A Casestudy on underfrequency load shedding scheme for hybrid systems

Preethu Prasad[1],Chithra.C.S[2]
[1]PG Scholar, Department of EEE,UKF College of Engineering and Technology,Paripally,Kollam.
[2]Assistant Professor, Department of EEE,UKF College of Engineering and Technology,Paripally,Kollam.

Abstract - Frequency is the most relevant module for the efficient working of electrical power system, therefore if any deviation from its rated value will collapse the entire system. So to protect the entire system from the serious condition under frequency load shedding schemes are used. The purpose of such scheme is to maintain the frequency within permissible limits during severe power deficit. Also, in case of hybrid systems connecting or disconnecting power generating source or loads may alter system parameters. These factors may affect the performance of load shedding scheme and reduces the consistency of the system. This paper describes the case study on underfrequency load shedding scheme (UFLS) and the optimal UFLS scheme for hybrid system is proposed.

Index Terms – UFLS-under frequency load shedding, hybrid system, power deficit, WAMS-wide area measurement system, comprehensive weight

◆

1 INTRODUCTION

Electricity considered the soul or the life without which the entire world remains dead and dormant and it is regarded as one of the indispensable means to growth of any country's economy. This source of power is the heartbeat of everything from the huge metropolitans, industries, worldwide computer networks, and our global communication system down to our homes. The main objective of any generation and distribution utility is to satisfy the demand of customers with a high quality product. This product namely electricity must be supplied continuously round the clock. To ensure this quality, the voltage and frequency should be constant during normal operation, and uninterrupted service requirement should be satisfied.One of the important requirements in power system is to ensure that sufficient power is generated to meet load demand under normal and emergency conditions. Under normal power system operation, the system is kept balance by providing a supply of generation that meet the load demand and system's loss as given in equation (1) below:

$$\text{Total Generation} = \text{Total Load} + \text{Total Loss} \qquad (1)$$

Under this balanced condition, the system will operates at the synchronous frequency of 50 Hz. In the event of that this balanced state is disturbed, the system frequency changes as in Table 1 below:

Table 1: Behaviour of power system frequency under three combinations of generation and demand.

System condition	System frequency
Generation > Demand + Losses	Increase
Generation = Demand + Losses	No change
Generation < Demand + Losses	Decrease

The decline in frequency is due to insufficient amount of generation that meets load demand, This will cause the load to acquire power from the stored kinetic energy in a rotating system and hence slowing the rotation (frequency). Most electrical machines are designed to operate under frequency of 50 Hz. Any frequency violation may cause damage to the machines. If a considerable amount of generation is lost, the only effective way to correct the imbalance is to quickly shed the load before the frequency falls so low that will eventually damage the system. So this paper describes about frequency restoration scheme(UFLS),and various types of UFLS schemes. In this paper a case study for UFLS scheme with dynamic correction and a proposed UFLS scheme is also done.

2 Under Frequency Load Shedding Scheme

Generally speaking, Under-Frequency Load Shedding (UFLS) is the last resort for tackling serious frequency declines in power systems. Therefore, when power systems are faced with huge disturbances or severe power deficiencies, the ability to maintain the power balance and stabilize the frequency is directly related to the UFLS strategy employed.

For a good UFLS strategy, the following requirements should be met:

- The frequency decline can be restrained and the normal frequency value can be restored.
- The time spent in the frequency recovery should be minimized, and frequency overshoot or hovering should be avoided.
- The load amount to be shed should be minimized.
- The overall cost of the UFLS strategy should be as low as possible.

The existing methods employed for developing UFLS strategies include mainly three versions, namely the traditional, semi adaptive and adaptive ones.

2.1 Traditional System

In traditional system frequency tripping relays are used which issues a trip signal to the circuit breaker when the system frequency falls under the relay's frequency setting. The tripping is done in several stages comprising certain amount of load until the normal frequency is restored. Common practices by most utilities use 49.3 Hz as the first frequency step and between 48.5 and 48.9 Hz for the last step. This load shedding scheme is based on frequency alone has several disadvantage, among which are load may tripped unnecessarily at low import level and too much load tripped at high import level .This phenomenon, commonly known as over-tripping will cause the overshoot of frequency. The reason being is that the system might not be able to recover fast enough between steps of tripping which leads to unnecessary tripping.

2.2 Semi Adaptive System

In the event of large disturbance, characterized by very steep frequency decline, shedding the load based on a preset frequency with a predetermined amount of load may not be adequate enough to prevent sharply declining frequency before the power system destabilizes. Therefore it is important that the load is not only shed based on the frequency alone, but on the rate of frequency decline as well. So in semi adaptive scheme the specific amount of load to be shed is determined in terms of the measuring value of the rate of change of frequency (ROCOF). The use of rate of frequency change (df/dt) is proposed, which provides advantages as follows:

- One can begin tripping load blocks without waiting until the frequency drops critically.
- Steps can trip simultaneously instead of sequentially.
- Improved response time.
- Flexible and can be tailored to different level of
- Reduced frequency swing.

2.3 Adaptive System

The main drawback of the above schemes is that the value of shedded load sometimes does not coincide with the value of active power deficiency. As consequence of this imbalance over frequency or frequency lowering situations can occur. By knowing the precise value of deficiency can optimize operation of existing UFLS system. The adaptive UFLS scheme operates in two steps:

- Calculating the active power deficit, P_{def} [1] in the system.
- Distributing the P_{def} into several load shedding steps.

By using the above technique adaptive system become more efficient than the formers. Also ithis scheme uses some algorithm for frequency calculation.

3. Case study 1: UFLS scheme with dynamic correction

This is an adaptive ufls scheme based on wide area measurement system. In this scheme power deficit calculation is based on voltage effect factor. Here load shedding criteria is based on the differences of load frequency characteristics and generation unit inertia. From those comprehensive weights of each node in the process, load shedding is calculated. Based on the weights, amount of load shedding is determined and the location where it is to be applied is determined. Power deficit calculated [2] is taken as the base of ufls shedding amount. With reference to the real UFLS, the conditions for activation of individual steps are equal to the following threshold frequencies: 49.2 Hz, 49 Hz, 48.8 Hz. Since the traditional scheme lacks of the correction of load shedding, this will inevitably result in overcut, so it’s necessary to adjust the predefined load shedding steps to the primary frequency-control reaction. It is obvious that the deficit power is a nearly linear function of frequency change rate, in general, the x% lowering of P_{def} is reflected in an x% lowering of frequency change rate. Based on this linearity concept, before the kth shedding step is activated, with the use of WAMS, monitor the changes in df_{COI}/dt between two neighboring shedding steps and compare it to the initial (df_{COI},max/dt)value, and the percentage change of df_{COI}/dt is calculated:

$$\Delta k\% = \frac{\left(\frac{d(f_{COI},k-1)}{dt}\right) - (d(f_{COI},k)/dt)}{df_{COI},max/dt} \times 100 \qquad (2)$$

The frequency variation rate change gradient Δk% demonstrates the change in deficit power. As a result, the upcoming shedding step can be altered from its predefined value $P_{shed,k}$ according to:

$$P'_{shed,k} = P_{shed,k} - \Delta k \qquad (3)$$

After the achievement of kth shedding amount, the requirement of control rapidity is taken into account to introduce a new method to distribute the $P'_{shed,k}$ in combination with the proposed comprehensive load weight. The shedding amount of each load node is calculated by:

$$P_{shed,j} = P'_{shed,k} \times \frac{\varphi_j}{\sum_{j\in M}\varphi_j} \qquad (4)$$

In which, M is a set of all load nodes. Consequently, activate each shedding step according to the thresholds to gradually restore the frequency. By following the above procedure, it dynamically adjust the amount of shedding steps to adapt the primary frequency control, response which reduces the possibility of overcut and unnecessary load losses. A multi-factor comprehensive weight is proposed to distribute the load shedding amount, which facilitates the recovery of frequency as soon as possible.

4. Case Study 2: Proposed Scheme

The proposed ufls method [3] uses the frequency first derivative for estimating the amount of power deficit. Hence, inertia constant is the only parameter of power system that might affect the estimated power deficit. In the proposed ufls method, the inertia constant is estimated after the first load shedding step. The next load shedding steps are carried out based on the updated power deficit which is calculated using the updated value of inertia constant. So, the proposed ufls scheme will be independent of the power system parameters. In addition it considers the changes in generated power during the load shedding process.As the above first stage is the power deficit calculation.

$$P_d = \frac{2H_{eq}}{f_N}.f'_{Hz}|\ t = t_0 \qquad (5)$$

where $f'_{Hz}|\ t = t_0$ is the value of frequency derivative immediately after the disturbance and the equivalent inertia constant of the power system is calculated as follows:

$$H_{eq} = \frac{\sum_{i=1}^{n} H_i.S_i}{\sum_{i=1}^{n} S_i} \qquad (6)$$

In cases where the inertia constant of generating units are not available, after occurrence of a power imbalance the equivalent inertia constant of the hybrid power system can be estimated by [4]:

$$H_{eq} = \Delta P \frac{f_N}{2.f'_{Hz}|t = t_{im}} \qquad (7)$$

where t_{im} is the moment when a change in generated or demanded power occurs and ΔP is the amount of this change.

In hybrid power systems the output power of some generating units such as wind turbines or solar cells changes during load shedding process. Due to this reason it is necessary to continuously update the value of P_d during load shedding process. Any sudden change in power balance of system appears as a step change in frequency first derivative, as shown in Fig. 1. A sudden decrease in P_d, which is caused by load shedding or increase in output power of generating units, results in an incremental step change in the frequency derivative. On the contrary, a sudden increase in P_d, caused by a sudden decrease in the output power of generating units, results in a step decrease in the frequency derivative.

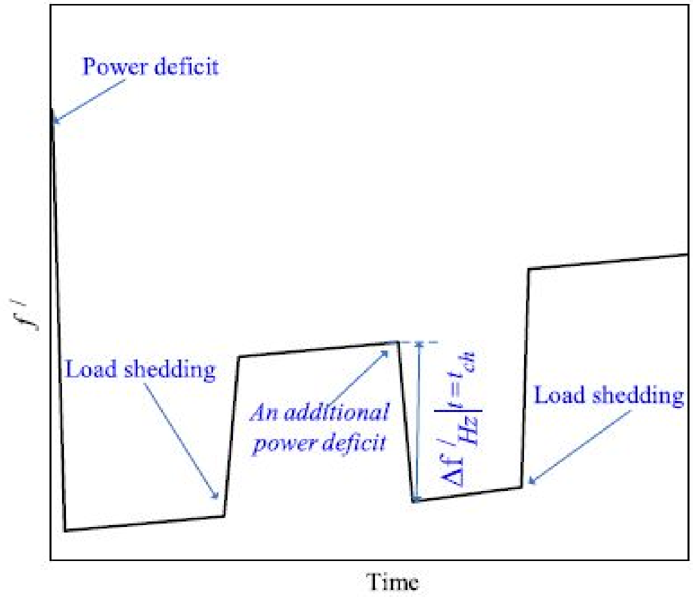

Fig.1. frequency derivative changes in case of change in power deficit

As a result, when an additional power deficit occurs during the load shedding process, P_d can be updated for the next steps of load shedding according to:

$$P_{d-\text{new}} = P_{d-\text{old}} + \frac{2H_{eq}}{f_N}\Delta f'_{Hz}|t = t_{ch} \qquad (8)$$

where $P_{d-\text{old}}$ is the previously calculated power deficit, t_{ch} is the time at which additional power deficit occurs and $\Delta f'_{Hz}$ is the change in frequency derivative.

In this load shedding scheme, power deficit is compensated in four steps of load shedding. Namely, if the frequency reaches 49, 48.8, 48.6, and 48.4 Hz, then 35%, 30%, 20%, and 15% of the estimated power deficit will be compensated by load shedding, respectively. These steps are deliberately chosen to prevent the frequency from falling below 48.4 Hz. Finally, if, for any reason, the frequency falls below 48.4 Hz, an amount of load equal to the difference between the initial power deficit and the load shed in the previous steps will be shed. It is worth mentioning that these frequency thresholds and distribution of load shedding in different steps are chosen to minimize the total shed load for the higher amounts of power deficit and make maximum use of the primary frequency response for compensating the power deficit. Before triggering each load shedding step, it can be checked whether the increase in power generated by DERs is higher than the amount of load which is to be shed until that step. If the answer is positive, that load shedding step will be cancelled. If the following criteria are satisfied, the kth step of load shedding will be cancelled [5]:

$$f'_k < 0 \text{ and } \frac{f'_0 - f'_k}{f'_0} \times 100 \geq TLS_k \qquad (9)$$

where f'_0 and f'_k are the frequency derivatives at the time power deficit occurs and immediately before kth load shedding step, respectively, and TLS_k is the total load, which is to be shed until the kth load shedding step.

It is important to note that power deficit is updated continuously using eq (1). If the percentage of shed load in the previous steps is different from the predetermined values (according to updated value of power deficit), it will be compensated in the next step. This reduces the possibility of under/overshedding which in turn enhances the reliability of the proposed UFLS scheme. Here the next load shedding step depends on the updated power deficit which can be calculated from the updated inertia constant. By using swing equation, the exact value of inertia constant is calculated as follows and used for the next load shedding steps:

$$H_{eqi} = \frac{f_N \times P_{sh_{i-1}}}{2\left(f'_{a_{i-1}} - f'_{b_{i-1}}\right)} \qquad (10)$$

An algorithm for the proposed system is given below:
Step 1: Start
Step 2: Set i=1, f_{th}=49, k=0.35.
Step 3: Calculate P_d using equation (5).
Step 4: Find P_{shed} from$P_{shed} = k.P_d$.
Step 5: Check $f \leq f_{th}$; if yes go to next step otherwise goes to step: 12.
Step 6: Check eqn (9) is satisfied or not, if yes go to step: 10 or else go to go the next.
Step 7: Specify the load to be shed.
Step 8: Trigger the i^{th} load shedding step.
Step 9: Update the value of inertia constant by eqn (10).
Step 10: Update P_d.
Step 11: Increment i as i=i+1.
Step 12: Check $f > 0$; if yes go to step: 16, otherwise go to the next.
Step 13: If $f < 48.4$, trigger all the remaining load shedding steps.
Step 14: Check i=5 or not if yes go to step: 16 or go to step: 15.
Step 15: Update f_{th} & k. Check whether a step decrease in f' or not, if yes update P_d using equation (8) not go to step: 4.
Step 16: End.

5. CONCLUSION

From the above two case studies, the former scheme estimates power deficit on the basis of voltage effect factor and multifactor comprehensive weight is proposed to distribute the load shedding amount facilitates the fast recovery of frequency. While in the latter one , frequency first derivative determines the amount of power deficit and for its calculation inertia constant is only considered. The main benefit of the second scheme is that it considers power generation variations during load shedding process. So it is applicable for hybrid systems.

REFERENCES

[1] U. Rudez and R. Mihalic, "A novel approach to underfrequency load shedding," *Elect. Power Syst. Res.*, vol. 81, no. 2 pp. 636–643, Feb. 2011.

[2] Zhaoou Song & Junyong Liu "A Method for the Design of UFLS Scheme with Dynamic Correction,"published in Energy and Power Engineering, 2013, 5, 442-447.

[3] Abbas Ketabi & Masoud Hajiakbari Fini " An underfrequency load shedding scheme for hybrid and multiarea power systems," published in IEEE transcations on smart grid, vol.6.no.1.January 2015.

[4] A. Ketabi and M. H. Fini, "An underfrequency load shedding scheme for islanded microgrids," *Int. J. Elect. Power Energy Syst.*, vol. 62,pp. 599–607, Nov. 2014.

[5] U. Rudez and R. Mihalic, "Analysis of underfrequency load shedding using a frequency gradient," *IEEE Trans. Power Del.*, vol. 26, no. 2,pp. 565–575, Apr. 2011.