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A Novel Pricing Based Algorithm for Intelligent and Economical Load Shedding for Conventional and Smart Grid Applications

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Abstract: — **Intelligent load shedding, as a concept has been in vogue from the beginnings of large scale power systems. Attempts to optimise load shedding using various optimisation techniques and parameters have given several approaches to this problem with tradeoffs in speed and performance. Emphasis on the speed of computation gives sub optimal solutions and emphasis on optimal results slows computations to such an extent that real time optimal solutions are rarely possible to implement. Also, in cases of open energy markets, load shedding involves heavy costs to be borne, by the consumer, the supplier and the facilitator. This makes a live, real time economically intelligent load shedding algorithm conducive for power system operators nowadays. This paper proposes and tests, by simulation, the performance of the novel AP algorithm for economic load shedding.**

Index Terms:— **AP algorithm, Computational efficiency, Genetic Algorithm, Intelligent Load Shedding.**

I. INTRODUCTION

The conventional optimisation algorithms in power management involve a severe number of complexities. Every such algorithm involves iterative operations, a cost function or a fitness function which is repeatedly solved across a set of constraints to provide optimal results. But due to constraints in time, iterations are limited and hence, optimisation is usually incomplete and the system is operated for sub optimal cases only. In case of speed prioritised code, low levels of optimisation in parameters allow rapid action, but do not perform effectively. Most of the localities in India work with no automation in load shedding. Indiscriminate load shedding will have deep impacts and far reaching consequences including loss of revenue and improper load reduction.

The AP algorithm has been designed keeping in mind major social, economic and electricity related constraints. It is not iterative and does not involve a fitness function in order to optimise any given variable set. Priority is given to revenue for the power supplier. This allows single variable, multi-constraint based optimisation to be carried out. But given that cost of electricity is linearly related to all other parameters in distribution system, the equations to solve in order to maximise it are linear. This allows for a theoretically greater performance than other comparable algorithms that use iterative techniques.

II. CONSTRAINTS FOR LOAD SHEDDING

The design of the AP algorithm has included social, economic and technical factors that need to be considered while performing load shedding operations. Priorities for buildings have been allotted using social factors using a scale of 1-5, where 5 signifies the highest priority to save, while 1 signifies
the highest priority to shed. The loads of a city are broadly classified into scales as below.

- 1 – Domestic loads, basically houses and businesses in houses.
- 2 – Public office buildings (Government related offices, not commercial establishments), street lights
- 3 – Commercial establishments, small industries, MSMEs
- 4 – Heavy industries.
- 5 – Emergency and critical services. Hospitals, Fire stations.

Band transitions may be allowed with fixed monetary costs.

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The technical constraints for load shedding include power factor of the load. The higher the power factor, the lower the chance of getting shed. Also, estimated instantaneous power consumption has been considered as a constraint, both in terms of economy as well as in the technical domain.

On the technical side, instantaneous power consumption will provide a means to determine if a given locality is consuming enough power to significantly cause a change in amount of load to be shed. As residential localities during the day do not have huge loads, but if large load is to be shed, then shedding a low load domestic locality will not cause a significant change. On the economics side, the higher the load one consumes, the higher will be the revenue.
Therefore, as technical and economic constraints oppose each other, economic factor is given higher importance and hence, centres that consume more are not shed.

Time of the day prioritisation has been implemented with regard to which sector of the loads use power at which instant of time, and on the nature of use. The prioritisation is as follows:

- Hospitals and emergency services - 24 hours a day.
- Domestic – 06:00 to 09:00 and 18:00 to 23:59:59
- Industrial – 09:00 to 18:00
- Commercial – 10:00 to 13:00 and 18:00 to 23:59:59
- Offices – 09:00 to 17:00.

III. ALGORITHM

The algorithm for intelligent load shedding has been designed to work in the most optimised fashion. The implementation is as:

1. Reading of input constraint vectors and instantaneous power consumption.
2. Reading of Maximum power consumed, which is the theoretical peak.
3. Read load to be shed.
4. Read system time (real time) for analysing priority based on time.
5. Populate time based priority vector.
6. Compute absolute priority to be the product of the power factor, the time-of-day priority, social and economic priorities.
7. Use selection sort algorithm for sorting the absolute priority vector. Every swap in the absolute priority vector must also swap the corresponding index element of the load in the input data.
8. Relay statuses of each of the load centres are represented by a zero in case the load is shed and as a one in case the load is not shed.
9. Load shedding is started from the lowest value in the absolute priority vector and continued till the load to be shed is attained.
10. The results are obtained and required control action may be taken.

IV. STUDIES OF PERFORMANCE

The optimised code has been tested in MATLAB for performance using the MATLAB inbuilt timer functions tic and toc. The codes have been programmed to run on single core only. The time for obtaining results for number of loads has been tabulated as below. The computer system used to simulate these has the following specifications:

- Intel Core i7 – 2600K @3.4GHz
- 4GB RAM
- 32 bit MATLAB R2012b

The number of loads versus time of execution are as follows:

Number of loads	Time of execution(s)
10	0.000183
100	0.003498
1000	0.892
10000	3.23
100000	190

Table 1: Performance metrics

V. COMPARISON OF COMPUTATIONAL EFFICIENCY WITH OTHER ALGORITHMS

The AP algorithm has the following advantages over other optimisation algorithms used for intelligent load shedding:

- Sorting of Absolute Priority matrix gives shedding loads in order. Selection sort is computationally lighter than other sorting algorithms like Merge sort, Bucket sort, heap sort or bubble sort for data sets like this.

- Comparable algorithms like Genetic Algorithm, use only search, and do not sort.
- Computational overheads do not occur as unnecessary steps like crossovers, mutations, backward substitutions and eliminations are not necessary.
- No nonlinear fitness function is necessary.
- Parameters are optimised such that the severe non-linearilities are avoided because the basal parameter is cost, which has a linear relationship with all control parameters.

VI. RESULTS

The novel AP algorithm has been developed for use in real time load shedding applications. It has been found to perform with exceptional speed in case of smaller number of load centres. The algorithm is scalable to decently large sizes and will, in each case, produce the best possible solution in terms of revenue to the utility. It, however, also incorporates the social responsibilities of a Load distribution centre.

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