Responses to Reviewers' Comments for Manuscript SPACE-D-23-00082

Maximum Allowable Current Determination of RBS By Using a Directed Graph Model and Greedy Algorithm

Addressed Comments for Publication to

Space: Science & Technology

by

Dr. Cheng Qian, on behalf of all authors

Dear Dr. Tian,

Please find enclosed the revised version of our previous submission entitled "Maximum Allowable Current Determination of RBS By Using a Directed Graph Model and Greedy Algorithm" with manuscript number SPACE-D-23-00082. We would like to thank you and the reviewers for the valuable comments which help improving the quality of our manuscript. In this revision, we have carefully addressed the reviewers' comments. A summary of main modifications and a detailed point-by-point response to the comments from Reviewers 1 and 3 (following the reviewers' order in the decision letter) are given below.

Sincerely,

Dr. Cheng Qian, on behalf of all authors

Note: To enhance the legibility of this response letter, all the editor's and reviewers' comments are typeset in boxes. Rephrased or added sentences are typeset in color. The respective parts in the manuscript are highlighted to indicate changes.

improve the general language expression during revision progress.

Authors' Response to Reviewer 1

Comment 1:

The authors should explain the most important achievements of the proposed method quantitatively, in the abstract.

Response:

Thanks for the reviewer's valuable feedback. We have carefully considered this suggestion and made the following modifications to address the reviewer's concern:

By introducing the shortest path(SP) of the battery, the greedy algorithm transforms the enumeration of switch states in the brute force algorithm into the combination of the SPs, which greatly increases the efficiency of determining the maximum allowable current (MAC) of reconfigurable battery systems (RBSs). We have also provided a theoretical estimation of the improved efficiency, which is proportional to $N_s 2^{N_s - N_b} \log N_b$, where N_s is the number of switches and N_b is the number of batteries.

Here is the specific modification we made in the abstract:

changes in abstract

We believe that these modifications provide a more quantitative explanation of the achievements of our proposed method in the abstract.

Comment 2:

The literature review in the introduction section is very short, and the related works, especially the works published in recent years, have not been well reviewed and compared, and the conclusions about the existing research gaps have not been presented.

Response:

Considering the Reviewers suggestion, we have expanded the literature review in the introduction section to provide a comprehensive overview of the existing RBS structures [1–7] and related works on structure analysis [8, 9]. Although many RBS structures have been proposed for different purposes, such as dynamically adjusting the output voltage , increasing energy utilization efficiency, and improving the system's ability to recover from battery failures, they also bring challenges in design and control of the systems. Therefore, several works on structure analysis, like the maximum switch current and the short-circuit problem, have been proposed to tackle these challenges recently. However, determining the MAC of RBSs remains blank accroding to our literature review. A straightforward method is to enumerate all possible switch states, but the complexity of this method increases exponentially with the number of switches, and has too ineffection to apply.

Here is the specific modification we made in the introduction:

changes in introduction

Thanks once again for the reviewer's comments, which have greatly improved the quality and comprehensiveness of our manuscript. We believe that the revised introduction section now provides a thorough review of the literature and addresses the existing research gaps in the field of RBS structures.

Comment 3:

It is necessary for the authors to clearly state research contribution and achievements as bullet points at the end of the Introduction section.

Response:

We appreciate and accept your suggestion and have added a clear statement of the contributions in the second-to-last paragraph of the Introduction, as shown below:

changes in introduction

We believe that these additions enhance the clarity of our manuscript.

Comment 4:

The authors need to present the complexity of their proposed method and compare it with some other state-of-the-art or successful classic methods.

Response:

It is really true as Reviewer suggested about the complexity of our proposed method and the comparison with other state-of-art methods.

We have derived the average time complexity of our proposed greedy algorithm-based MAC determination method to be approximately $O(2^{N_b}N_s^2 \log N_b)$, where N_b and N_s are the number of batteries and switches, respectively. However, as mentioned in our response to Comment 2, there was a blank in the literature regarding MAC determination methods. The brute force method, the most straightforward and intuitive method, was used as a benchmark for comparison, whose time complexity is $O(2^{N_s}N_s^3)$. Since the number of switches in RBS is typically 3 to 5 times the batteries[10–15], the method we proposed is theoretically more efficient than the brute force method. It has been validated by the case study in the manuscript.

The detailed derivation and discussion of the above points have been added to the revised manuscript under the Discussion subsection. Here is the specific modification:

changes in discussion

Comment 5:

The authors don't discuss the limitations of the study correctly.

Response:

We are sorry for our negligence of the limitations of the study. As far as we are concerned, although the method we proposed is strongly efficient than the brute force method, it still has a exponential relationship with the number of batteries, which means unsufferable time cost will be caused for systems with large number of batteries.

Here is the specific content we added in the discussion:

changes in discussion

Comment 6:

Some typos should be double check.

Response:

We are very sorry for our incorrect writing, and have carefully checked the manuscript and corrected the typos.

Comment 7:

The author should explain more why solution quality of their proposed approach is much better than the others?

Response:

We appreciate the reviewer's concern regarding the explanation of why the solution quality of our proposed approach is better to others. However, after careful literature research, we would like to clarify that there are currently no existing works on the MAC determination of RBSs that we could compare our solution with. Therefore, it is not possible to directly compare the solution quality of our proposed approach with others.

Comment 8:

Authors should mention some novel works in the field in the introduction, specially refer to this 2023 reference: An efficient lightweight algorithm for scheduling tasks onto dynamically reconfigurable hardware using graph-oriented simulated annealing, which uses graph-based method. Mention and refer to it in the introduction section.

Response:

Thanks to the reviewer's suggestion, we have introduced two novel works in the RBS structure analysis field in the introduction, which respectively study the maximum switch current [8] and the short-circuit problem [9] in RBS structures. We believe that these works represent the innovation and recent advances in the field of RBS structure analysis.

The reviewer also specially mentioned the work published in 2023: An efficient lightweight algorithm for scheduling tasks onto dynamically reconfigurable hardware using graph-oriented simulated annealing. We have carefully read this paper, and after fully discussion, we finally agreed that this paper is not relevant to our research. Although this paper uses a graph-based method, whose name is similar to the method described in our paper, it mainly studies the task scheduling problem in time series. While our research is about the maximum allowable current of RBS structure, which belongs to the field of structure analysis. Therefore, we believe that it is not appropriate to include this paper in our introduction and will not cite it.

Comment 9:

Authors need to explain about the accuracy, sufficiency and reliability of their results? How do they verify and validate the results?

Response:

TODO: explain about the accuracy, sufficiency and reliability of our results with Xu and Qian.

Thanks for the reviewer's valuable feedback. We have carefully considered the reviewer's question. In response, we complemented the computation with the brute force method and provided more detailed explanation and discussion.

In the Case Study section of the paper, we investigated the MACs of three RBS structures, two of which are from published literatures [4, 5] and the other is designed by ourselves, as shown in Figure 1a, 1b and 1c, respectively. The results of the three RBS structures calculated by our proposed method are shown in Tables 1, 2 and 3, respectively. The results by brute force method are shown in Tables 4, 5 and 6, respectively.

On the one hand, as shown in the Tables 1 to 6, the reconfigured structure results from our greedy algorithm are consistent with the results from the brute force algorithm, which enumerates all possible reconfigured structures. It shows that our algorithm does find the global optimal solution. On the other hand, the output current of the system calculated by our directed graph model is consistent with the experience and common sense. To illustrate this, the RBS structure shown in Figure 1c is taken as an example here. The four batteries in this structure can be divided into two groups: B_1 and B_2, B_3 and B_4. The relationship between the two batteries in each group can be switched between series and parallel by reconfiguration. While the two groups can only form a series connection or be disconnected, rather than a parallel connection. Therefore, the MAC of this structure is the maximum of the output current of the two groups, which is twice the maximum allowable current of a single battery, consistented with the result $\max \eta = 2$ shown in Table 3.

We hope that our above content can address the reviewer's concerns.

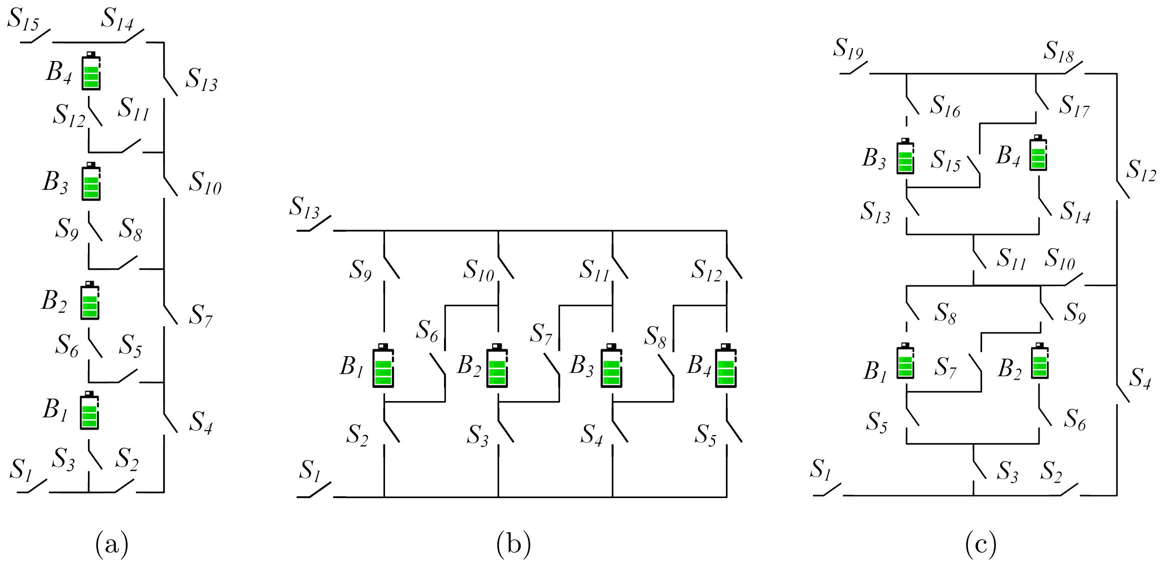

Figure 1: The 4-battery RBS structures proposed by (a)Lawson[5], (b)Visairo[4] and (c)this paper.

Table 1: MAC Calculating result of the RBS structure in Figure 1a with our method.

Structure	Figure 1a with 4 batteries and 15 switches
Switch ON	S_1,S_3,S_5,S_7,S_{10},S_{13},S_{14},S_{15}
I_o	$u_b/(R_o+r_b)$
$\boldsymbol{I}_b$	$[u_b/(R_o+r_b),0,0,0]$
$\max\eta$	1
computed structure count	11

Table 2: MAC Calculating result of the RBS structure in Figure 1b with our method.

Structure	Figure 1b with 4 batteries and 13 switches
Switch ON	S_1,S_2,S_3,S_4,S_5,S_9,S_{10},S_{11},S_{12},S_{13}
I_o	$4u_b/(4R_o + r_b)$
$\boldsymbol{I}_b$	$[u_b/(4R_o + r_b), u_b/(4R_o + r_b), u_b/(4R_o + r_b), u_b/(4R_o + r_b)]$
$\max \eta$	4
computed structure count	1

Table 3: MAC Calculating result of the RBS structure in Figure 1c with our method.

Structure	Figure 1c with 4 batteries and 19 switches
Switch ON	S_1,S_3,S_5,S_6,S_8,S_9,S_{10},S_{12},S_{18},S_{19}
I_o	$2u_b/(2R_o + r_b)$
$\boldsymbol{I}_b$	$[u_b/(2R_o + r_b), u_b/(2R_o + r_b), 0, 0]$
$\max \eta$	2
computed structure count	11

Table 4: MAC Calculating result of the RBS structure in Figure 1a with brute force method.

Structure	Figure 1a with 4 batteries and 15 switches
Switch ON	S_1,S_3,S_5,S_7,S_{10},S_{13},S_{14},S_{15}
I_o	$u_b/(R_o + r_b)$
$\boldsymbol{I}_b$	$[u_b/(R_o + r_b), 0, 0, 0]$
$\max \eta$	1
computed structure count	32768

Table 5: MAC Calculating result of the RBS structure in Figure 1b with brute force method.

Structure	Figure 1b with 4 batteries and 13 switches
Switch ON	S_1,S_2,S_3,S_4,S_5,S_9,S_{10},S_{11},S_{12},S_{13}
I_o	$4u_b/(4R_o + r_b)$
$\boldsymbol{I}_b$	$[u_b/(4R_o + r_b), u_b/(4R_o + r_b), u_b/(4R_o + r_b), u_b/(4R_o + r_b)]$
$\max \eta$	4
computed structure count	8192

Table 6: MAC Calculating result of the RBS structure in Figure 1c with brute force method.

Structure	Figure 1c with 4 batteries and 19 switches
Switch ON	S_1,S_3,S_5,S_6,S_8,S_9,S_{10},S_{12},S_{18},S_{19}
I_o	$2u_b/(2R_o + r_b)$
$\boldsymbol{I}_b$	$[u_b/(2R_o + r_b), u_b/(2R_o + r_b), 0, 0]$
$\max \eta$	2
computed structure count	524288

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