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Situation Analysis of Load Shedding and its Effectiveness in the Area of Power System Security

Raghu.C.N[1], G.Raghavendra[2], Doddabasappa N[3], Anil Kumar D B[4]

[1,2,3,4]Assistant Professor, School of Electrical and Electronics Engineering, REVA University, Bengaluru, Karnataka-560064, India.

Abstract

With the hasty growth of the power system to impact increased consumer demand and with more inflexible economic and ecological boundaries, power systems become more composite and severely stressed. Subsequently, system extensive disturbances which lead to the disturbance of voltage and frequency stability which is a critical threat to the power system security. The frequency and voltage instability may lead to the blackout and severely damages the power system gadgets. This upturns the significance of instigating a protection scheme that conserves the system stability. The ultimate procedure prevents the occurrence of a system collapse incident is the functioning of a load shedding scheme. These paper emphases on the overview of the UFLS and UVLS scheme. This paper performs the situational analysis of the existing load shedding scheme. And reassessments some of the frequently adopted techniques along with the brief discussion of the existing scheme to extract the research gap in this area. The outcome of the review will assist the researcher to have a greater visualization of the contribution of the earlier studies.

Keywords: Under voltage load shedding, Under frequency load shedding, power system blackout

INTRODUCTION

In the area of power security, load shedding plays a vital role to captivate the dynamic power requirements of the customers. When all fundamental controls are vulnerable to preserve the power system security operation during a disturbance or contingency, load shedding will be used as the last procedure to make the loss of blackout minimum [1]. The core objective of an effective LS scheme is to curtail a lowermost number of loads and deliver a rapid, steady, and safe transferal of the system from an emergency situation to a normal stability state[2]. The Power system reaches to emergency state at the moment of an unexpected increase of system load, the unanticipated outage of the transmission line or generator or malfunction in any of the power system constituents. This disturbance may result in some problems alike line overloading, under frequency, voltage collapse, and angle insecurity. The disturbances in the power system differ in magnitude and will cause the instability of the power system. This needs, the stability condition of the system must be reviewed and forecast to avoid such incidences. The prominence of stabilizing electric power system equilibrium and consistency has encouraged the evolving of novel methods to capitalize the system stability. The main issues in load shedding are the location of load shedding, amount of shedding load, and time of load shedding. Consequently to avoid post contingency problems, detecting the location of the buses for load shedding must be determined based upon the load significance, curtailment cost and the distance of the curtailed load to the contingency location[3].

Basically, the load shedding scheme is categorized into Under frequency Load shedding (UFLS) and Under voltage load shedding (UVLS). As previously stated, when a power system distraction creates active power imbalance, consequential causes in a frequency deterioration and emergency action such as UFLS may be enforced. If system frequency decline further than the given threshold, for a short amount of time, power stations may trip off causing additional load imbalance which may lead to a power system collapse [4,5]. To prevent massive voltage collapse due to the occurrence of desperate inadequacy in reactive power reserves, power utilities designate Under voltage load shedding(UVLS) because it is an economical procedure to accomplish voltage stability.[6]

The load-shedding schemes proposed by many researchers can be categorized into three groups.

• **A fixed amount of load shed:** The number of loads to be shed is fixed earlier. This group uses time simulation analysis to determine the minimum amount of load shed using dynamic parameters. The shortcoming of such group is time-consuming and in addition incorporating optimization technique in time domain analysis.

• **Dynamic features:** In this group minimum load, to be shed is determined by using load dynamic parameters, tries to determine a minimum load for shedding by estimating dynamic load parameters. This procedure is, results are extremely vulnerable to dynamic load model parameters.

• **Optimal power-flow equation**: Lastly, in this group, minimum load shedding is fixed using optimal power-flow equations by employing the static model of the power system. The dynamics associated with voltage stability are often slow, and hence static approaches may represent a good approximation. The preliminary idea of this method is to establish a sensible solution to the power-flow equations. [7,8]

This paper, therefore, discusses various traits of the DG system with special emphasis on the research contribution in the same topic. The primary aim of this paper is to find the effectiveness of the available research contribution and elicit significant open issues and research gap at the end of the discussion. Section II of this paper discusses the significance of the distributed generation followed by a brief discussion of technologies used in framing up DG in Section III. Illustrative discussions on Government Policies are given in Section IV using the case study of India. Section V discusses the frequently used techniques by the various researchers followed by a review of existing literature in Section VI. Finally, the open issues and research gap explored from the study are discussed in Section VII and Section VIII respectively. Section IX makes some concluding remarks about the paper.

MAJOR BLACKOUTS ARROUND THE WORLD

Several dominant blackouts universally caused due to voltage collapse and frequency decline incidents globally. This section of the paper describes some of the blackouts occurred in the recent years

- *New York **Disturbance**[1970]*: Tripping of 35MW generator because of over loading on the transmission line resulted in a post contingency voltage decline.
- *New Zealand Disturbace[1979]*: Tripping of 270 MW causes voltage decline , within 15minutes of the tripping voltage decline to 0.75pu.Which results difficulty in synchronization of 70MW gas turbine. Finally using manual load shedding both the systems brought to normal state.
- *Tokyo[1987]*:The unanticipated sizzling weather condition because of unfavorable characteristics of air conditioners activated the load to pick up at almost 1% per minute and contributed to a major voltage collapse.
- *France[1987]*:This outage caused by malfunction of protection relay. Voltage collapse occur due to the tripping of many generators by the field current protection relays instead of being field current limited.
- *New D**elh**i[2012]:* This outage is considered as a world's massive outage. Primary facts for this outage are Delicate inter-regional power transmission corridors due to multiple outages. Over loading on 400 kV Bina–Gwalior–Agra link. Lacking corrective actions by State Load Dispatch Centers (SLDCs) to the strategies of Regional Load Dispatch Centres (RLDCs) to cut over drawal by the Northern Region utilities and excess generation by the Western Region utilities. Since there was a miss operation of protection system because of which there was a Loss of 400 kV Bina–Gwalior link.
- *Arizona-southern California[2011]*: On September 8, 2011, cascading outage occurred due to an 11-minute system disturbance occurred in the Pacific Southwest, and approximately 2.7 million customers left without power.
- *U.S.-Canada[2003]*: It affected Northeastern United States and parts of southern Canada, from New York north to Toronto and west to Detroit In this blackout, because of the faults instigated by tree contact results in sequential hasty tripping of three main transmission line which results in rapid succession of severe power swings, and voltage and frequency oscillations that caused blackout[9]. Failure of automated method to alert power system operators and technical support personnel before they take appreciated corrective actions

With the survey of the major blackouts we can conclude that When the frequency/Voltage goes down in a distribution system, it should be brought back near to the reference by shedding a number of loads using UFLS/UVLS. In last decade many outage reported is because of voltage decline rather than frequency. So from last few years UVLS gain main attention in power system security.

LOADSHEDDING KEY ISSUES AND CHALLENGES.

As discussed by many researchers, three main issues to be considered in load shedding are, calculating the amount of load to be shed during load shedding, the timing to execute load shedding event, and to identify the appropriate location for load shedding [6]

• **Amount of Load Shed:** The main factor in establishing System stability is curtailing appropriate quantity of the load. Curtailing fewer loads than required will not efficiently beat voltage or frequency collapse. However, curtailing an excessive amount of loads may raise a new concern, which leads to over frequency situation, because the system will generate additional power in excess of the load appeal.

• Location for Load Shedding: The powerful tool in UVLS for the analysis of small/large disturbance and identification of load shedding locations are dynamic simulation and optimal power flow approach. PQ curve is used to rank the load buses in the sequence of weakest to the strongest bus. The weakest bus possesses high dV/dQ rate which is more vulnerable to voltage collapse. So Weakest bus is the right option for the load shedding. Another method which employs power–voltage characteristics of the lines. In this method, each bus is monitored for the voltage decline. When it is detected UVLS scheme is triggered at the particular bus. Optimum amount load shedding is not possible by this method.

Comparatively, in UFLS scheme, the under frequency relay is set to shed the definite amount of loads when frequency decline below the specified frequency threshold. This scheme is unreliable for obtaining the optimal amount of load shedding. Consequently, to increase the efficiency, a new UFLS scheme is proposed which is found as an adaptive and intelligent method. In this adaptive load shedding scheme, the amount of load shedding is estimated based on the magnitude of disturbance calculation. To calculate the magnitude of disturbance swing equation is used which in turn requires an estimated value of the rate of change of frequency (df/dt) in the system. Practically this scheme is not efficient because the instant df/dt changes so ferociously that it cannot directly give any information about the severity of generation deficiency in the power system. These changes can either cause underestimating or overestimating at the time when the magnitude of generation loss should be assessed. The new scheme explained in reference[9] in which integrating df/dt which is represented by "h" sign. In this method, there will be different alternatives in each load shedding active step. The core idea behind using this modern load shedding scheme can be evaluated for applicability in Smart Grids. Kirar et[11] al.indroduced a load shedding scheme using Artificial Neural Network and also implemented an optimization technique. The result of this method is analyzed in terms of frequency factor, mechanical power, and electrical power.

A method to underfrequency load shedding is presented in the reference[12], frequency trajectory is forecasted using frequency second derivative which is the principle source. A Newton-method-based approximation and the interpolation of the frequency second derivative are continuously performed in order to forecast the minimum frequency value using a numerical integration. Many other techniques and criteria is incorporated to improve the performance of UFLS scheme. [13]

- *Timing for Load Shedding*: The timing of load shedding performance should consider the amount of load shed and the location for load shedding. In reality, various system components attempt system recovery at different time frames. The minimum amount of time allowed before LS scheme is activated is the time taken from the commencement of system collapse. Moreover, the maximum amount of time allowed before LS scheme is triggered is the time taken for all the intervening system components to attempt system recovery.

EXISTING LITERATURES

This section discusses the most recent studies being done in the area of Load shedding framework in the power system, where the recent research work of 2007 to 2014 is discussed in the following categories:

A. Load Shedding on Frequency Framework :

M. Karimi H. Mohamad[14] in their study have exhibited the approach of UFLS scheme to solve the stability and under-frequency issue for an islanded system in a distribution network is presented. This approach has implemented the using adaptive and intelligent scheme for two approaches firstly response based which is on the power imbalance whilst and second event based using swing equation based on the frequency and ROCOF measurement. The scheme achieves to instantly perform the load shedding in a single step and intelligently distinguish between the event and response based condition.

The study presented by Tamer Adanir[15] has evaluated an approach to under frequency protection in power systems. In this approach, the system frequency is calculated one second advance into the future using a dynamic estimator. Comparing with ordinary under frequency protection relay the proposed algorithm is to provide a smooth and proactive load.

R. Mageshvaran et al.[16] has used the glowworm Swarm optimization (GSO) algorithm which is inspired by nature activity. The optimization of load shedding is accomplished by squaring the difference between active and reactive power. This approach gives a better voltage profile, more supplied power and better convergence characteristics compare to the conventional method.

Manson et al. [17] have presented a study for under-frequency load shedding by proper coordination between protective relays. The author of this method modeled the power system using inertial and load tracking mechanism. This method gives a better outcome for several contingencies.

Mokari et al. [18] proposed an adaptive technique in which load to be shed is prioritized. In this method, multiple loads can be shed based on the severity of the disturbance.

B. Load Shedding on Voltage Framework :

M.M. Hosseini-Bioki et al. [19] presented techno-economic multi-objective function which comprises extreme social welfare for an optimal load shedding scheme. This approach uses Particle swarm optimization (PSO) optimization method. The obtained results demonstrate the performance of an intelligent-based optimal load shedding with the minimum curtailment of the load sustaining extreme social welfare and preserving voltage stability.

R. Kanimozhi et al. [20] exhibited a novel method with a computationally simple index based load shedding algorithm using weighted sum genetic algorithm where an AC power flow solution cannot be found for the stressed conditions. Minimization of total load shed and some of New Voltage Stability Index (NVSI) at the selected buses are considered as two objectives of this algorithm. Results obtained by using NVSI and for finding weak buses have been proved as the optimal location of the load shed. Using weighted sum genetic algorithm ensures a minimum amount of load shedding in selected locations.

T. Amraee et al. [7]. The main objective is modified to consider both the technical and economic aspects of each load. In their method, they include first-order sensitivity factors of the load margin in the objective function with respect to active and reactive loads. The proposed PSO algorithm can quickly identify a global optimum solution. It also demonstrates that the success of PSO is not influenced significantly by increasing the magnitudes of the problem.

Ahmadi et al. [8] proposed a novel methodology integer-value modeling for optimal load shedding. This method overcomes the drawbacks of real value modeling such as it uses continuous values in the amount of load shedding but practically it discontinuous. One more limitation is, it considers a fixed power factor for the load shedding amount, etc. The proposed method records subsequent advantage of minimizing the total number of participating feeders in load shedding also reduces the number of contributing load shedding bus and load curtailing amount.

RESEARCH GAP

This section presents a research gap obtained after reviewing the contribution of presented literature in Section IV.

- There are few of the existing approaches towards load-shedding considering both frequency and voltage stability factor. Moreover, comparatively to UVLS and UFLS very limited number of work is contributed towards coordinated strategy between voltage and frequency stability. Because of this, there is a need for benchmarking work in this regard. Studies towards the optimal loadshedding in dynamic power system with distributed generation are very limited.
- Studies towards the optimal load-shedding in dynamic power system with distributed generation are very limited.
- At present, the existing researcher is using only voltage as the dependent variable for the load model which is modeled independently of reactive power at a load bus.
- The prior literature implemented focusing on macroscopic problems than the microscopic where accuracy is limited in optimization which reduces the scope of implementation.
- There are various limitations associated with existing literature in obtaining the best solution or optimal solution for large power system problem. Large power system received less attention from the research society.

CONCLUSION

With the increasing power demand in the modern era, there is a significant impact on power system stability. This paper has attempted to showcase existing load shedding methods is not solitary sufficient for the modern power system, smart grid system, and power system with distributed generation. This paper has initially discussed the different load shedding technique with voltage and frequency considered separately. The next phase of our discussion was towards different challenges of load shedding. The different literature studied shows the importance of working towards joint operation. Therefore, studies towards joint operation receiving more attention in the area of load shedding. Our future work is in the direction of addressing both voltage and frequency stability by evolving up with an optimized modeling approach and we will also investigate the better feasibility of the designed optimized modeling by benchmarking with an existing model to showcase the effectiveness of the proposed modeling.

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