Assessing Effectiveness of Research for Load Shedding in Power System

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Article Info	ABSTRACT
	The research on loadshedding issues dates back to 1972 and till date many studies were introduced by the research community to address the issues. A closer review of existing techniques shows that still the effectiveness of loadshedding schemes are not yet benchmarked and majority of the existing system just considers the techniques to be quite symptomatic to either frequency or voltage. With an evolution of smart grids, majority of the controlling features of power system and networks are governed by a computational model. However, till date not enough evidences of potential computational model has been seen that claims to have better balance between the load shedding schemes and quality of power system performance. Hence, we review some significant literatures and highlights the research gap with the existing technqiues of load balancing that is meant for assisting the researcher to conclude after the selection process of existing system as a reference for future direction of study.

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1. INTRODUCTION

With the consistent rise of technological advancement in production field, there is a growing need of adequate power supply. It is required to increase the capacity of an electricity generation to be at par with the required number of active loads. To some extent, the existing smart grid system is capable of identifying such issues [1],[2]. However, the scene of trade-off between the power requirement and power availability is not same in all the countries. The impending factors that controls the availability of the power supply are i) geographical location, ii) availability of conventional / non-conventional sources of power supply, iii) economic status of the country, and iv) level of urbanization [3]. In India, there are 28% of the renewable power plants and 72% of non-renewable power plants [4]. Majority of the sources of power supply are from coal, hydroelectricity, renewable energy source, natural gas, and oil [5]. As such sources are quite dependent on the natural geological factor as well as economic factor, the number of capacity plants and distributive generation points are quite limited. The fixed number of power generation plants can never cope up with increasing population and their discrete demands of power supply. The circumstances when the power demands cannot be fulfilled by the service provider can eventually lead to power system collapse, which is one of the irreversible processes of restoration [6]. A restoration process can be only effective and channelize if there is any form of mechanism to understand the pattern of load shedding process in predictive way. Hence, a better process of load shedding prediction can add some value added method in the direction of restoration process. When a grid carries a massive amount of power, it leads the transmission channels to fully utilize to highest level. At the same time, the availability of restricted generation reserves and

inadequacy of reactive power to cater up the load demands are quite evident. This phenomenon also leads to significant level of power outage as well as disturbances over the power system. Hence, one way to resist the power system breakdown is to perform load-shedding. According to theory and concept of distributed generation system, the role of system voltage as well as frequency is quite high in load shedding. It is essential to ensure stabilized voltage over the buses. The active power affects the frequency while reactive power affects the voltage [7]. Whenever there is a difference between the load demands and generated power, frequency is significantly affected. Such form of disturbances leads to degradation of the capacity of generation. Hence, load shedding is the best option to restore such frequency.

Similarly, when the demands of the reactive power cannot be met by the power system than it leads to unstabilized voltage. During such condition, capacitor banks are normally deployed to provide availability of reactive power. On the other hand, when such capacitor banks are not sufficient enough to restore the levels of voltage within their maximum and minimum limits, it switches to stage of load shedding. Hence, whenever there is any form of disturbances, it leads to degradation of the core grid system as well as negatively affects the quality of power system. Hence, load shedding is the only way to restore the power system. However, load shedding can also be performed by many techniques and each technique has their own advantages as well as pitfalls.

Therefore, the prime aim of this manuscript is to investigate the techniques of load shedding from research contribution viewpoint and explore the research gap in this area. Section 1.1 discusses about the background of the study followed by Section 1.2 discusses about the problem identification and Section 1.3 briefly discusses about the proposed system. Section 2 discusses essential of load-balancing schemes followed by Section 3 discussing about issues in load shedding. Section 4 discusses about the existing research studies carried out to address the problem associated with load shedding followed by brief discussion of research gap in Section 5. Section 6 summarizes the findings of this paper.

1.1. Background

This section gives the background of the study by generalizing the research contribution and existing technqiues towards load-shedding. The most recent work done by Lu et al. [8] have fairly discussed about the review of the research efforts with respect to under-frequencyload shedding schemes discussing 65 research papers published during 1971-2014.

From Figure 1, a closer look into review of work carried out Lu et al. [8] has covered samples of research paper with more paper discussion focused on year 2009 followed by the years 2005, 2012, and 2013. However, all these work discussion is only restricted to the under-frequency load shedding schemes. Similarly, a reviw of technqiues pertaining to voltage factor was also published by Glavic [9] in 2011, where the review gives more theoretical insights on taxonomies of voltage instability detection techniques with an aid of 53 references ranging between the publication years of 1993-2011.

Review work on under-voltage schemes was also published by Verayiah [10] and Mozina [11]. Review of load shedding techniques has also been seen in the work carried out Lakra and Kirar [12] where a good and simple description of load shedding schemes can be found. Hence, we carry out further updation of the recent works with respect to different forms of technqiues that has not been discussed or reviewed in the existing system. Therefore, the background study can be found to be more involved in identifying the techniques of load shedding with respect to voltage or frequency, and not much on other techniques. The next section highlights about the problem that has been identified in the existing system.
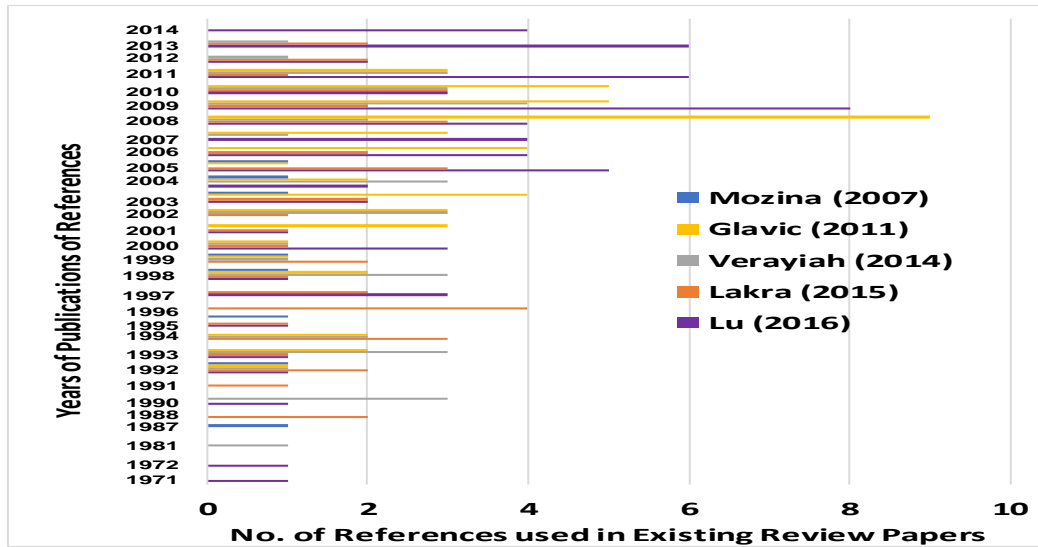
Figure 1. Statistics of Paper reviwed by Lu et al. [8]

1.2. The Problem

The problems identified in the existing system are as follow:

- Although, there are majority of the existing techniques on the basis on under frequency and under voltage concept, but still it has not be discussed which is the best technique in this. As, in terms of reality, under-voltage load shedding schemes are always the last option and therefore priority has to be given to under-frequency based load shedding schemes. There are less evidence to highlight this trade-off.

- As per the discussion laid by Lakra [12], there are three types of load shedding schemes i.e.conventional. adaptive, amd computational intelligent schemes. It was highlighted that there is not much involvement of large simulation studies in adaptive and computational intelligent-based schemes as compared to conventional scheme. However, reliability of outcomes are only proven if any techniques were evaluated on a larger scale with respect to benchmarking and evidence of computational complexity.The biggest problem here is very few of the existing techniques in research has proved the reliability of outcomes in this regards.

- Majority of the techniques that are designed based on under-frequency schemes of load shedding suffers from following problem: i) there is an inclusion of delay while evaluating gradient of frequency during the event of disturbance, and ii) there is no inclusion of load voltage in the schemes.

- The most frequently used under-frequency schemes is multiple pitfalls. Normally, such strategies have different performance with respect to small-scale domestic and large scale commercial usage. The significant issues with under-frequency based schemes are it causes unwanted breakdowns at significant cost of power system owing to its regular disconnections of load. This problem is solved using inertia-based schemes. But such schemes too non-adaptibility of inertia changes of the system.

- Another frequently used technique uses breaker interlocking system, which is one of the simple techniques of load shedding. It allows the circuit breaker to get associated with the breakers leading to tripping of load circuits. However, such schemes also suffers from significant problems e.g. i) alternation to existing power system using breakers is expensive affair, ii) doesn't support dynamic system response as the breaker interlocking is pre-defined, iii) it doesn't support multiple stages of load shedding schemes for curtaining the supply to the entire system, and iv) due to non-supportability of dynamic states, the system cannot prioritize the load to be shed.

- Existing system also deploys logic controllers to formulate load shedding but they are quite slower in generating response. They are also restricted to monitor only a part of power system in the network.

1.3. Proposed System

The prior Section 1.2 has discussed about the unsolved problems in existing techniques of loadshedding. In the proposed system, we perform a theoretical study of the existing techniques which are

quite updated from the prior review papers by including more insights on different techniques and approaches used in load shedding schemes. First, we discuss the importance of load shedding scheme citing a current statistics of power consumption in our country India followed by issues associated with it. Then we review the existing technique of enhancing the load shedding scheme which are published more recently. We classify the discussion with respect to i) techniques using under-frequency load shedding schemes, ii) techniques using under-voltage load shedding scheme, iii) joint techniques of voltage and frequency, iv) optimization techniques to enhance the power system operation during load shedding, and v) miscellaneous techniques. Our discussion is a continuation of the work being carried out by Lu et al. [8], which is one of the recent review publication in the similar direction but the author have confined only on under-frequency techniques. We add more research paper on top of its findings with analysis of each paper with respect to problems being addressed, techniques applied, advantages of the adopted technique, and limitations.

2.   ESSENTIAL OF LOADSHEDDING

According to the recent stats of World Bank, 2016, India consumes about 684.11 kWh power supply, which is highest in comparison to neighboring countries e.g. Pakistan (449.25 kWh) and Bangladesh (258.62 kWh) (Figure 2). This is a simple statistics to show the increasing power demands by the consumer markets. However increasing power demands compared to power supply causes failures of the power distribution system and only way to restore the state of supply is to perform load shedding [13]. This state of inequilibrium causes disturbances over the power system that leads to infrequent switching of the loads along with loss of generators. In such cases, the frequency factor is negatively affected due to the imbalance between the demand of power load and generated power supply. This problem occurs only when there are disturbances in the power system. Hence, in order to resists such form of disturbances, the power system must be restored to its natural state. This will mean that there is a need to restore the load in highly organized manner without negatively affecting the power system. One way to do this is to adopt the mechanism of load shedding.
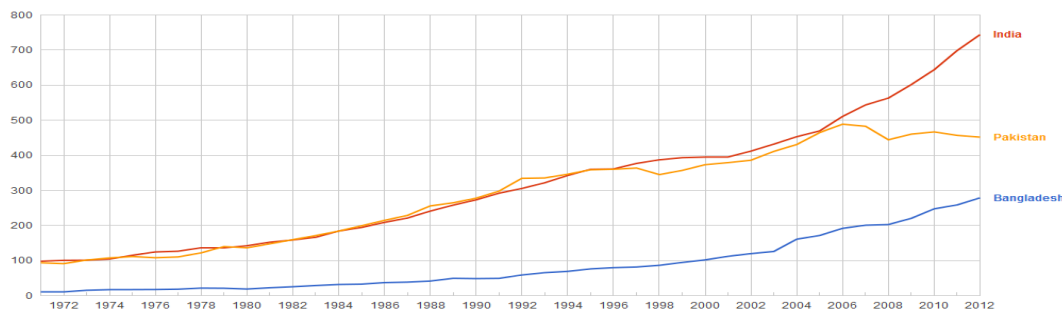

Figure 2. Statistics of Power Consumption in India (Source: World Bank, 2016)

Hence, load shedding can be defined as the process of temporary shutdown of the electrical power supply in order to meet the balance between dynamic power supply demand and prevention of power distribution system crash down [14]. The process of load shedding targets to eliminate the load from the system of power supply for the situation of inequilibrium between power demands and power availability. During load shedding, the system or the service providers switches off certain region of power supply in highly controller manner in order to restore the system stability. However, load shedding is highly technical term and should be confused with power conservation scheme. The prime difference is load shedding is done in order to prevent the power distribution system to collapse in situation of unavailability to meet the massive power demands, which is not in the case of power conservation techniques. The power conservation techniques adopts various equipment and devices that can significant conserve unwanted dissipation of power supply. Usage of non-conventional resources, automatic switching off the electrical devices in idle states, etc are some means to conserve power. Although conservation of power also leads to minimization of load on power distribution system, but it is never linked with similar cause of its usage aim. There are two specific states of load balancing as follows [15]:

2.1. Brownout-State

This state calls for minimizing the power demands on specific regions by periodic disconnection of feeders for relatively shorter interval.

2.2. Blackout-State

This state calls for reduce the power demands by completely cutting down the power supply for entire region. Some common means and frequently used techniques of load shedding in majority of the countries are as follows:-

o *Minimizing Voltage Feeds:-* The regulators are used to control the single feeds of voltage at power substations. This reduces the voltage supply but not current supply and can sustain for some time to resist blackouts. It is applicable only on low voltage networks.

o *Manually Disconnecting the Smaller Networks:-* Sometime the service providers dissects the complete network into smaller network on the basis of priority of power supply usage. The lower prioritized smaller network (house, shops, etc) are then manually shut to restore the balance.

o *Scheduled-Based Power Cuts:-* In many metropolitans and urban areas the providers declares the schedules of power cuts, which is called as scheduled power cuts. Normally, scheduled power cuts are meant to inform the users about the necessary backup during outage. However, there are many regions, where such declaration is not required as it doesn't affect much. In such area, providers performs unscheduled power cuts.

Although, such process creates inconvenience, but it has a long term benefits in restoring the balance between less availability of power and increasing demands of power.

3. ISSUES IN LOADSHEDDING

Although the process of load shedding is carried out for long-term benefits, but it is associated with some of the serious problems in the essential operation of power system. Following are the problems that surfaces owing to the process of load shedding in the power system.

3.1. Involuntary Switching Mechanism

In order to resists the negative affect of load shedding, majority of the users started adopting alternative solutions, which includes auto switching of electrical devices. There are various industries which connects service provider through circuits using high-speed reclosing mechanism. Normally, the service provider trips both the end of line during fault and the start the high speed closure. The problem is such non-synchronization of the reclosing mechanism with other components. It is very important to disconnect the power load before performing this re-closure mechanism in order to avoid irreversible damage to expensive machineries. This problem also leads to unsynchronized voltage supply, slowing the pace of machineries and equipment creating hidden damage on them.

3.2. Load on Motor

If the motor load on any one of the substation is very high, it poses a bigger issue for application that demands time coordination. Such motor tends to maintain similar voltage during the occurrence of tripping. However, in this situation, there is a degradation of frequencies causing the slowing down of the motor invoking damage to it. Usage of under-frequency relay of high speed may cause long lasting of slower degradation of voltage. This situation finally results in trip or undesirably lock out of breakers. The existing solution for this problem is to extend the operation of under-frequency relay to approximately 20 cycles. Another solution is to utilize the under-voltage cutoff in order to rectify the problems of load-shedding.

4. STUDIES ON EXISTING TECHNIQUES

This section discusses about the existing technique that has been introduced in last 5 years pertaining to load shedding techniques.

4.1. Techniques based on under voltage / Frequency Schemes

Usage of under-voltage load shedding is one of the frequently adopted techniques for addressing the issues of voltage instability. Arief [16] have presented a study that performs trajectory sensitivity analysis for improving the voltage stability factor. The study outcome shows an efficient sensitivity analysis. Similar direction of under-voltage scheme was also seen in the work done by Deng and Liu [17]. The technique derives the dynamic voltage using local estimations using centralized scheme by mathematical modelling.

Similarly, there are also studies that has focused on under-frequency load shedding scheme in power system. Mokari et al. [18] have introduced an adaptive technique along with load prioritization scheme. The scheme allows multiple ranges of load to be shed on the basis of types of an event. Joint study of voltage and frequency are also observed in couple of literatures. Study on under-frequency load shedding was also carried out by Bambaravanage et al. [19]. The technique also considers islanding mechanism for formulating dual condition of emergency load shedding scheme based on the power model practiced in Sri Lanka. The presented study implements grid disintegration scheme to evaluate the frequency response as well as voltage profile as an outcome. Studies towards addressing islanding mechanism was carried out by Ramavathu et al. [20]. The authors have also discussed a mechanism that assists in involuntary curtailing loads from the power system. Study towards under-frequency was also seen in the work carried out by Shahgholian and Salary [21]. Gjukaj et al. [22] have presented a scheme that enhances the performance of the power system pertaining to load shedding scheme. It addresses the problem of under-frequency load shedding. Manson et al. [23] have presented a study for mitigating under frequency problems in load shedding by bridging a communication between centralized under-frequency components and protective relays. The authors have also used compensation of inertial and load tracking mechanism in modelling the power system. The technique has also considered multiple case studies of load-shedding schemes to access the outcome of their study. Zhang et al. [25] have formulated a study by considering stability factor for both voltage and frequency. The technique assists in identifying the location of load shedding along with equivalent information about the amount of load to be shed. The modelling is performed by evaluating swing in rotor movement, rate of change in frequency, amplitude of disturbance, location identification, etc. Joint study of voltage and frequency was also studied by Yang and Zhang [25]. The technique evaluated coupling effects to investigate the positive influence of charecteristics of load and reactive power over coupling effects of frequency and voltage. Douglass et al. [26] have addressed the similar issues by developing a unique hybrid controller system. With an aid of simulation study, the technique uses a distributed network framework to investigate the controller performance. Amini and Alikhani et al. [27] have presented a technique that performs load balancing on islanded systems using frequency factor. The technique provides a lookup table based on two new parameters i.e. i) willing to pay parameter and ii) change in frequency rate parameter. The study outcome was evaluated with respect to simulation time, variance, and decline in frequency etc. Combinatorial method of under voltage and under frequency was also witnessed in the work carried out by Wang et al. [28]. The author have studied load balancing based on these two factors in order to investigate participation process of smart appliance tested in IEEE-39 bus system. Similar line of joint study of under voltage and under frequency was studied by Ye et al. [29].

4.2. Technique based on Optimization Schemes

Mageshvaran and Jayabarathi [30] have presented an optimization technique in order to reduce the occurrences of load shedding. The authors have presented a bio-inspired algorithm addressing the issue of steady-state load shedding over various ranges of IEEE bus system. The study outcome was evaluated with respect to the real / reactive power and system losses over generated power. Study towards optimization technique was also emphasized by Kanimozhi et al. [31] have used evolutionary algorithm for minimizing the cumulative load shedding and increasing the voltage stability index. Experimented over wide range of variables (viz. contingency, heavy loading condition, base loading, etc.), the study outcome shows reduction of 30.70 MW loads. Meier et al. [32] have introduced a technique for addressing the joint problem of load shedding and islanding mechanism. The author have implemented a computational model for performing optimization of network during contingency. With an aid of Monte-Carlo simulation, the study outcome shows stabilized performance of power system during contingency. Study of under voltage optimization scheme of load shedding was carried out by Pandey and Titare [33] where the authors have introduced a computational model using differential evolution. Basically, the technique is based on stochastic principle to investigate the network stability factor. The contribution of this work is consideration of i) amount of load to be shed, ii) instance of load shedding, and iii) position of load shedding. The complete modelling of optimization is carried out using stability inequality and operating charecteristics as constraints. Another unique study towards optimization problem was seen in the work being carried out by Khamis et al. [34]. The author have considered quantity of load to be shed and linear voltage stability margin to formulate multi-objective optimization problem. The implemented technique also assists in prioritizing the load on multiple operating situation of power generation system. The work was especially focused on islanded system in order to resist the collapse of voltage. The optimization is performed using search-based technique and the study outcome was also compared with conventional optimization technique (e.g. genetic algorithm). Adoption of genetic algorithm as optimization technique was also witnessed in the work of Chawla and Kumar [35]. The study uses the technique to stabilize the voltage on severe contingency. The system also computes the margin load along with its sensitivity factor in order to check if it has met the stabilized condition. Applying genetic

algorithm, it attempts to minimize the unstabilized conditions in terms of fitness function. Usage of logical reasoning over the condition with less availability of inputs are also seen the existing studies. The study performed by Kaewmanee et al. [36] have adopted fuzzy logic for the purpose of optimization. The technique presented is basically a form of load shedding scheduling approach for the adverse situation of under frequency. The technique provides a table that can sort the relevant feeder using membership function in fuzzy logic. The study outcome was evaluated with respect to 11 cases of position of shedding and amount of load that was shed. Adoption of Fuzzy logic was also seen in the work done by Mokhlis et al. [37]. Similar adoption was also seen in the work of Mahapatro [38]. Kirar et al. [39] have carried out optimization technique over the load shedding scheme using Artificial Neural Network. The study outcome was compared with relay-based technique with respect to frequency factor, mechanical power, and electrical power. Similar direction of under-voltage optimization scheme was seen in the work done by Deng and Liu [17]. The technique derives the dynamic voltage using local estimations using centralized scheme by mathematical modelling. Particle Swarm Optimization was also seen in the work of Hagh and Galvani [40]. The author have adopted linear programming approach in order to reduce the extent of load balancing. The study outcome was analyzed with respect to 1-14 buses and its respective generated active power, reactive power, calculation time along with percentage of load shedding.

4.3. Miscellaneous Techniques

A completely different scale of work is carried out by Connell who have presented a technique that provides better tabulation of contingency. The technique uses Markov chain and uses sampling and counting operation. This technique could be quite fruitful in analysis of the load shedding behaviour. The study conducted by Wu et al. [41] uses multi-agents in order to retain better level of frequencies during islanding mechanism. The study have used distributed load shedding policy for identifying the global data with an aid of neighboring communication. The study uses mean consensus for this purpose. Adoption of multi-agents can be also seen in the work of Kohansal et al. [42]. A unique technique was introduced by Majidi et al. [43] called as intelligent scheme of load shedding. The study uses multiple condition viz. i) activation of distance relays, ii) monitoring the impedance factor, iii) conditioning of trip commands on specific interval. The technique basically identifies the critical lines and evaluate their dynamic behaviour. Sensitivity analysis is carried out for checking the outcomes along with discovering the cascading failures over the power systems. Zhao et al. [44] have presented a technique where the standard of IEC61850 is deployed for mapping the events generated at substations. Kim and Dobson [45] have presented a scheme where a standard DC load is used to represent a power system. The study outcome was assessed using probability over various load sheds over multiple levels. The paper was developed by Ajay-D-Vimal Raj [46] a new technique is presented to establish the best location and the best amount of load to be shed in categorize to stop the organization voltage from obtainable to the unstable. H. Bevrani et al. [47] a summary of the key problems and novel disputes on best LS production concerning the incorporation of storm turbine components into the power classifications.

Therefore, it can be seen that there are multiple forms of techniques that has been introduced in order to address the problem of load shedding. All the techniques that has been presented till date are majorly focused on either under voltage or under frequency constraints. There are also combined schemes based on voltage and frequency. Similarly, there are also good number of techniques that have adopted optimization principle of Artificial Neural Network, genetic algorithm, particle swarm optimization etc. Table 1 summarizes the significant work being carried out till date in order to evaluate the effectiveness and limitation of the existing studies towards load shedding.

Table 1. Summary of Existing Techniques

Author	Problem	Technique	Advantage	Limitation
Mageshvaran [30]	Optimization in load shedding	Bio-inspired algorithm, IEEE 14-30-57-118 bus	Better convergence behaviour	-Not applicable to dynamic load-shedding -computationally complex process due to inclusion of iterations
Arief [16]	Under Voltage Load Shedding	Trajectory Sensitivity, 14 IEEE bus	Ensure better voltage stability	-Less effective benchmarking
Kanimozhi et al. [30], Chawla and Kumar [35].	Multi-objective optimization of voltage Load shedding, islanding	Genetic Algorithm, IEEE 30-69 bus system	Conservation of 30.70 MW of load	-Less effective benchmarking
Meier et al. [32]		Policy switching, IEEE-39 bus	Capable fo solving complex constraint during grid congestion	-Algorithm complexity not computed
Mokari et al. [18], Shahgholian and Salary [21]	Under-frequency Load shedding	Adaptive approach, load prioritization, IEEE-14 bus system	Faster response time	-Not applicable to dynamic load-shedding
Zhang et al. [24]	Under-frequency Load shedding	Voltage & frequency sensitivity, IEEE-39 bus	Enhances voltage stability margin, minimize occurrence of breakdown	-Comparative analysis not carried out
Wu et al. [41], Kohansal et al. [42].	Islanding, load shedding	Consensus theory, multi-agents	Highly adaptable	-Less effective benchmarking
Yang and Zhang [25]	Investigation of Coupling effect of Frequency & Voltage	Empirical approach, EPRI 36-bus system	Establishes relationship between load shedding and coupling effects	-Less effective benchmarking
Pandey and Titare [33]	Optimization of voltage stability	Differential evolution, Stochastic, IEEE-14 bus	Resist voltage collapse during breakdown	-computationally complex process due to inclusion of iterations -Less effective benchmarking
Khamis et al. [34]	Multi-objective optimization, load shedding, islanding	Backtracking search algorithm	Better voltage stability compared to Genetic Algorithm	-computationally complex process due to inclusion of iterations
Kaewmanee et al. [36], Mokhlis et al. [37], Mahapatro [38]	Scheduling load shedding	Fuzzy logic, IEEE-14 bus	Ensure high power efficiency	-accuracy depends upon ruleset formulation
Douglass et al. [26]	Autonomous Load shedding control	Hybrid Load Controller	12% minimization in load	-Less effective benchmarking
Bambaravanage et al. [19]	Under-frequency load shedding, islanding	Combining multiple load balancing scheme	Stabilize power system	-Less effective benchmarking
Kirar et al. [39]	Load shedding for industrial system	Artificial Neural Network	Better performance than relay-based method	-Less effective benchmarking -No applicable for dynamic load-shedding.
Majidi et al. [43]	Identification of critical lines in load shedding	Intelligent Agents, IEEE 39-bus	78% reduction of cascading failures, 50% reduction in load shedding, & 59% reduction in islanding	-Computationally complex process due to iterative operations of relays
Manson et al. [23]	Under-frequency load shedding	compensation of inertial and load tracking	Cost-efficient scheme	-No benchmarking
Ramavathu et al. [20]	Islanding, load shedding	Change of frequency rate,	Simple simulation approach	Less evidence to justify outcomes
Deng and Liu [17].	Under-voltage load shedding	Particle swarm optimization, IEEE-39 bus	Enhance voltage stability	-No benchmarking
Gjukaj et al. [22]	Under-frequency protection	Adaptive design approach using frequency rate	Stabilized power system	-computational complexity not studied, scalability analysis not performed
Hagh and Galvani [40].	Load shedding	Particle Swarm optimization	Effective benchmarked work	-should be evaluated with more contingency condition to prove its robustness
Kim and Dobson [45]	Load shedding	Standard blackout model, IEEE 300 bus	Reduced load	-No benchmarking

5.   RESEARCH GAP

This section presents an explicit point of the research gap, which has been explored after reviewing the contribution of the existing system.

5.1. Few Benchmarked Studies on Load Balancing

The first IEEE journal for loadshedding was published in the year 1954 and till date there are presence of 531 journals and 1458 conference in IEEE. However, 98% of the research papers published till date are not found to have concrete benchmarking mechanism. Although, there are few studies with good performance comparative analysis, but majority of the research papers are found to discuss the individual outcomes and not the outcomes compared with some best model to show effectiveness. Because of this, it becomes challenging even to understand the best work till date with more reliability for future research continuation.

5.2. Less focus on Joint Operation of Frequency & Voltage

There are good numbers of research work towards under-frequency as well as for under-voltage schemes; however, the design is inclined more independently and less on joint operations. Although, there are many studies found using voltage and frequency parameters, but there was never a good balance found between voltage & frequency. Majority of the technqiues uses pre-set rules for which applicability narrows down towards static scenario of load shedding and never on dynamic scenario. Hence, such mechanism of under-voltage and under-frequency scheme fails to provide enough frexibility in case of multiple situations of instabilities.

5.3. Unpractical Assumptions

A closer look into the existing techqniue of load shedding distribution assumes starting point to be individual load bus in IEEE bus system in terms of allocation. The biggest problem in this assumption is that in such cases it will select all the load buses and they will be engaed with sharing task of cumulative imbalance of power in absence of any specific selection process. Such assumption is actually not possible for sophisticated power system where there is huge number of load buses.

6.   CONCLUSION

This paper gave some brief insight of the significance of the existing technqiues of carrying out load shedding operation. It can quite understood from the adoption of techniques in existing literatures that with an inclusion of smart grid system and sophisticated distributive network of power supply, there is a significant impact on the power delivery over the transmission lines. Such phenomenon leads the grid to be quite dependent on the transmission network in order to supply resulting in magnified loss of reactive power during the tripping of transmission lines. Our review says that there are significant amount of work being carried out considering under-voltage and under-frequency based schemes of load shedding, but quite a less towards joint operation. There are also technqiues of optimization of power system using particle swarm optimization, genetic algorithm, and neural network. However, even such optimization technqiues are found to devoid of inclusion of both voltage and frequency factor at a same time. Optimization techniques using bio-inspired algorithm are often associated with inclusion of iterative computational steps. However, there was no discussion found in existing system how the existing optimization techqniues overcomes such computational complexity. Hence, our future work will be in the direction of evolving up with a novel scheme of load balancing which is supported by computational modelling approach considering both voltage and frequency factor. We will also investigate better feasibility of novel optimization techniques which leads to provide a good balance between the load shedding schemes and quality of power system restoration process.

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