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Interface Protection and Energy Management System for Microgrid using Internet of Things

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Abstract

The restructuring of power systems, performance enhancements in the renewable energy generation technologies and evolutions in power electronics based high power switching devices has collectively facilitated the technical realization of microgrids in power systems. Reduction in Peak power demands on the main grid, good voltage regulation and utilization of renewable energy sources are the important technical benefits of Micro Grids with Distributed Energy Resources(DERs). Control and protection of micro grids during its various operating modes are very essential for the secure and reliable operation of microgrid interfaced main grids. Isolation of micro grids after a fault in main grid and energy management during mode transition are the important challenges of micro grids. The power electronics based micro grids requires faster isolation of faulty parts hence the operating time of the control and protection systems need to be faster. Hence this paper proposes a method for interface protection and energy management using Internet of Things (IoT).

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Keywords: Distributed Energy Resources; Interface Protection; Interfacing Switch; Internet of Things; Load Shedding; Microgrid;

1. Introduction

The power system has been experiencing major transformations right from its inception. Invention of transformers played a major role in the transformation DC power systems to AC power systems. The developments in power

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electronics switching devices contributes to power system by providing reactive power compensation and power quality Improvement. The efficient conversion of green energy produced using Solar PV and wind is facilitated by power electronics based converters and inverters [1]. The transformations of power system coinciding with challenges faced by the power system in the respective periods. The demand for electric power is increasing due to industrialization and the change in life status of people. The peak power demand, transmission losses due to low voltage distribution systems and poor voltage profile during peak demand periods are the major power system problems in recent years. The power generation using Distributed Energy Sources (DERs) and the efficient power conversions using power electronic converters helps the power system in overcoming those challenges [2-4]. The micro grids which are effectively interfacing micro energy sources, supplies power to local loads and reduce the burden of the main grid during peak periods. Further effective power transaction between micro grids and main grids enhances the reliable and economic operation of power systems[5,6]. For example, energy will be exported to main grid during peak power demand and imported from main grid during off-peak periods. The penetration of DERs and evolution of micro grids necessitate changes in conventional operation and protection methods [7]. Isolation of micro grid from the main grid during faults in main grid is one of the important issues in micro grid. The reliable operation of micro grids during its operating modes such as, grid connected and islanded modes[8]. The power electronics circuits are predominantly used in micro grids requires faster operation and protection systems to avoid damages to its components [9,10]. The operation and protection of micro grid requires faster sensing, communication and switching systems. The methods proposed in the literatures used Zigbee, WiMax based communication systems for faster response. This paper proposes an IoT based operation and protection of micro grids. This paper addresses two major issues of power systems with microgrids. Interface protection and effective power management during transition between operating modes will be achieved using IoT.

2. Proposed Method

Penetration of Distributed Energy Sources and micro grids in the conventional power system requires major changes in operation and protection schemes. The interface protection and energy management during different operating modes of micro grids are the important protection and operation issues.

2.1 The interface protection

- Figure 1 shows the schematic diagram of typical micro grid, connected with main grid through interfacing switch.
- The main source represents the main grid, local source represents the distributed energy sources and L1, L2 and L3 are the loads in microgrid.
- The Line A represents the grid line. Following a fault in the grid line the switching devise S1 will isolate Line A from the source. The maintenance person may go and inspect the line for fault rectification. If the interface switch is in closed condition Line A will be energized by DERs present in the micro grid and the maintenance person will be in danger.
- It is necessary to open the interface switch immediately after a fault in micro grid.
- This paper proposes a method for interface protection using IoT.
- The Line A voltage will be measured continuously and the data will be communicated to cloud. The interface switch will be turned OFF if the line-A voltage falls below a pre-specified value.

2.2 Power Management

- The interface switch will be closed or opened to maintain power balance in the microgrid.
- Power will be exported to main grid or imported to from main grid depending upon the operating modes.
- Consider an operating condition, when the power generation in micro grid is lesser than the power demand and grid line also cannot export power to micro grid. The Power supply is lesser than the demand hence the

loads has to be shutdown to maintain the power balance. This paper proposes a method to shut down the least priority loads during power shortage.

- The Arduino processor will be pre-programmed in such a way that, during power shortage, the least priority loads will be shut down one after another till the power balance is achieved.
- Sensors R2, R3, R4 records the current passing through local loads continuously and Switches S3, S4, S5 will shut down the local loads after receiving command from Arduino.

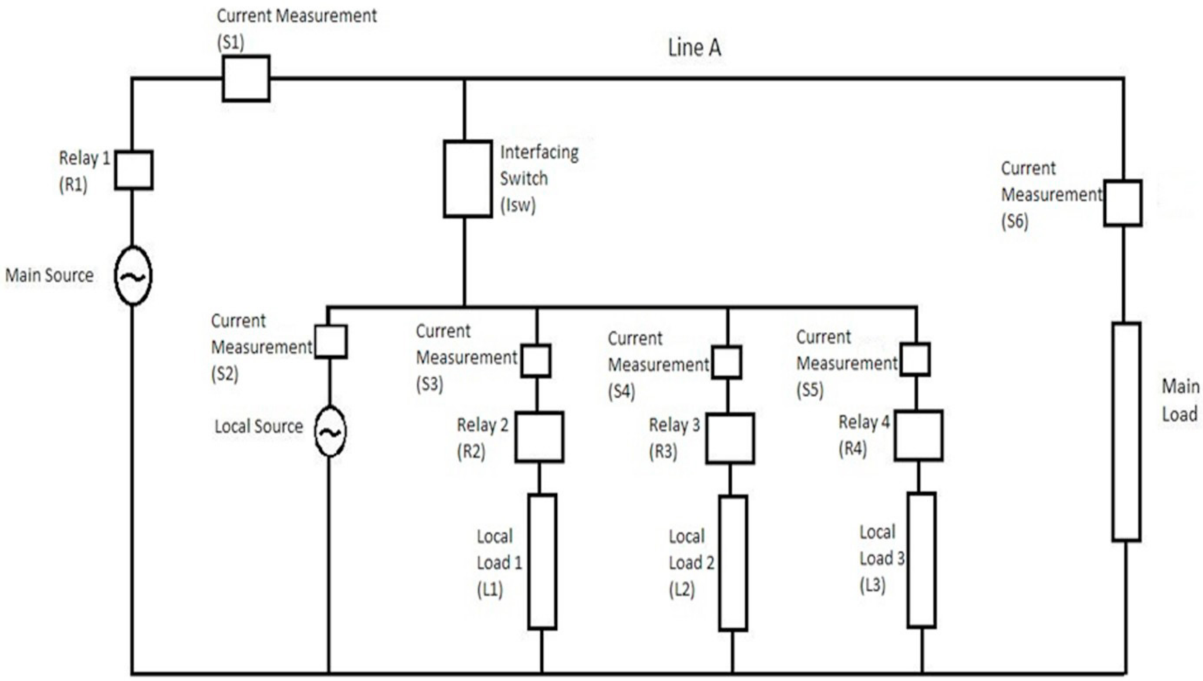

Figure 1 Schematic diagram of micro grid with main grid

3. Design specifications

The design of interface protection hardware model needs a voltage measuring circuit which constantly monitors the voltage at grid line. The voltage measured is to be checked continuously for any fault conditions. The initial design consisted of 8051 (microcontroller) in the processing unit. But usage of ADC resulted in real time errors so it was replaced with Arduino UNO which has an inbuilt ADC circuit in order to simplify the implementation of the idea in real time. The use of Arduino will enhance the reliability and accuracy compared to the previous hardware design adopted. The major components used in the proposed model are given in Table 1.

Table 1. Design specifications

Components	Design Specifications
Arduino UNO	Micro controller atmega328, o/p voltage 5V
Current Measuring Devices	ACS 712
General Packet Radio Service Module (GPRS Module)	SIM 180
Loads	40W, 100W Bulbs
Interfacing Switch and Local load Switches	Relay 12V
Power Supply	Transformer 230-12V, AC to DC rectifier, 5V Regulator using 7805

3.1 Arduino UNO

Arduino is an open-source physical computing platform based on simple I/O board and a development environment that implements Processing/Wiring language. Arduino can be used to develop stand-alone interactive objects or can be connected to software on your computer. Arduino UNO is the basic board of all the boards available in market. The software programming is done in the software called Arduino IDE. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable and dump the code. Once code is dumped Arduino works even it is disconnected from computer. But power supply is necessary.

3.2 Current Sensor

Current sensor ACS712 is used to measure the current and voltage. It gives accurate current measurement for both AC and DC signals. These are good sensors for metering and measuring overall power consumption of systems. This sensor produces an output voltage which is directly proportional to sensed current. It works on the principle of Hall Effect. 5V should be supplied to V cc of ACS712 breakout board and the GND should be the negative of 0v of supply. Once it is powered, the V out should produce output voltage which represent current going through the sensing pads. When the load is in OFF state then the sensor produces Vcc/2 voltage (no load voltage).ACS712 is able to measure current in two directions. Output voltage more than 2.5V (VCC/2) indicates current in one direction and voltage less than 2.5V indicates current in another direction.

3.3 Power Supply

The power supply output is given to Arduino and other circuit also; the design of the power supply is mainly because of the Arduino, the Arduino work in Dc source with a voltage of +5V. As we are getting the line voltage V_L has 230V in ac source, so it is not possible. This power supply designs an output of +5V DC to activate the Arduino. Supply Voltage of 230V AC is converted to 5V DC using a 230-12V step down transformer, AC to DC full wave rectifier and 7805 voltage regulator connected in series.

3.4 GPRS Module

Internet of Things (IoT) is implemented using “GPRS Module”. This GPRS module connects Arduino and website that is subscribed from the modem seller itself. Data between the circuit and the cloud is exchanged through this module. Arduino controls the circuit and receives data from sensor ACS712 and transmit it to GPRS module. These parameters are pushed to the cloud through GPRS module. In addition to monitoring the circuit, GPRS module allows to control the circuit from the website whose URL is synced with given module.

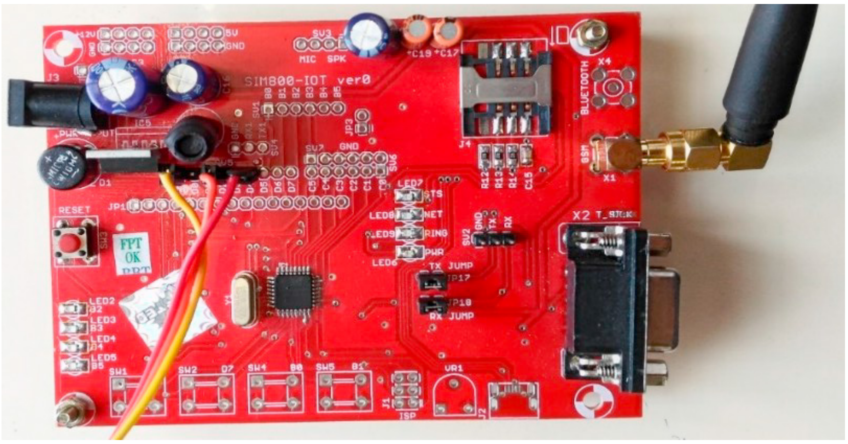

Figure 2 GPRS Module

To transmit the data from Arduino to cloud, 3 pins are interconnected between Arduino and the module. The connections are as follows:

Table 2. Connection between Arduino and GPRS Module

Arduino	GPRS Module
TX (Digital Pin 1)	D2 (Receiver Pin for GPRS Module)
RX (Digital Pin 0)	D4 (Transmitter Pin for GPRS Module)
GND (Ground Pin)	GND (Ground Pin)

TX – Transmitter pin; RX – Receiver pin;

3.5 Loads

The prototype is developed using three lighting loads. Any electrical appliance whose power consumption is less than 200Wcan be used in developed system. The sampling rate for the fabricated sensing modules was setup with 50 Hz, so that electrical appliance usages within (less than 10 s) interval of time will be recorded correctly.

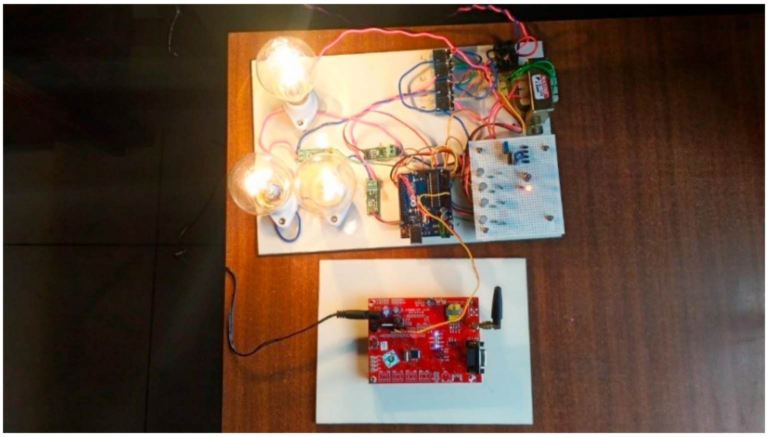

Figure 3 Hardware Model Implementation

4. Operating Conditions

Main Source	Distributed Energy Source	Local Load 1	Local Load 2	Local Load 3	Main Load	Interfacing Switch
ON	ON	ON	ON	ON	ON	ON
OFF(Under Fault,<0.7pu)	ON	ON	ON	ON	OFF(After Certain delay)	OFF(After certain delay)
ON(>0.9pu)	ON(>0.9pu)	ON(>0.9pu)	ON(>0.9pu)	ON(>0.9pu)	ON(>0.9pu)	ON
ON	ON(0.8-0.9pu)	ON	ON	OFF	ON	ON

Table 3. Operating Condition and Status of Interfacing Switch

Pu- Per unit of 230V

5. Monitoring and Control through Webpage

Webpage is designed such that it consists of buttons (Button C & D) to control the “interconnection switch”. Apart from this, the load status at main load (Main), sub load 1 (Load), sub load 2 (Sub) and the interconnection switch status (Isw) are also shown in the webpage. After a change is made in the circuit GPRS module takes 24-30 seconds to push the data into the cloud from where the data can be accessed by the website. Similarly, if we give a command from the webpage to control the circuit, it gets pushed into cloud and the GPRS module takes the same time to receive and execute the command. Apart from “Button C” and “Button D”, we have “Refresh” button to update the status in the webpage and “Clear details” button to clear previous unwanted data. Reading are recorded as shown in Figure 4.

Figure 4 Webpage

6. Conclusion

This paper proposed an IoT based interface protection scheme and energy management method. The test results shows that the interface switch is turned OFF whenever the grid line is disconnected from the power source. Sensing and communication of power system parameters took very less time. The interface protection also faster using IoT. Microgrids, predominantly uses Power electronics based converters and inverters require faster isolation of faults. Hence the IoT based interface protection scheme will be more suitable. The variation in frequency and voltage due to sudden power imbalance might damage the switching devises. To protect them from these variations, shedding of least priority loads during power shortage and charging the energy storage elements during excess power need to be carried out within few milliseconds. The proposed method for switching OFF least priority loads using IoT found to be very effective and suitable for microgrid applications.

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