMI)*

I. INTRODUCTION

Now a day's power systems are shifting the paradigm of centralized regulated power systems to a deregulated evolving electric power system. Energy demand in a modern day power system dynamically changes as well as more and more distributed renewable sources and nonlinear loads being connected to the power grid. This effort requires smarter monitoring, control and energy management to ensure economical and reliable operation [1-6]. This will also empower the consumers to make smart decision on energy usage and integration of renewable sources which are distributed in nature [1-2, 6]. Distributed generation (DGs) such as micro turbines and renewable photovoltaic sources are getting integrated into modern day electrical networks at a considerable pace to diversify the electric energy generation. Microgrid (MG) provides one of the most viable infrastructure for this integration and can be considered as a building block of the smart grid approach [1-4]. MG is an advanced organization of both renewable/nonrenewable DGs and load [1-2]. In MG the random output from DGs is managed by proper control of energy storage systems and dispatched loads. It can be worked either in islanded mode or in grid connected mode if wanted [1-2]. A MG is composed largely of off-the-shelf physical components such as Sensors, Switches, Power electronics, Energy storage devices, Generators, Protection equipment, Control Systems and Smart Metering [2]. Some typical example of MG is in industrial plants, in commercial buildings, in military or university campuses [2, 6]. By adding a separate layer of communication mechanism between physical devices and secure the communication is a very critical step toward smart grid that is capable of properly responding to dynamic changes of demand. Modern wired and wireless communication technology is playing a vital role in implementing the smart networking of sensor that gather status information of intelligent devices using industry standard protocols.

Ali Ipakchi and others [6] mentioned that many believe the electric power system is undergoing a profound change driven by a number of needs such as environmental compliance and energy conservation. This transformation will be necessary to meet environmental targets, to accommodate a greater emphasis on demand response (DR), and to support plug-in hybrid electric vehicles (PHEVs) as well as distributed generation and storage capabilities [1-6]. From a design perspective, smart grids will likely incorporate new technologies such as advanced metering, automation, communication, distributed generation, and distributed storage. Faisal R. Pazheri1 and others [7] describes the attributes of a smart grid and how these acts as driving force to modernize the electrical power grid. The necessity of conservation of oil in Saudi Arabia is argued. Moreover, the vast availability of renewable energy sources like solar and wind in Saudi Arabia and advantages in utilizing these sources through smart grid technologies is advocated. In [8], Faisal R. Pazheri1 and others mentioned that, "even though Saudi Arabia is the world's largest producer and exporter of petroleum and petroleum based products, it is also blessed with high potential of renewable energy sources like solar and wind. The authors also emphasize that untapped wind and solar energy sources, which are abundant throughout the Kingdom, can be integrated into the grid through the use of smart grid technologies. In [9], Tsoukalas and Gaoan describe

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smart grids is an energy Internet where energy flows from suppliers to customers like data packets do on the Internet.

Digital computer technology with the proper networking capability is the key to smart operational of MG [2]. DCS is employed to control the MG operation. Sensors are the ear and the eyes of the networks that provide the status information to the DCS then the processor of the controller make the control decision based on these sensory information [2-5]. Traditionally the DCS system is usually employed in process plants and for electric grid supervisory control and data acquisition (SCADA) is generally employed to control. In our MG we used DCS from ABB Inc. (800-XA system) and customize it according to the present and proposed future critical assets of the grid. This DCS is the key component to process sensor data and network with external devices and network through its protocol independent networking interface. It also supports human machine interface (HMI) using its proprietary software. We wrote our HMI according to the customize control strategy of MG.

II. Microgrid Organization

A. *Conceptual design of MG*

A model campus MG has been implemented at McNeese State University in Lake Charles Louisiana to provide teaching and research facilities to the students and faculties. It also provides a training platform for the professionals working in local refineries and petro-chemical plants [3-4]. At the beginning, before purchasing the hardware and to prove the concept, we did some system level simulation using licensed commercial software (ETAP) to see the voltage regulation, power quality, synchronization with the utility etc. Figure 1(a) shows the conceptual single line diagram of a campus MG with DG, lighting and rotating load. Figure 1(b) shows the HMI view of the one line diagram of the McNeese MG with only currently active components.

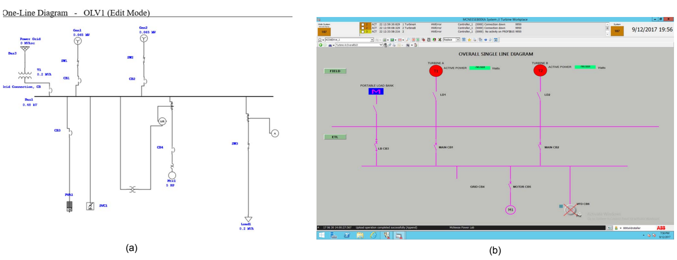


Figure 1. Single line diagram of campus MG. (a) conceptual oneline diagram using ETAP simulator and (b) oneline diagram shown in written HMI

B. *Physical Components of MG*

In the MG, there are two 65 KW of combined heat and power (CHP) generators from Capston Inc., 1.4 KW of photo voltaic (PV), battery storage unites, resistive and rotating loads are available. We integrate several variable speeds, derive into the MG which has probable application in petro chemical processes [9-11]. A real-time web based condition monitoring system is also working for motor health monitoring. We are monitoring the performance of MG at different loading conditions and available generation and make proper computer based control action. All these critical assets such as DGs, bus, load feeder and motors are protected by microprocessor based protective relay system. Figure 2 shows MGG control center with attached generator and load.

Figure 2. Components of McNeese MG. (a) MG control center (b) CHP generators and (c) resistive and rotating load with sensors attached to it

III. Control of MG Critical

Because of the small size and having intermittent renewable sources and load available in MG it requires special attention to control its operation to supply stable, reliable, economic and quality power. In a traditional power system, power is instantly balanced by the inertia of the rotating system and the frequency changes to control the active power [2]. However, since the islanded microgrid does not have enough spinning reserve, this kind of primary control is not inherently available.[1-2] Also, since micrograds are set up in the distribution system, the active power transfer mainly depends on the voltage magnitude, whereas in transmission systems, the active power transfer is mainly controlled by the phase-angle difference across the line.

Centralized control for microgrids can take care of the voltage control, power quality, and reactive power sharing in addition to the active power sharing. The centralized control can be decentralized by using new technologies such as DCS that allows intelligence to be distributed, where local controllers have their own autonomy and can make decisions [1-4]. A DCS can be a viable solution for controlling critical physical component for stable operation of the MG as well as protecting the critical assets. The DCS provides the primary control of MG that ensures proper power sharing between the different DGs and local voltage control for stable operation of the microgrid. It acts in milliseconds, due to the lack of inertia in the MG. Figure 2(a) shows DCS from ABB Inc. (800XA) used to control the McNeese MG. Beside I/O module the system support is interfacing multiple protocol. HMI script in Figure 2(b) shows functionality of different MG components.

Intelligent Electronic Devices (IEDs) are key components of MG automation [2-4]. It is a microprocessor-based device with the capability to exchange data and control signals with another device (IED), electronic meter, controller, SCADA, etc.), over a communications link [2]. Typical IEDs are protection relays, meters, and Monitoring devices. IEDs can perform protection, monitoring, control, and user interfacing functions on one hardware platform [2-4]. IEDs are fully

IEC.61850 compatible and compact. Figure 4 shows a typical IED in our case microprocessor based relay for feeder and motor protection (REF/REM 615 from ABB). Figure 5 shows the way the microturbine communicate with DCS and LAN using Modbus protocol. Through internet switch/router, it can access through the internet provided that proper authentication has been done prior to that.

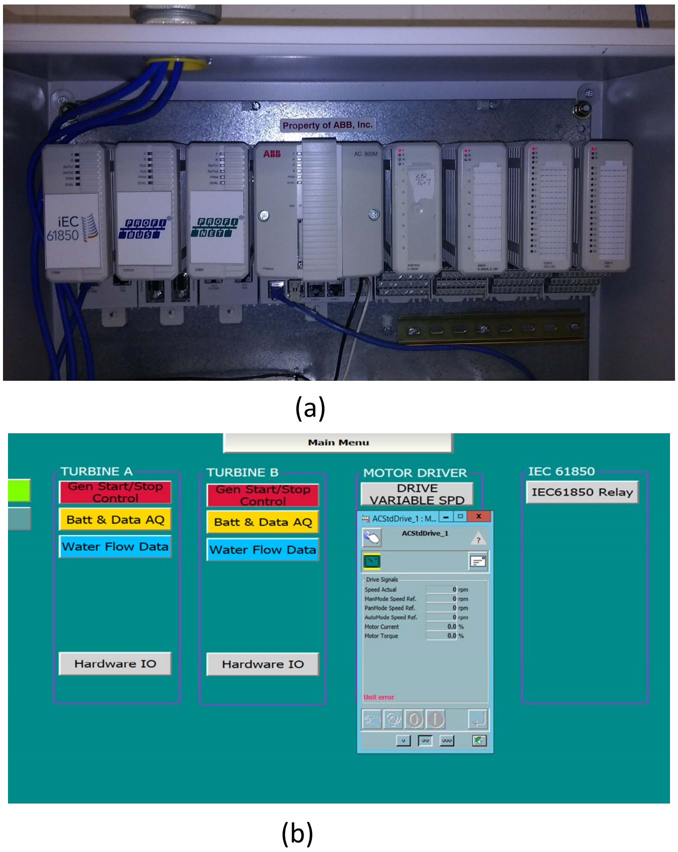


Figure 3. (a) ABB 800 XA with interfacing of devices that support multiple protocol and (b) HMI showing MG automation and data acquisition function

Figure 4. Typical IED connected to DCS for MG load side protection

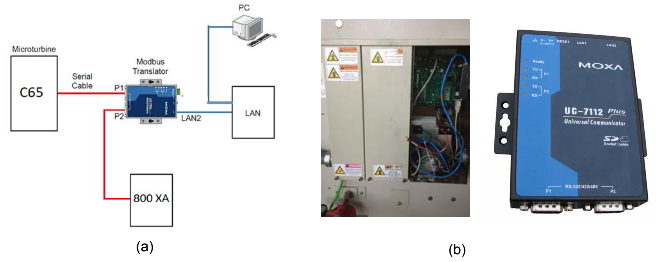


Figure 5. Microturbine of the MG communicating with DCS using Modbus protocol

Control operation of MG is performed remotely by using a personal computer along with OLE for process control (OPC) server. Background control builder along with a graphic builder from ABB was used to build HMI for data acquisition and control action. Figure 6 shows the HMI screen for turbine automatic operation and data acquisition from a remote terminal. In our MG we have a CHP generator so thermal gain is important to achieve higher efficiency of the overall system and energy savings [11]. We decide the control operation of turbines such as openning or closing of circuit breakers or keep the turbine in standby mode, based on aquiring data such as inlet and outlet water temperature etc. It is observed that by knowing thermal gain we make control operation and save energy.

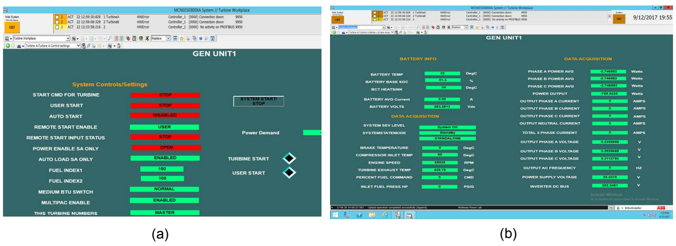
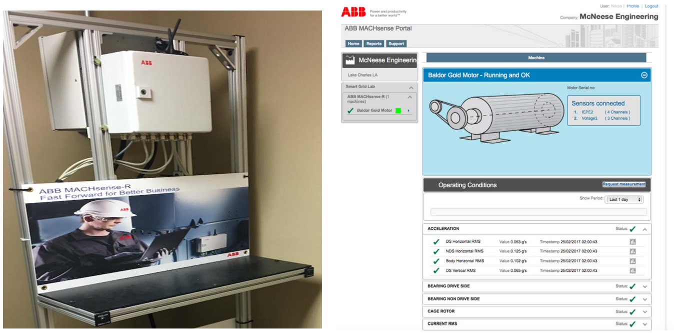


Figure 6. HMI screen for remoter turbine operation and aquired data.

IV. Condition Monitoring of MG Critical Assets

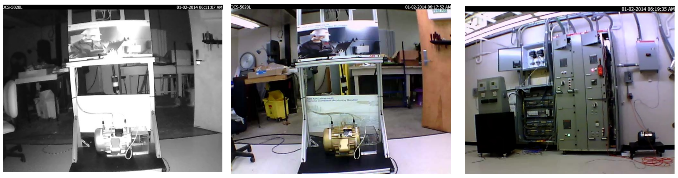
An important aspect of smarter grid operation is that the grid critical devices are monitor continuously and identifying potential problems before they occur. It significantly reduces costs and increases productivity [2-4, 10]. Condition monitoring helps to prevent unplanned downtime and the associated costs of lost production [10]. Motor condition monitoring by utilizing the IoT can bring any motor into the proper servicing before unwanted failure. Smart sensor makes motor condition monitoring very economical for large operation [10]. Monitoring and diagnostics in smart grids require three fundamental elements in the broadest sense: data intelligent, algorithms, and communications ranging from a local HMI to a broadband IP or fiber optic network [2]. On line condition monitoring of the critical MG assets not only require deploying smart sensor network also it require integration of IoT. As a first step we monitor the rotating load connected to MG. The load is an Induction motor equipped with sensors to collect line current and vibration data and transmit data to ABB MACHsense server through dedicated wireless channel which is subscribe earlier [10]. ABB proprietary algorithm process the sensor data and presented that in the portal. Figure 7 shows the MACHsense portal and the wireless transmitting unit.



(a) (b)

Figure 7. Machsense (a) wireless transmiting unit and (b) web portal showing processed data for the induction motor connected to MG

IoT is generally defined as the network of physical devices to connect and exchange data. Each thing is uniquely identifiable through its embedded computing system but is able to inter-operate within the existing Internet infrastructure [13]. In our microgrid we deploy IED and condition monitoring devices connected to internet. We also deploy IP camera to visualize the operation of MG and condition monitoring of critical resources. Figure 8 shows several snapshot of rotating load and MG control center from video obtained by the IP camera.



(a) (b) (c)

Figure 8. Snapshot of deployed IP camera images (a) running motor with night vision on (b) running motor and (c) control center of MG with IED on

V. Conclusion

A currently running campus MG operation has been controlled by using computer based DCS. Its critical assets such as generators, PV inverter, loads can be monitored and protected by using a smart sensor network with online monitoring capability. Deployment of sensor network and IoT make MG automation more viable and control decision are more accurate to save energy. Online condition monitoring along with IoT make preventive maintenance of critical assets of MG easier.

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