A New Under-Frequency Load Shedding Scheme Based on Adaptive Neuro-Fuzzy Inference System and Evolutionary Programming Shedding Priority

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Abstract. Frequency stability of islanded distribution system is a topic of interest, due to the significant penetration of distributed generation (DG). This paper proposes a new under frequency load shedding technique, which address the over-shedding issue caused by fixed priority. The proposed scheme consists of two units; first, the power imbalance estimation unit (PIEU), which use adaptive neuro-fuzzy inference system (ANFIS) to estimates the power imbalance. Second, the load shed unit (LSU), which is based on binary evolutionary programming (BEP) technique to shed the optimal loads. To validate the performance of the proposed UFLS scheme, different simulation studies have been conducted using PSCAD software. Moreover, the response of the proposed scheme is compared with another UFLS scheme having fixed priority loads. From the simulation results, the proposed scheme can shed the optimal loads, which is not achieved in the existing load shedding schemes.

1. Introduction

Recently, controlling the frequency within the permissible limits during islanding operation is the most important technical challenge being investigated worldwide. Hence, alternative techniques are required to enhance the reliability of today's complex distribution network. This can be mitigated by using accurate load shedding (UFLS) scheme, which balances the system. Accurate load shedding depends upon two main factors; accurate estimation of power imbalance and accurate amount of load to be shed. In the literature, several load shedding schemes have been proposed: conventional, adaptive, and intelligent. The conventional UFLS is the most applicable in this case [1-3]. In this technique, a pre-determined load values will be shed based on frequency value. Although this technique is very simple, it is suffering from over-shedding issue. For this reason, the adaptive UFLS technique comes with advantage of using swing equation to calculate the imbalance of power. Further efforts to accurately estimate the power imbalance were the application of computational intelligence based techniques such as artificial neural network (ANN) [4-6], fuzzy logic control [7-9], particle swarm optimization technique (PSO) [10, 11], and genetic algorithm (GA) [12, 13]. From reviewing different load shedding techniques, there is inaccurate load shedding issue since every technique is bounded by fixed priorities shedding load. Fixed load shedding priority is linked to the loads that are shed sequentially based on lookup table which consist of critical and non-critical loads. For this reason,

an UFLS scheme called fixed and random load shed priority (FRLSP) is proposed to shed the optimal combination of loads [14]. However, study proposed in [14] takes quite a while, since it goes through all the possible combination of loads. In this paper, an optimal UFLS scheme is proposed to stabilize the frequency of islanded distribution network. This scheme consists of two main units: (a) power imbalance estimation unit (b) load shed unit. For the former, an adaptive neuro-fuzzy inference system (ANFIS) is used to estimates the power imbalance. While for the latter, a BEP technique is used to shed the optimal number of loads from fixed and variable priority loads [15].

2. Method and system description

This paper proposed a new UFLS strategy, which combine precision in estimating the imbalance power and the appropriate shedding loads. Proposed UFLS strategy is based on both frequency and *df/dt* values to estimates the power imbalance. The ANFIS uses these values as input and intelligently estimates the power imbalance during disturbances. After estimating the power imbalance, this value is sent to LSU for shedding loads according to load priority using BEP. Where, loads from 1-10 are selected to take random priority, and loads from 11-12 are selected to take fixed priority. Figure 1. illustrates the overview of load shedding scheme for an islanded distribution network, which is modeled using PSCAD software. This network consists of two mini-hydro generators, each rated 2MVA, and four photovoltaic units each rated, 0.5 MW.
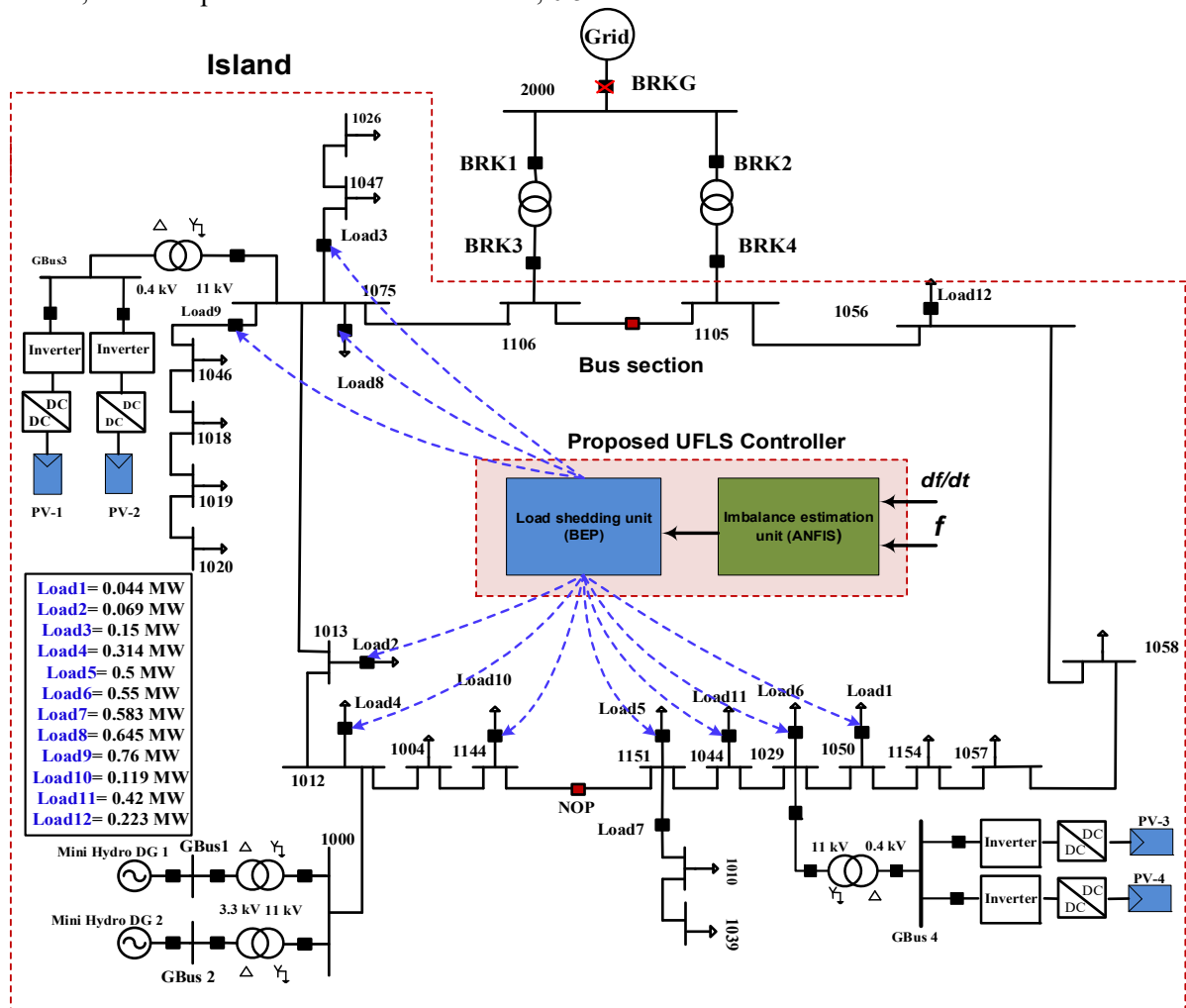

Figure 1. The overall test system

3. Methodology of proposed UFLS scheme

The methodology of proposed UFLS scheme is shown in Figure 2. When a disturbance (islanding, load increment, generator trip) occurs in the distribution network, PIEU estimates the amount of load to be shed by using the ANFIS. Since, the PSCAD does not provide ANFIS tool, it is designed and trained in MATLAB software as shown in Figure 3. The ANFIS has two inputs (frequency and rate of change of frequency) and one output power imbalance (ΔP). After calculating the amount of load to be shed, the system frequency is checked to show whether it drop to certain value (49.5 Hz). If this happens, The LSU receive the amount of load to be shed value. Then, if this value is larger than the total random priority loads, the LSU directly shed all random priority loads and start shedding from fixed priority loads. Otherwise, the BEP is initialized to shed the optimal combination of loads.
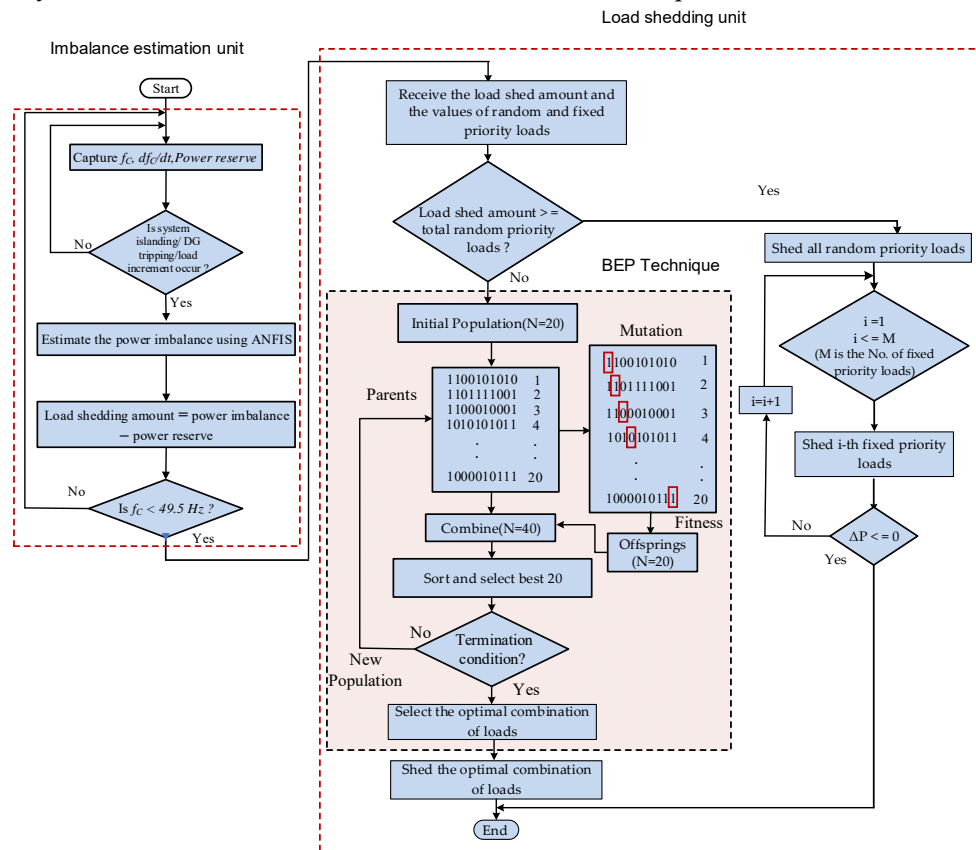

Figure 2. Proposed UFLS scheme flow chart

4. Results

In this paper, a comparative study is implemented to show the preference of proposed UFLS scheme over the adaptive and conventional UFLS schemes. This comparative study is performed for load increment of 1 MW occurring at 40s after islanding. Immediately after islanding, the system frequency begins to decline in response to excess loads (0.32 MW). Accordingly, the mini-hydro generators use their spinning reserves (0.48 MW) to cover the unbalance power. At 40s after islanding, the total power demand will be 6.68 MW. For this reason, the UFLS automatically activate to stop the frequency declination by shedding the (loads 2,3,8) for proposed UFLS scheme, (loads 1-5) for adaptive and conventional schemes. The frequency responses of three scheme and adaptive UFLS scheme are shown in Figure 3.
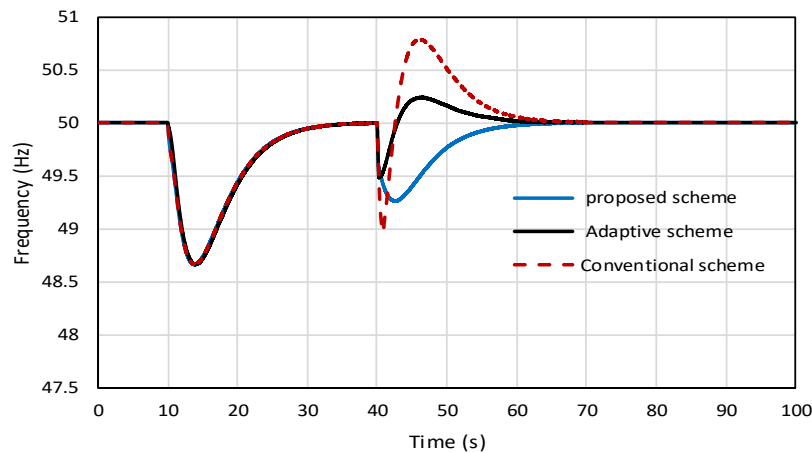
Figure 3. The Frequency response for 1-MW load increment

As shown in Figure 3, it is noticed that due to fixed priority of loads, the adaptive and conventional UFLS schemes shed more load (1.07 MW), which leads to overshoot in the system frequency. However, the proposed UFLS scheme shed less load (0.84 MW) and recover the system frequency without any overshooting. To show the advantage of proposed scheme over FRPSL scheme, another comparative study is implemented as shown in Figure 4. Immediately after islanding, the system's frequency begins to decline in response to excess loads (0.32 MW). Accordingly, the mini-hydro generators recover the frequency. At 40s after islanding, a mini-hydro DG of (1.71 MW) is tripped from the islanded microgrid. For this reason, all load shedding techniques are initiated to restore the system frequency by shedding the same amount of power (1.63 MW). However, FRPSL technique fails to prevent the system's frequency from dropping below 47.5 Hz, which leads to total blackout. In fact, the large execution time of this technique is the main reason of operation inability.
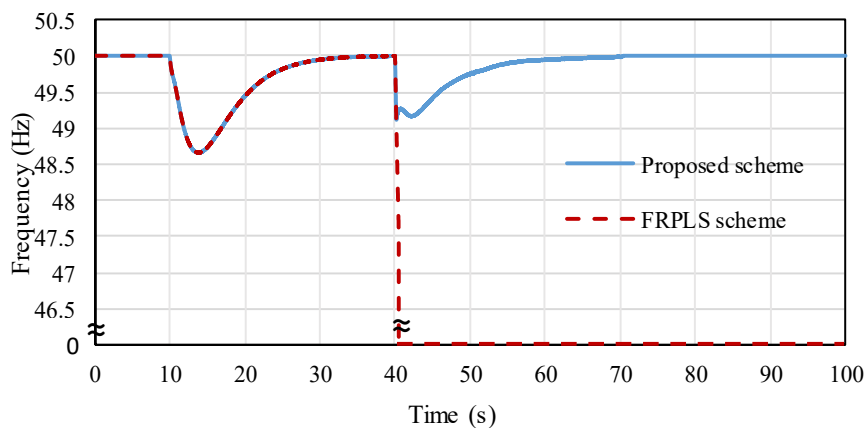

Figure 4. Frequency response for mini hydro DG tripping event

5. Conclusion

This paper proposed a new UFLS scheme that is suitable for islanding distribution networks. This scheme utilizes the application of ANFIS and BEP techniques to determine the optimal combination of loads needed to be shed from the network. As concluded from the simulation results, the proposed UFLS scheme combines the advantage of high speed response with the ability to separate the optimal loads, therefore, this UFLS scheme can improve the reliability of the distribution network after islanding.

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