Metaheuristic Approach for Controlled Islanding in Power Systems based on Load Shedding Scheme

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Abstract: In the event that there is a catastrophic loss, one precaution that may be taken to decrease the likelihood of blackouts is the controlled islanding of the electrical system. This can be done to keep the power on for as long as possible. Managed islanding will result in just a limited percentage of islands being self-sufficient and capable of doing day-to-day duties without assistance from outside sources. On the other side, when islanding is implemented, not every island will have balanced generation and load. It is necessary for it to implement an effective load-shedding technique in order to encounter the power equilibrium criteria so that it can perform the functions of a balanced autonomous island. The method known as discrete evolutionary programming, or DEP, was modified for the purposes of this study in order to provide a metaheuristic that is founded on the load shedding scheme. This plan was devised to determine how much electricity should be taken from the grid in order to generate islands that are capable of supporting themselves without outside assistance. We are able to validate that the load shedding technique that has been provided is efficient by comparing it to the conventional EP method as well as the comprehensive search methodology. According to the findings, when compared to traditional EP and exhaustive search techniques. When compared side by side, these two strategies are quite different from one another.

Key words: Minimal power imbalance, Balanced Island, Power system islanding, MDEP load shedding technique.

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1. INTRODUCTION
In the case of widespread blackouts and breakdowns on the electrical grid, a controlled islanding operation is used [1]. After it is put into place, it will be evaluated using a number of criteria, one of the most important of which is power balance [2]. Each newly formed island must meet the power balance condition if the islanding strategy is to be used. To rephrase, the combined power output of all the islands must be enough to satisfy the whole load demand. In light of the aforementioned, this is of crucial importance for carrying out the islanding strategy [3]. However, it is possible that unbalanced islands will appear when islanding is implemented. The overall load would exceed the entire generation in this case. It is crucial that the islands maintain their balance since further disruptions to their power source might lead to their complete destruction. It is crucial to employ a load shedding plan and cut down on unnecessary load in order to bring the islands back into balance. After this is done, the islands may be able to perform as well as they do now. Several researchers in recent years have proposed fresh methods for regulated island development. Here are a few examples: the tabu search algorithm [4, 5]. However, the explanation provided is somewhat scant. None of the other approaches place as much emphasis on load shedding, a technique used to equalise islands that have become imbalanced as a consequence of adopting controlled islanding. Still, one must construct islands with balanced generation and load balancing in order to effectively execute islanding.

Load shedding methods of the under voltage (UVLS) and under frequency (UFLS) varieties are two common examples of how power systems manage load reduction. Reduced power consumption may be accomplished using either "under voltage load shedding" (abbreviated as "UVLS") or "under frequency load shedding" (abbreviated as "UFLS"). When a power imbalance threatens to cause a drop in frequency implemented towards prevent this, while under voltage load shedding (UVLS) is used to keep the system's voltage stable [6]. The electrical grid may utilise either dynamic or static load shedding to manage demand. Based on the findings of this research, a load-shedding approach was developed that employs the UVLS method. The UVLS method may be used in practise through any of many different avenues, including but not limited to exhaustive searching, conventional techniques, computational intelligence, and hybrids thereof. To find out how much weight you need lose, exhaustive searching is a tested and reliable way [7]. To find the most efficient method of relieving the pressure, it examines all possible permutations of the solution space. If, for instance, ten buses are available for load shedding, then there are ten times ten squared (1023) possible combinations. The system’s scalability grows linearly with the number of combinations available. Large-scale power systems are not suitable for this approach since there are so many distinct possible permutations of solutions [8]. This makes it useless for certain kinds of setups. This means more time will be required to find the optimal solution. When an electrical grid undervoltage is detected, the standard procedure is to temporarily shut down certain loads. This is done to protect the system against malfunction. The ease of the constant amount may make it advantageous in certain situations, but it also comes with the danger of overshedding or undershedding the loads. This is annoying, to put it mildly. Inadequate load shedding may lead to instability in the electrical system, such as voltage drops and blackouts.
Also, the tried-and-true technique of load shedding cannot be adopted since, when put into effect, it does not enable the best quantity of load towards be shed. Because of this, the strategy fails [9, 10]. This prevents the regular scheduling of load reductions. Computational intelligence algorithms can calculate how much load to remove from a system during controlled islanding, allowing for the creation of islands with optimum load distribution. These approaches are the most efficient, trustworthy, and versatile in handling non-linear, complex circumstances like the load shedding issue. The field of computational intelligence, to which metaheuristics belongs, has been used in this investigation. If any islands become unbalanced due to controlled islanding, this method might be used to determine how much weight should be removed from them to bring them back into ecological balance.

The widespread use of a load-shedding method in power system applications has led to the development of a wide range of metaheuristic approaches. Some examples of such methods include Particle Swarm Optimisation (PSO). The load-shedding approach utilised during managed islanding deployment is not elaborated upon, but each of the others identifies the optimal load-shedding rate and geographic region to maintain the reliability of the electrical grid. This is due to the lack of a definable justification for the phenomenon in question. This research aims to address this issue by creating a original load-shedding mechanism using the MDEP metaheuristic [11]. After controlled islanding has been implemented, this approach seeks to identify how much weight should be reduced to create islands that can sustain themselves. The current power imbalance will be mitigated by the proposed approach. There is a possibility that people who live on artificial islands created using a process known as ”controlled islanding” will not have access to sufficient amounts of power to keep themselves alive. This occurs as a result of the fact that the existing supply of power is not sufficient to meet the current load demand. To guarantee that the power balance requirement is satisfied, it is necessary for each island to have its own load shedding system. In this investigation, we make use of a technique known as modified discrete evolutionary programming (MDEP) to figure out how much load should be reduced in order to satisfy the power balancing requirement imposed by the islands.

\[
\sum P_{IMB} = \sum P_{GEN} - (\sum P_{LOAD} + \sum P_{LOSS})
\]  

2. METHODOLOGY
The suggested MDEP remains used here since the collection of buses for load shedding accomplishment involves separate integers such as 2, 4, and 7. Any island with a power imbalance may utilize the suggested load shedding approach, which is based on a discrete optimization strategy, to determine which loads should be shut down. The proposed load shedding approach may help with this. Below, we’ll go more into the specifics of the proposed method of shedding for the sake of this study. The steps involved in determining which loads may safely be removed using the MDEP method are shown in the flowchart of Figure 1. Figure 1 depicts the load shedding procedure steps. This group of people is selected from the bus fleet that may be used for load shedding. Examples of arbitrarily produced beginning inhabitants are provided in Table 1.
Table 1. Random seeding used in an MDEP load-shedding system example

<table>
<thead>
<tr>
<th>No. of buses</th>
<th>1st bus</th>
<th>2nd bus</th>
<th>3rd bus</th>
<th>n'th bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A3</td>
<td>A4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A5</td>
<td>A7</td>
<td>A7</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>A6</td>
<td>A7</td>
<td>A9</td>
<td>An</td>
</tr>
</tbody>
</table>

Using Table 1, we choose a single available bus at random. The fitness function for each of the new populations will then be decided by chance. Equation 1 represents the fitness function, sometimes called the target function, which is determined by the magnitude of the power imbalance. The second thing the computer does is look for populations where the fitness function is below the target value for the power imbalance. If none of the existing populations match these criteria, a new, randomly generated starting population will be generated. To be considered viable, a random starting population must have a fitness function equal to or larger than the desired power imbalance. In the first phase of each cycle, a single bus is selected at random from the starting population to be mutated, and then another bus is chosen from the pool of buses that may be used for load shedding by picking it diagonally. In the shape of a slanting, Table 2 depicts the alteration process. This value may be used to determine whether or not the bus can be used for load shedding. This value will be substituted...
for the bus in each and every one of the original population’s buses. As shown in Table 2, mutation will produce two new populations, each of which will have three modified load-shedding solutions if there are three buses in the seed population. This is the case if there are three buses in the seed population. Every one of the beginning populations will conduct themselves in accordance with the process. After that, an analysis of the fitness function of each individual population is carried out. It is established that a population cannot be employed as a load shedding solution if its fitness value is less than the goal power imbalance; at this point, it is labelled as the null value. If this occurs, the population in question is referred to as the null value. This occurrence takes place when it is found that the population’s fitness level is lower than the intended gap in strength.

Following the step of assigning a rank to each population, $xb$, depending on how low their fitness function is, the top 20 are picked to participate in further rounds of the mixing process with the original populations. When a predetermined maximum number of times has been repeated, the operation is deemed to be finished. In conclusion, from among the twenty most viable possibilities for load-shedding, the $xbb$ solution that results in the least amount of power imbalance is selected to be implemented.

After selecting the first choice for load-shedding, $xbb$, from the set of optimum solutions, we do a second check to ensure that none of the buses have voltages that are either too high or too low. If there isn’t a single bus on the island that has an unsafe voltage, then the method of load-shedding that is the most efficient will be applied. The algorithm will next choose the best remaining option from the pool, and it will continue to cycle through these steps until it determines the method of load shedding that is most effective for the island. This strategy has the potential to provide the greatest outcomes for load shedding, given the right circumstances.

### 3. RESULTS AND DISCUSSION

In directive to demonstrate the practicability also efficacy of the MDEP load-shedding strategy that was devised, it was put through its paces. Comparatively, the test system with 30 buses only has 41 transmission lines and six generators, but the system with 39 buses has 10 generators and 46 transmission lines. The amount of various buses that are run through their paces is what sets these networks apart from one another. The total length of time spent calculating and the greatest amount of load that may be lowered at any one point in time during this validation procedure are the two elements that are considered to be of the utmost importance. MATLAB R2015a was used to execute the methodology that was developed for this investigation. This version of MATLAB is supported on an Intel® Core™ i7-5500U CPU that operates by 2.40GHz and has 8 gigabytes of random access.
memory (RAM). We put the idea of controlled islanding to the test by examining it through the lens of two distinct examples of hypothetical situations.

Table 3 shows that the best sum of load towards be shed using the comprehensive search also the MDEP load shedding methods is 35.1 MW, whereas the conventional EP approach only yields 35.7 MW. Due to the employment of a Gaussian function in conventional EPs, which leads to only minor changes throughout the mutation process, this method is unable to deliver the greatest possible optimum value. This is due to the fact that the Gaussian function causes very small shifts. This takes much longer than the MDEP approach. It is standard procedure to account for every conceivable combination of buses in a system when doing a search. Computational effort for this method grows in direct correlation with the complexity of the system (and, by extension, the number of potential solutions). The MDEP’s recommended strategy for lowering load is superior than all of the other methods described in Table 4 because it can find the appropriate amount of load shedding in the least period of time. Then, the required amount of load on Island 2 is shed using the MDEP load shedding so that the island can fulfil the power balance requirement.

Table 3 reveals that, as in Case I, the ideal amount of load to be shed is more when using the exhaustive search and MDEP load shedding approaches (112.63 MW) than when employing the standard EP methodology (115.33 MW), as shown by the comparison between these three methods. This is due to the fact that unlike conventional EP methods, both the exhaustive search and MDEP load shedding operations reduce overall system load. The main cause of the incorrect ideal value produced by traditional EP is the use of the Gaussian function. In contrast to the 89486.7264 seconds required by the exhaustive search technique, the MDEP strategy only requires 3.1935 seconds of processing time to achieve the same level of performance. This is because the calculation time required to find the best solution using the exhaustive search technique grows proportionally with the size of the system. EP and comprehensive search methods are inappropriate for this inquiry because of the need for creative load shedding. MDEP’s recommended load shedding technique has been shown to be the best alternative since it can quickly and accurately ascertain the ideal load shedding amount.

Using the MDEP load shedding technology, the necessary amount of load was shed to satisfy Island 1’s power balance need. After load shedding (112.630 MW) was implemented on Island 1, the overall quantity of generating power, Pgen (4063.821 MW), exceeded the whole amount of demand, Pload

### Table 3. Case with the best islanding approach

<table>
<thead>
<tr>
<th>Islands</th>
<th>Buses Info</th>
<th>Active Power (MW) Before load shed</th>
<th>Power Imbalance (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Pgen</td>
<td>Total Pload</td>
</tr>
<tr>
<td>Island 1</td>
<td>1-6, 12-19, 24</td>
<td>337.433</td>
<td>180.410</td>
</tr>
<tr>
<td>Island 2</td>
<td>6-12, 18-23, 25-31</td>
<td>78.956</td>
<td>123.010</td>
</tr>
</tbody>
</table>
(4021.50 MW), as shown in Table 8. This is the optimal strategy for islanding. Island 1 can now more reliably fulfil its responsibilities as an independent island.

4. CONCLUSION
In order to facilitate managed islanding, a novel load-shedding strategy based on MDEP was presented in this article. The goal was to make controlled islanding easier. After islanding has been established, the plan’s goal is to identify how much weight must be lost in order to construct islands that are both habitable and self-sufficient. Conventional exhaustive probing (EP) and exhaustive searching are used to assess the effectiveness of the proposed method on the IEEE 30-bus and 39-bus test systems. Results from Cases I and II showed that the proposed MDEP load shedding strategy could determine the optimal amount of load to be shed with less computational time compared to standard EP and exhaustive search approaches. The suggested MDEP load shedding technique was able to reduce the maximum load in the shortest amount of time, proving this point. To meet the power balance condition on any islands where load shedding is necessary after the controlled islanding implementation, the MDEP load shedding system is recommended. The conditions for a power balance may therefore be satisfied.

References
