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# Robust PI Controller for Frequency Stabilisation of Islanded Microgrid Operation using Battery Energy Storage System

**N. S. Srivatchan[1*], P. Rangarajan[2] and S. Rajalakshmi[2]**

[1]Department of Electrical and Electronics Engineering, Sathyabama University, Chennai 600 – 119, Tamil Nadu, India; srivatchan_ns@hotmail.com

[2]Department of Electrical and Electronics Engineering, R.M.D. Engineering College, Anna University, Chennai 601 – 206, Tamil Nadu, India; rangarajan69@gmail.com, rajalakshmisambasivam@gmail.com

## Abstract

**Background/Objectives:** Maintaining constant frequency in an Islanded microgrid is highly demanding and challenging issue. Therefore it is proposed to use Robust PI Controller for controlling the frequency of islanded microgrid using Energy Storage system. **Methods/Statistical Analysis:** The proposed Robust PI controller provides the required frequency stability to the islanded microgrid. The test modeled in **MATLAB Simulink** environment. The Test system modeled as typical remote location (Island or Military Power Grid or Geographically Disconnected or Hilly Terrain) with a wind turbine and Solar panel, along with distributed loads and Energy storage system. **Findings:** The drawbacks of the traditional PI controller to adapt to the parametric variations and to provide faster response is overcome using proposed Robust PI controller. The inherent disadvantage of PID controller such as instability and peak overshoot is also overcome with the proposed controller. The Proposed Robust PI controller provides the improved dynamic frequency stability and reduced peak overshoot to the islanded microgrid with in 0.3seconds, if the microgrid is suddenly disconnected from the main grid. The controller also tested under various conditions and it provides required frequency stability to test system during islanding operation. The proposed method is simple, flexible and provides improved performance as compared to the existing methods and approaches for frequency stability of islanded microgrid. **Application/Improvements***:* The proposed controller can be used in remote location and provides simple, yet cost effective solution as compared to costlier PID Controller based on fuzzy logic and neural network.

**Keywords:** Battery Energy Storage System, Distributed Renewable Energy Systems (DRES), Frequency Stability, Islanded Microgrid, Robust PI Controller

## 1. Introduction

Microgrid is an integrated singular energy system consisting of Distributed Energy Sources predominately renewable energy sources, Battery Energy Storage Systems (BESS) and distributed loads[1]. The presence of large number of renewable energy sources in microgrid pose number of control challenges such as synchronization, voltage and frequency stability and power quality[2]. Microgrids can be connected or disconnected to the main grid through Bidirectional Static Transfer Switch (BSTS) either due to fault or deliberately[3]. When the microgrid is disconnected from the main grid it said to be operating in islanded mode[4]. In an Islanded microgrid, most of distributed energy sources are renewable sources and they have very less inertia. Due to low inertia of these Distributed Renewable Energy Sources (DRES) they are unable to meet the sudden loss of generation from the

** Author for correspondence*

grid. Therefore during Islanding frequency limits are violated and it leads to collapse of the grid, unless proper control action is initiated.

One of the key issues in islanded microgrid is to control and maintain the frequency[5]. Battery Energy Storage System (BESS) linked Inverter can provide frequency stability in an islanded microgrid consisting of slower response distributed energy sources. A Properly tuned battery energy storage system can provide faster frequency stability to the islanded microgrid even with dynamic load changes. The controller designed and tuned in such way that dynamic load requirement is shared by battery storage system as well as other distributed energy sources, thereby provides smooth frequency stability in an islanded microgrid[6,7].

## 2. Configuration of the System

In an Islanded Microgrid Battery Energy Storage system plays a vital role for stabilization of frequency. Microgrid Island Controller (MIC) provides coordination for frequency regulation and power sharing between BESS and DGs in an Islanded microgrid. Microgrid Island Controller provides reference for power at the primary level[8]. The Secondary level control is provided by local controller that controls the power output of each DG's in tune with the reference provided by the MIC.

The system is configured as Low voltage and the block diagram of the configuration is shown in Figure 1. It Consists of Photovoltaic Generator, Wind Turbing and Battery Energy Storage System (BESS)[9,10]. The Microgrid is connected to the main grid through Bidirectional Static Transfer Switch (BSTS), which is disconnected during Islanding. Under Grid connected mode power can be imported or exported based on condition of Distributed generation and connected load in the microgrid side.

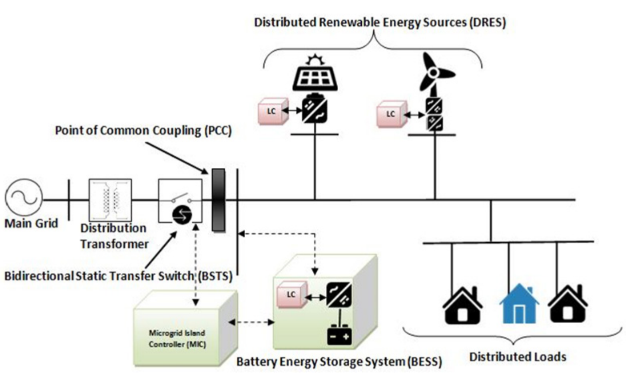


**Figure 1.** Configuration of Islanded Microgrid with BESS.

In Grid connected mode BSTS is closed and MIC takes the role of primary control and provides necessary control and coordination. During Islanding BSTS is open, MIC senses this open status of the switch and thereby gives necessary control signal to the BESS. At this instant BESS takes role primary control to provide the frequency stability. The BESS can provide frequency stability only for short duration due to storage limitation and for ensuring spinning reserve. So it is very important that MIC takes over the control secondary control within specified boundary time interval. The MIC ensures frequency stability by sharing the real and reactive power among the DG's.

## 3. Battery Energy Storage System

Major focus of the paper is in BESS as shown in Figure 2. and it consists of Robust PI Current Controller. In an Islanded microgrid, the battery takes the primary control role and operates the grid in constant frequency mode, there by provides frequency stability. MIC plays the secondary role and coordinates power sharing between the DG's. In an Islanded microgrid, the MIC deducts the open status of BSTS and sends the control signal to Battery Energy Storage System along with voltage/frequency reference to provide frequency stability to the microgrid.

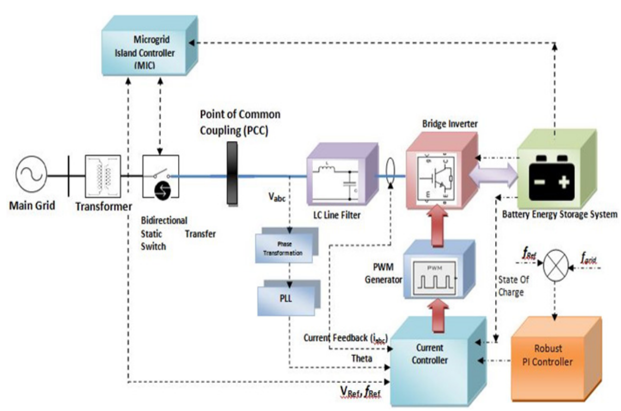


**Figure 2.** Configuration of Battery Energy Storage System (BESS).

The error frequency ($\mathbf{e = \delta f = f_{Ref} - f_{Grid}}$) signal is given to the Robust PI controller which provide the control signal to current controller. The Current Controller generates control signal to PWM generator. The PWM generator produces required gate pulses and there by controls the firing of Inverter. The Frequency stabilization only through Battery Energy Storage System is not a feasible option as the battery cannot support the entire islanded load. Therefore MIC Sends (Real and Reactive) Power Reference Control signal to each of the local controller based on the total (Real Power and Reactive Power) load demand and shared among the DG's 12,13 as per equation (1) and (2) given below

$$P_{Ref\,i} = \frac{P_{GC\,i}}{P_{GAC}} \text{ x } P_{TLD} \qquad (1)$$

$$Q_{Ref\,i} = \frac{Q_{GC\,i}}{Q_{GAC}} \text{ x } Q_{TLD} \qquad (2)$$

$P_{Ref\_i}$ and $Q_{Ref\_i}$ are Reference real and reactive power generated by MIC for each local controller for smooth power sharing between DG's.

$P_{GC\_i}$ and $Q_{GC\_i}$ are real and reactive power generation capacity of each DG.

$P_{GA}$ and $Q_{GA}$ are total real and reactive power capacity of the DG's in the islanded microgrid.

$P_{TLD}$ and $Q_{TLD}$ are total real and reactive power load demand of the islanded microgrid.

## 4. Robust PI Controller Problem Formulation

In an Islanded microgrid there is a fluctuation of real power and it leads to frequency deviation. The fluctuation can be eliminated by matching the generation with respect to load demand. Therefore the main objective in an islanded microgrid is to minimize frequency deviation (δf) and it is given by the function.

$$\text{Minimize } E = \int \delta f \, dt \qquad (3)$$

Use of PID controller is not flexible, because they are tuned based on fixed parameter values. In PID Controller uncertainties associated with the system are not considered, and this leads to increased errors this leads to system instability. Designing controller for frequency stability and to improve the dynamic response, it is essential that controller can adapt to the uncertainties. Therefore it is proposed to use Robust PI Controller for the system with Parametric Uncertainties. The Block diagram of the Robust PI Controller is shown in Figure 3. The main objective of the Robust PI Controller is to maintain the system frequency at 50Hz with minimum deviation. The main objective of the Robust PI controller is to maintain the system frequency at 50 Hz with minimum deviation.

The Robust PI Controller parameters are chosen to provide the improved dynamic stability by being sensitive to variations for closed loop response. This provides greater flexibility in control for remote location islanded Microgrid operation.

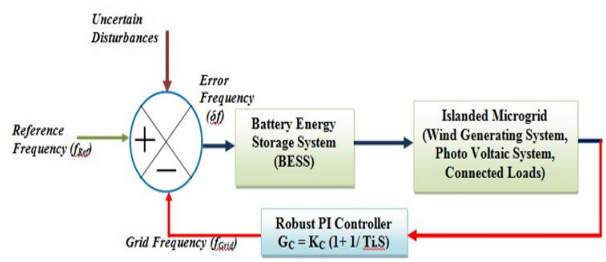


**Figure 3.** Configuration of Robust PI Controller.

## 5. Simulation System

The Microgrid test model is designed and simulated in the MATLAN SIMULINK environment as shown in figure 4.

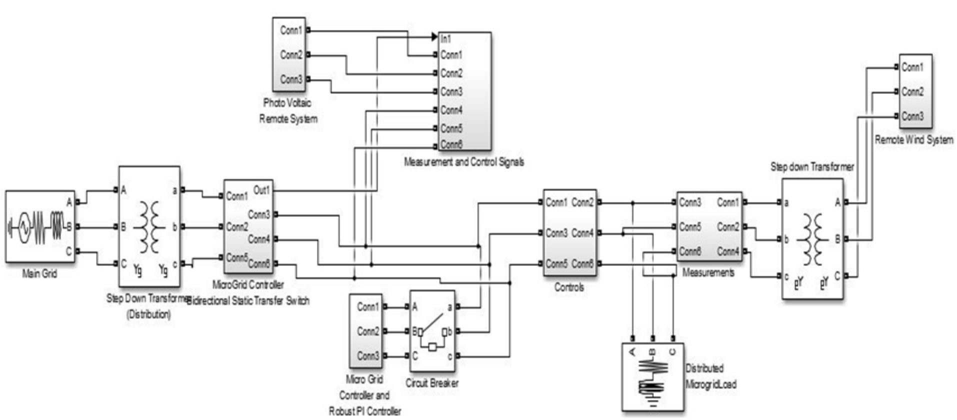


**Figure 4.** MATLAB SIMULINK Model of the Microgrid Test Setup.

The main grid is modeled as three phase voltage source. The Main grid is connected to the microgrid through the step down transformer along through the circuit breaker. The status of the Circuit Breaker is given to the Micro grid Island controller. The Microgrid consists of a PV system, Wind Generator System, Load and Battery Energy Storage System. The PV System is connected to the grid through the inverter and step up transformer along with the local controller.

**Table 1.** System Configuration

| S.No | Component Description | Parameter Value |
|---|---|---|
| 1 | Photo Voltaic System | 2 kW |
| 2 | Wind Generator System | 3 kW |
| 3 | Battery Energy Storage System | 2 kW |
| 4 | Connected Load | 4 kW+j1 kVar |
| 5 | System Voltage (***V***) | 380 Volts |
| 6 | System frequency (***f***) | 50 Hz |

The Wind Generator system consists of Asynchronous generator controlled by local controller and it is connected to the micro grid through the isolation transformer. The Battery Energy storage system is connected to the microgrid through the circuit breaker and it is controlled by Microgrid Island Controller through the Robust PI Controller. The Energy Storage System is connected to the microgrid , when the microgrid gets islanded from the main grid. The parameters of the test system is given in Table 1.

## 6. Simulation Results and Analysis

The microgrid is connected to the main grid and the main grid provides the control action for frequency stability till 1 seconds. At 1 second microgrid is disconnected from the main grid through the circuit breakers, thereby creating the islanding. Microgrid Island Controller (MIC) senses the grid disconnection and provides the grid outage information to the Robust PI controller. The Robust PI controller initiates the control signal to the Battery Energy Storage System there by provides the required frequency stability to the microgrid. The Controller provides fast dynamic response with minimum overshoots and there by settle the system with in 0.3 seconds as shown in simulation output in Figure 5.

The main Grid provides strong voltage stability when the microgrid is connected to it till 1 second. When the Islanding happens after 1second, the Robust Controller provides required control action and ensures the voltage of the grid is within the specified voltage range as shown in simulation Figure 6.

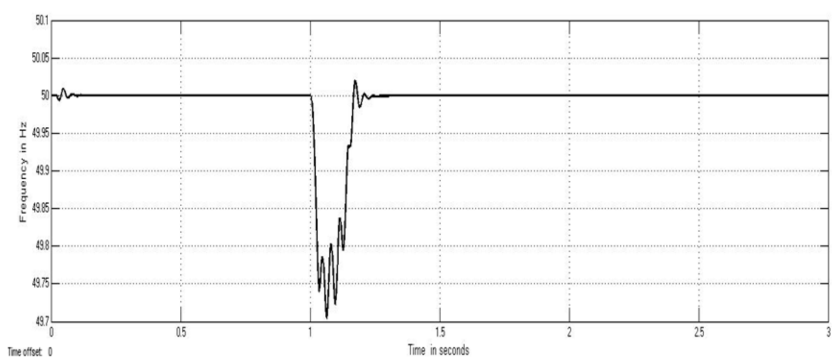


**Figure 5.** Grid Frequency (Before and After Islanding).

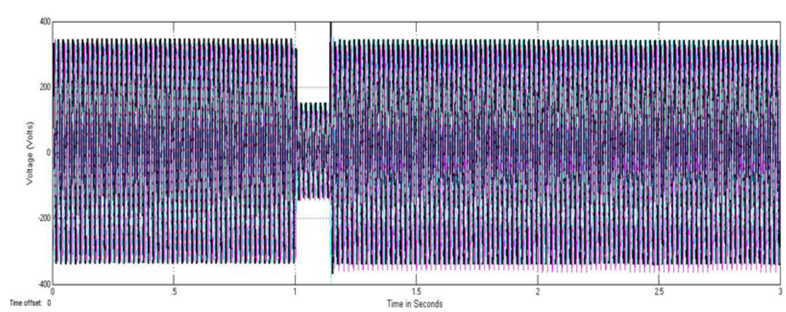


**Figure 6.** Grid voltage (Before and After Islanding).

## 7. Conclusion

The proposed Robust PI Controller Provides the required frequency stability during islanded mode of operation. Due to the presence of Distributed Renewable Energy sources, the microgrids have low inertia and this leads to poor dynamic response. In the proposed model the poor dynamic response of the system during islanding is improved with the help of battery energy storage system. However the battery storage system cannot support islanded operation for extended time period due to finiteness of battery energy storage system.

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