Ain Shams Engineering Journal (2016) 7, 223–232

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

ELECTRICAL ENGINEERING

A hybrid method for optimal load shedding and improving voltage stability

V. Tamilselvan [a,*], T. Jayabarathi [b]

[a] Department of Electrical and Electronics Engineering, Adhiyamaan College of Engineering, Hosur, Tamil Nadu, India
[b] VIT University, Vellore, India

Received 31 August 2015; revised 8 October 2015; accepted 3 November 2015
Available online 28 December 2015

KEYWORDS

Load shedding;
Eigenvalue;
Voltage stability;
GA;
NN;
Hybrid method

Abstract In this paper, a hybrid method is proposed for reducing the amount of load shedding and voltage collapse. The hybrid method is the combination of Genetic Algorithm (GA) and Neural Network (NN). The GA is used by two stages, one is to frame the optimization model and other stage is to generate data set for developing the NN based intelligent load shedding model. The appropriate buses for load shedding are selected based on the sensitivity of minimum eigenvalue of load flow Jacobian with respect to the load shed. The proposed method is implemented in MATLAB working platform and the performance is tested with 6 bus and IEEE 14 bus bench mark system. The result of the proposed hybrid method is compared with the GA based optimization algorithm. The comparison shows that, the proposed method ensures voltage stability with minimum loading shedding.

1. Introduction

As transmission systems, particularly those opening up the electricity sector to competition, across the globe are getting heavily loaded, voltage instability is rising as a novel dispute to the power system planning and operation [1]. Due to the serious use of the transmission networks, voltage stability is turning into one of the most essential problems in the power systems [2]. It is worried with the capability of a power system to sustain acceptable bus voltages under standard conditions and after being subjected to a disturbance [3]. The voltage instability of a power system can be calculated by acquiring the distance of the static power flow equations from the first point of operation to its saddle node bifurcation point, known as the voltage collapse point, in a tangible generation and demand evolution direction. By a scale factor called load margin, this generation and demand evolution are parameterized [4–7].

The process of tripping certain amount of load with lower priority is Load shedding which is to keep up the constancy of the remaining portion of the system [8]. Successful load shedding scheme is required to uphold the power system stability [9]. Lacking of load shedding will cause serious system frequency decay and a stability problem [10]. Conversely, too much load shedding will trip the load too much to cause an unnecessary power outage problem [11]. It is a general practice

* Corresponding author. Mobile: +91 9345744846.
E-mail address: tamilselvanv7910@gmail.com (V. Tamilselvan).
Peer review under responsibility of Ain Shams University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.asej.2015.11.003
2090-4479 © 2015 Faculty of Engineering, Ain Shams University. Production and hosting by Elsevier B.V.

for utility companies to carry out load shedding by applying under-frequency relays to trip the predetermined load with several shedding steps when the frequency drops lower than set values. The transient stability investigates for all the potential fault cases of the external utility power system have to be executed to get an efficient load shedding scheme [12–14].

As a result, the critical load margin obtained is one of the optimization problems which is computed by optimization technique. The optimal load shedding problem formulation has also been growing with shedding constraints. At a particular site, it is providing an appropriate framework for restricting the maximum amount of load to be shed. An early version declared the problem as a minimum load shedding problem. In this approach, the objective was to find the minimum amount of load to shed while gratifying load flow equations and static constraints such as line flows, voltage, angular limits and shedding constraints. Over conventional load flow, the formulation has numerous benefits. One of its strongest points is that it offers an optimization frame for distributing the slack among generation and load throughout the accessible nodes. This is mainly constructive, particularly after disturbances or equipment outages, when corrective action, other than rescheduling, might be required. Transmission limits could get the form of transfer limits or angle differences [15–20].

2. Recent research works: a brief review

In power system, several connected works are already presented in literatures that are based on load shedding with voltage stability. A few of them are reassessed here. A computationally easy algorithm has been progressed by Fu and Wang [21] for studying the load shedding problem in emergencies where an ac power flow solution can never be found for the stressed system. The suggested algorithm was partitioned into two subproblems: restoring solvability subproblem and improving Voltage Stability Margin (VSM) subproblem. To work out each subproblem, Linear optimization (LP)-based Optimal Power Flow (OPF) is used. In restoring solvability subproblem, rather than taking restoring power flow solvability as direct objective function, the objective function of maximization of voltage magnitudes of weak buses is utilized. In VSM subproblem, the traditional load shedding objective is expanded to include both technical and economic effects of load shedding and the linearized VSM constraint was included into the LP based OPF.

Seethalekshmi et al. [22] have offered a load curtailment in the power system necessary for its self-healing under critical contingencies, which may pose a threat to frequency with the voltage stability of the system. Based on the calculated disturbance power with the voltage stability condition of the system, the load shedding requirement in the system has been worked out with the help of real-time data, believed to be accessible from the synchrophasor based wide area monitoring and control system. This idea calculates voltage stability based on a dynamic voltage stability criterion, formulated by means of a Voltage Stability Risk Index (VSRI). Proper locations for the load curtailments have been selected according to the VSRI, computed at each load bus.

Load shedding algorithms for avoiding voltage collapse have been progressed by Sasikala and Ramaswamy [23]. These fuzzy based approaches have been coined to enhance Voltage Profile (VP), in addition to improving Voltage Stability (VS). The results attained on four standard examples over a range of load patterns have been authenticated to bring out its advanced computational ability. The presentation indices that have been calculated brought to light the effectiveness of the algorithm. The fact that the fuzzy strategies have been found to need a considerably lower execution time for larger systems serves to depict its computational competence. Although load shedding has been an accepted methodology for improving VS and enhancing VP, yet the key feature in the suggested formulation was to make certain a minimum load shedding to complete the needed objective.

Arya et al. [24] have offered an algorithm for anticipatory load shedding optimization at chosen load buses of the system accounting voltage stability consideration. Load buses have been graded based on sensitivities of minimum eigenvalue of load flow Jacobian relating to the load. It was pressured that load shedding was executed at current loading condition. Attained results by Differential Evolution (DE) have been compared based on mean, standard deviation, best value, worst value, frequency of convergence, standard error of mean, confidence interval and length of confidence interval of objective function, with PSO and its variant. Advantage of DE algorithm was that its mechanization was easy without much mathematical complexity and global optimized solution. It was examined that DE executes much better than PSO and its variant.

Tang et al. [25] have conversed under frequency load shedding and under voltage load shedding as large disturbances occur more repeatedly than in the past. They suggested a centralized, load shedding algorithm, which uses both voltage and frequency information offered by phasor measurement units. The consideration of reactive power together with active power in the load shedding strategy was the main input of the method. As a result, this technique addresses the combined voltage and frequency stability issues better than the free approaches. In order to compare it with the other techniques, the technique was experimented on the IEEE 39-Bus system. The Simulation effects show that, after large disturbance, this technique can bring the system back to a novel stable steady state that is better from the point of view of frequency and voltage stability, and loadability.

Yan Xu et al. [26] have suggested an alternative approach based on Parallel-Differential Evolution (P-DE) for powerfully and globally optimizing the event-driven load shedding against voltage collapse. Functioning in a parallel structure, the approach contains candidate buses selection, Voltage Stability Assessment (VSA) and DE optimization. Compared with conventional techniques, it fully regards as the nonlinearity of the problem and was able to successfully escape from local optima and not limited to system modeling and unrealistic statements. In addition, any kind of objective functions and VSA methods can be applied. The suggested approach has been checked on the IEEE 118-bus test system regarding two cases for preventive control and corrective control, correspondingly, and compared with the two presented techniques.

Hamid and Musirin [27] have conversed the application of fuzzy logic as a decision maker that has been extensively executed for working out different engineering problems, particularly in the field of voltage stability improvement. They suggested a method for locating the appropriate load buses for the purpose of load shedding considering multi-contingencies,