

Interface Protection of Smart Grid using Static Relaying Scheme

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Abstract

The penetration of Distributed Energy Sources necessitates the changes in the relaying schemes of protection system. Interface protection following a fault is critical to ensure the safety of servicemen. This paper proposes a static relaying scheme for interface protection. The voltage of the grid line will be monitored continuously, whenever the voltage reduces to a very low value rapidly then the MOSFET acting as an interface switch will be turned off through the ARDUINO processor. The proposed model for interface protection is tested using a simulation circuit developed in Proteus software. A hardware model is developed to test the technical viability of the new interface protection scheme and tested in different operating conditions. The test result shows that the interface protection is effectively working. The proposed method uses the simple circuitry with MOSFET and ARDUINO as major components. This makes the proposed method simpler and the prototyping will be easier. The proposed method can be implemented in the real time power system with the addition of instrument transformers, rectifiers and higher rating switching devices. The micro grids with distributed energy sources can effectively use this hardware model for interface protection. Effective utilization of information and communication systems will further enhance the capability of the proposed method.

Keywords: Distributed Energy Sources, Interface Protection, Islanding Operation, Smart Grid, Static Relaying

1. Introduction

The exponential demand for electricity necessitate the increased power generation. The performance of distributed energy sources like solar PV, wind turbines, pumped hydroelectric sources and many other sources is also getting enhanced through extensive research. The interconnection of all such sources with grid and loads might lead to a catastrophic condition as the fault identification and clearance will be difficult with existing protection schemes^{1,2}. The major protection issues of power system with Distributed Generations (DGs) are bi-directional power flow, islanding or isolation of DG during fault conditions and dynamic fault current level. Hence there is a need for efficient and adaptive protection systems which can identify and clear faults besides isolating DGs^{3,4}. In the power system consists of DGs, if a fault occurs in the main grid line the circuit breakers will isolate the faulty part of the system. But the Interface switch connecting the DGs

and grid line will be in ON state and continue to feed the fault. This will result in electrical accidents and unstable operation of smart grid on islanding mode of operation. So in order to avoid the supply of power to a faulty line, proper isolation of DGs from the Grid connection is essential. The Information and communication systems⁵⁻⁷ and Power electronic devices^{8,9} find application in protection of power systems. This paper develops a simple and reliable protection system for power systems consisting of DGs by employing IEDs and microcontroller. In a grid with multiple sources the islanding of a part of system is required for avoiding power supply to a faulty line from D.G. and also for ensuring the safety of service men. Islanding is done by measuring the voltage across the potentiometer connected to the grid line. Whenever the voltage is positive it refers there is no fault and when it is zero or less than zero that means the grid line is isolated following a fault and DG is supplying the faulty line, so DG should be isolated from the Grid line. The islanding

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mode of operation enables that the power flow to the faulty line from DG is prevented by continuously measuring the voltage of main line.

2. Interface Protection

In the power system with DGs, fault in one part might cause damage to other. This can be prevented with reliable protection systems. The intentional islanding is one such protective measure adopted in a system with interconnected sources. The block diagram of the proposed method is shown in Figure 1 describes a system with Grid line which is the main source and a DG supplying a local load. DG can also be synchronized to grid line through static switch. If the power generated by DGs is more than the demand of local load, the power may be exported to grid line. If the power demand of local loads is more, then the grid line and DGs will supply power to local loads¹⁰. If the grid line goes off-line the static switch will be open and DG will supply power to local loads.

The demand side management will be carried out to maintain the load balance. When there is a fault in the grid line then the primary circuit breaker of the main protection system acts by disconnecting the main load. But the DG which is connected both to the main line as well the local load continues to supply to the faulty line through static switch. This results in live wires which may be dangerous to the service men. To avoid this, when the grid line goes off-line the DG has to be disconnected from the grid line by operating the static switch and continue to supply the local load. This is called the intentional islanding operation. Islanding operation is done by measuring the voltage across the source end and ground which should be positive always except for faulty condition. It becomes negative or zero when there is fault due to the reverse flow of power from DG. Then the static switch is to be opened to achieve islanding of DG and the local load.

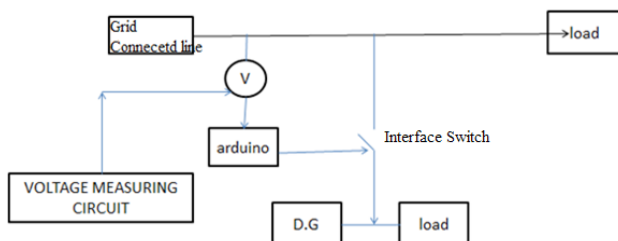


Figure 1. Interface protection scheme.

3. Design Specifications

The design of islanding 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.

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 or power it with an AC-to-DC adapter or battery to get started.

3.2 Power Supply

The Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre - positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin

Table 1. Design specifications

Components	Design Specifications
Arduino UNO	Micro controller atmega328, o/p voltage 5V
Voltage measuring devices, Loads	Rheostat, 50k POT
Power MOSFET	IRF540
Voltage Divider	Output voltage: 5V
Bluetooth modules	HC-05 (2)

headers of the POWER connector. The board can operate on an external supply from 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

3.3 Voltage Measurement and Loads

To demonstrate the technical viability of the proposed model a DC system is considered and the voltage measurement is carried out using POT. Resistive loads are used for both grid line load and local loads for DG. In a practical power system potential transformers with rectifier circuit can be used to get analog voltage.

3.4 Voltage Divider

A voltage divider is included in the design keeping in concern the maximum input voltage to the Arduino is 12V. For this reason the voltage across the voltage measuring devices need to be minimised. This can be done using a voltage divider as the test sources are DC sources. The voltage divider used in this design is a 1:3 divider that means it provides 5V to the analog input pin if the source is of 20V. In the real time AC power system this will be done by the instrument transformers which conveniently step down the voltage or current using the principle same as transformer.

4. Hardware Implementation

The hardware implementation of the interface protection scheme for islanding and the grid connected modes using the above mentioned components. The circuit diagram is given in Figure.2. Two voltage sources are used to demonstrate the working of proposed model. One source acting as grid line source and the second one represents

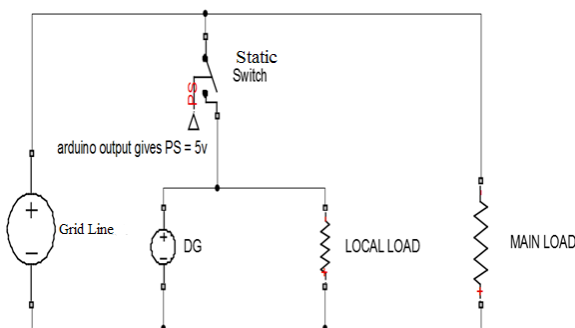


Figure 2. Interface protection hardware circuit.

Table 2. Operating conditions and status of static switch

Grid Source	DG	Local Load	Main Load	Static Switch Status
ON	ON	ON	ON	ON
ON	OFF	ON	ON	ON
OFF	ON	ON	OFF	OFF

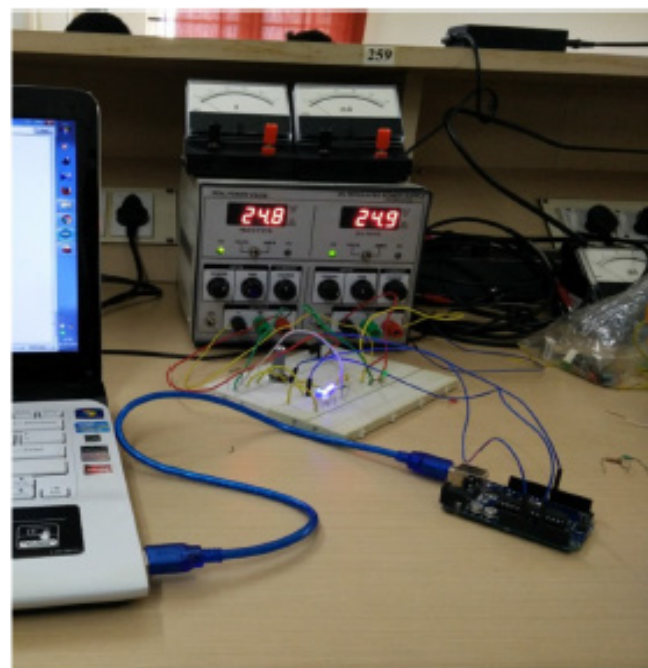
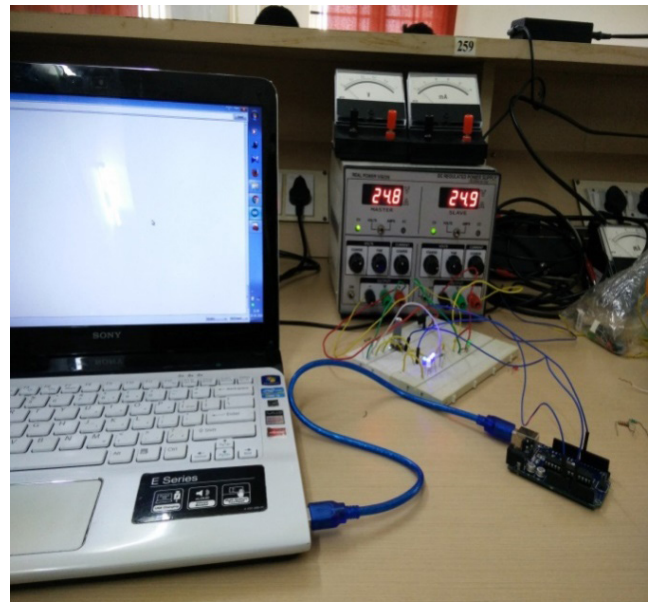


Figure 3. Hardware model for interface protection.

DG. The grid line voltage is measured using POT and is given to the Arduino for determining fault condition.

Divider circuit is used in this condition to reduce the voltage applied across potentiometer. It receives approximately 5 Volts which is a safer signal to Arduino UNO board. This voltage is positive in a no fault condition. On fault condition the circuit breaker will be tripped and the line will be isolated from power supply hence the voltage will be zero. If the DG is connected to grid line the voltage may be –ve. So whenever the voltage drops across the potentiometer to 0 or –ve, the interface protection system is activated and the static switch between grid line and the DG is opened. MOSFET IRF540 is used as static switch for interface protection. The switching status of static switch during different operating conditions is given in Table 2.

The working of developed hardware model was tested using the operating conditions mentioned in the Table 2. The operation of static switch with respect to various operating conditions listed in Table 2 was verified by suitably setting the DC sources. The MOSFET acting as a switch is very fast at switching action and so the stability needs to be maintained. For that reason a little delay between each reading is considered. When there is no fault and both sources are supplying power the static switch was ON. When the grid line goes off-line following a fault, grid line voltage is dropped then static switch was OFF, then the local DG source supplies power to local loads. Whereas the main load is off as there is no source supplying power to the main line. In case when the DG voltage is shut off then the main line should feed the local load too and that case is achieved by switching ON the static switch. The hardware model of the proposed method is shown in Figure 3.

5. Conclusion

With the penetration of distributed energy sources for electric power generation, the control and operation need to be adaptive. Smart grid enables the bidirectional power flow in the power system. The protection schemes should be able to differentiate between the grid connected and islanding operation of the system to ensure reliable and safe operation. The conventional schemes of protection are unable to accommodate the changes in the power system. This paper proposed and developed a protection scheme using Arduino for interface protection which makes it adaptive to the change in operating conditions. The method proposed for interface protection for islanding operation is able to detect a faulty condition

and isolate the DG from faulty part. The circuit is more reliable and assures the safety of the service men working and also prevents the supply of power to a faulty line. Whenever the voltage in the main grid line goes low the circuit is able to detect the abnormal condition and isolate the faulty part by this power to the local load is supplied uninterruptedly. The proposed method is very simple and cost effective.

6. References

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