

Dear Editor-in-Chief, Associate Editor and Reviewers,

We thank the reviewers and editorial team of Energies, MDPI for their timely feedback, useful comments and review of our Manuscript ID: energies-760945 titled, "Solid State Transformers: Concepts, Classification and Control".

We agree with all the suggestions and concerns raised. Accordingly, we have corrected the manuscript. In this revision following major changes were made:

1. Editorial corrections raised by reviewer 1, 2 and 3 have been corrected.
2. As suggested by reviewer 3, section 6.2.3 has a new table highlighting insulation materials and their properties.
3. As requested by reviewer 3, section 6.2 has been re-organised.
4. New references cited as [2], [5], [151], [153] and [156] have been included as suggested by the reviewers.
5. As suggested by reviewer 3, a new table, namely table 3, has been included to summarize isolation materials features.

The changes in this revised version of the paper have been highlighted in blue. Please see below a short reply to each concern raised.

Attached in the following pages reviewers will find all our comments to their concerns. We decided to include all reviewers and authors comments into the same document. Thus, the reviewers can have the overall view of the implementation of all changes in this new version of the manuscript.

Looking forward to your feedback.

Sincerely yours

Authors

Responses to reviewers' concerns

For simplicity, authors reply **(AR)**, for each of the reviewer's comments, are marked in blue:

Reviewer 1:

Comments and Suggestions for Authors:

1.- The article presents a wide, complete literature review of Solid State Transformers, with including concepts, topologies, classification and control. The classification of Solid State Transformers is based on introducing the new methodology. The properties of individual properties are described and discussed. Selected applications of SSTs are presented.

The article is written in proper scientific form. But the length of the article seems to be too long and the reading of the article with the tracing of all detailed descriptions needs much attention and patience. The number of cited References is also quite great and includes 154 positions. The article consists of 9 main Sections, the principal Sections are divided into several Subsections.

The article is not ended with the notes about Author Contributions, Funding and Conflict of Interests.

There is a great number of abbreviations used in the article. The presentation of the list of abbreviations with the explanations is very helpful for study of the article. But this list is too long and some positions can be omitted, for instance the lines with precise descriptions of SST or common used abbreviations, as RMS, FLC, SVM, etc.

Authors Response (AR1):

We thank the reviewer for his time to review our manuscript. Also, we appreciate the reviewer for his useful comments.

We have updated the notes about Author Contributions, Funding and Conflict of Interests. This is written in lines 720 to 728 in the new version of the paper.

Also, some common of common abbreviations have now been removed. The removed abbreviations were listed at line 692 of the original version of the paper and are listed as:

- CHB : Cascaded H-Bridge
- COMM : Communication
- DAB : Dual Active Bridge
- DFIG : Doubly Fed Induction Generator
- EMI : Electro-Magnetic Interference
- FC : Flying Capacitor
- FLC : Fuzzy Logic Control
- MIMO : Multiple Input Multiple Output
- MMC : Modular Multilevel Converter
- NPC : Neutral Point Clamped
- PRC : Parallel Resonance Converter
- RMS : Root-Mean Square
- SISO : Single Input Single Output
- SRC : Series Resonance Converter
- SSTblocks : Solid State Transformer Blocks
- SSTi-blocks : Solid State Transformer Isolated Blocks
- SSTcells: Solid State Transformer Cells
- SVC & Space Vector Control
- ZCS & Zero Current Switching
- ZVS & Zero Voltage Switching

2.- There are some editorial mistakes stated in the article:

Line 11: The last sentence of the Abstract should be ended with the dot.

AR2: We thank the reviewer for bringing this to our notice. The abstract now ends with a dot, line 11 of the new version of the paper.

3.- Lines 49-52 - The sentence in Lines 49-52 is too long and contains more than 50 words. It is difficult to memorize and to understand such type of sentence.

AR3: We thank the reviewer for the comment. This sentence has now been paraphrased and has been split into two sentences. These sentences are written between lines 53 and 56 in the new version of the paper.

4.- Lines 432-437 - The sentence in Lines 432-437 is too long and contains more than 90 words !!. It is difficult to memorize and to understand such type of sentence.

AR4: We thank the reviewer for helping us improve the quality of our paper. The sentence has now been improved to be more readable. New sentences are written between lines 440 to 445 in the new version of the paper.

5.- Lines 446-449 - The sentence in Lines 446-449 is too long and contains more than 50 words. It is difficult to memorize and to understand such type of sentence.

AR5: We thank the reviewer for his useful comments. The sentence has been improved for better readability, the new sentences are written between lines 454 and 457 in the new version of the paper.

6.- The numbers and the titles of the tables are usually placed at the top.

AR6: We thank the reviewer for this comment to meet the usual standards. Table number and captions for table 1, table 2 and table 3, are placed at the top in the new version of the paper. Table captions appear after line 226, 535 and 591 in the new version of the paper.

Reviewer 2:

For simplicity, authors reply (**AR**), for each of the reviewer's comments, are marked in blue:

Comments and Suggestions for Authors

1.- A brief summary

The authors' main goal is to present a complete overview on SST: concepts, topologies, classification, power converters, material selection and key aspects for design criteria and control schemes proposed in the literature. Also authors proposed a simple terminology to identify and homogenize the large number of definitions and structures currently reported in the literature. The article is based on an in-depth analysis of literature sources. It is worth noting the use of rich literature sources (154 items) for analysis.

The overall quality of the manuscript is good. The manuscript contains good-quality contents and results. Analysis results and conclusions presented in the paper can be used by designers and exploiters power systems. Furthermore, it constitutes suitable solutions in applications in energy conversion, traction, energy routing, grid interconnection and reactive power industry.

The proposal for a new terminology for a simple classification of SST deserves special recognition.

The topic of the manuscript is also interest to the readers of energies.

Authors Response (AR1): We extend our gratitude and thank the reviewer for his positive remarks and appreciate for his time to review and improve our manuscript. We specially thanks to highlighting the contribution on classification on SSTs. All the following reviewer comments, made to improve the quality of this paper, have been implemented in this reviewed version.

2.- Broad comments

Introduction - section without comments.

Results and discussion – section without comments.

Conclusions - section can be slightly improved focusing on the its importance in the field of research and practical applications.

AR2: We thank the reviewer for his useful comment to improve the quality of our paper, we have now included a sentence highlighting the importance of SST for practical application. This is written in the conclusion section, lines 701 to 703 in the new version of the paper.

3.- Specific comments

Line 117 - in the Fig.3, extend the description of the drawing. The descriptions are only for parts 3a) and 3b);

AR3: We thank the reviewer to bringing this to our attention. The description of Fig. 3 has now been completed. The new description is found after line 123 in the new version of the paper.

4.- 134 - in the Fig.4, extend the description of the drawing. The descriptions are only for parts 4a), 4b), 4c), 4d) and 4e)

AR4: We thank the reviewer for bringing this to our notice. Figure description has now been improved for better understanding. New caption can be found after line 140 in the new version of the paper.

Reviewer 3:

For simplicity, authors reply (AR), for each of the reviewer's comments, are marked in blue:

Comments and Suggestions for Authors

1.-The paper provides a comprehensive literature review from the solid-state transformers, from their applications, categorization, and construction. The paper provides a great summary from the state-of-the-art of the topic

AR1: We thank the reviewer for his careful reading and useful comments to improve the quality of the paper. We have now restructured certain sections to improve the readability of the paper and all his comments have been implemented in the new version of the paper.

, however the English language (structure of the text, readability) of the text should be checked again and the following notes should be corrected:

Notes.

Please, correct this information:

2.- Passive transformers are an indispensable component in electrical power systems since William Stanley demonstrated the first commercial transformer in 1886

"The first power transformer was shipped on September 16, 1884 by Ganz & Company. This first unit was a one-phase, shell-form transformer with the following specifications: 1400 W rated power, 42 Hz network frequency, 120/72 Volts, 11.6/19.4 Amperes, and 1.67:1 turn ratio ..." [1]

[1] Orosz, T. (2019) "Evolution and Modern Approaches of the Power Transformer Cost Optimization Methods", Periodica Polytechnica Electrical Engineering and Computer Science, 63(1), pp. 37-50. <https://doi.org/10.3311/PPee.13000>.

AR2: We thank the reviewer for bringing this information to our attention. The sentence indicated by the reviewer placed between lines 15 and 17 of the original version of the paper has been improved and the recommended reference has been incorporated. The improved sentence is now between lines 15 and 17 in the new version of the manuscript. The new reference is included and cited as [2].

3.- What does 'passive transformer' phenomena mean? This is not straightforward for me, because it can mean that the conventional transformers cannot be regulated, however, there are a lot of on-load tap-changing methods, which can change the voltage ratio on an 'active' component. But I can find out other meaning, it's not a clear terminology.

AR3: We thank the reviewer for his useful comment, we might have been not clear enough with our meaning. As the reviewer said, passive transforms can also regulate voltage magnitude with tap-changer. This has been clarified in line 18 to 19 in the new version of the manuscript.

4.- The forthcoming explanation is not clear and I guess not correct, because it does not consider the phase-shifting, insulating and etc. special transformers, which not contains semiconductor technology for reactive compensation or etc. [2] : "However, unlike passive transformers, Solid State Transformers (SSTs), also known as Power Electronic Transformers (PETs), are capable of compensating voltage sags and harmonic distortion, interconnecting asynchronous networks, interfacing DC and AC port(s), compensating reactive power, regulating voltage magnitude, isolating disturbances from source and load or vice versa and eliminating the use of mechanical actuators or tap changers."

[2] Del Vecchio, R. M., Poulin, B., Feghali, P. T., Shah, D. M., Ahuja, R. "Transformer Design Principles: With Applications to Core-Form Power Transformers", 2nd ed., CRC Press, Hoboken, USA, 2010

AR4: We thank the reviewer for pointing out this issue. For the sake of completeness, a new paragraph listing the benefits and advantages of passive transformers have been included in line 24 to line 27 in the new version of the manuscript. The new reference is included as [5].

5.- The reduced volume/weight ratio is mentioned several times, in the introduction and in the medium frequency transformer design section:

"Medium frequency transformers are key elements in SSTs. AMFT coupled with a power converter

504 achieves low footprint and higher power density while, enhancing its efficiency [46],[126]."

However, the conventional distribution transformers or power transformers are optimized for generally four different objectives: mass, volume, efficiency and lifetime cost. This fourth criterion is very interesting and explained in [1,3], which shows some interesting results. Some comparisons would like to be interesting to prove these concepts. The smaller footprint is very close to the term smaller carbon footprint, which should be proofed with some citation, or/and smaller size, etc terminology can be luckier.

[3] Georgilakis, P. S. "Spotlight on Modern Transformer Design", Springer-Verlag, London, UK, 2009.

AR5: See AR7

6.- - The economic viability of the conclusions should be supported with more publications.

AR6: See AR7

7.- - The achieved watt/kg performances should be supported/illustrated with some examples from the literature.

AR7: We thank the reviewer for his useful comments listed as 5, 6 and 7, which helped us to improve the quality of the paper. We have now included an additional paragraph addressing the above notes on volume, efficiency, power density, lifetime costs and economic viability. This is written between line 597 to 608 in the new version of the manuscript. The recommended reference has been incorporated and cited as number [156] in the reviewed version of the paper.

8.- Galvanic insulation seems not an advantage, compared to the conventional technology.

AR8: We thank the reviewer for the comment. We agree with your view that galvanic insulation may not seem as an advantage and it represents a limitation for medium frequency transformer miniaturization. A sentence highlighting this has been included in line 592 to 595 in the new version of the manuscript.

9.- 6.2.2. Winding Material and Arrangement --- here the problem of the aluminum and copper selection is a typical problem below 4-10 MVA units, above 15-20 MVA, the short-circuit currents become larger than the aluminum materials are too soft for these large machines.

AR9: Thanks for pointing out this technical issue important for real implementation. A sentence discussing the issue of short circuit current and melting point of winding material i.e. aluminum and copper has been added in section 6.2.2. , lines 564 to 565 in the reviewed version of this paper.

10.- - Please, explain these sentences and correct the ideas behind them:

571 ... Air is preferred for 572 cooling. Epoxy is used if air insulation is insufficient to reduce the temperatures. Epoxy or cast resin is solid insulations in the manufactured winding systems, they can increase the electrical withstand of the winding or the mechanical, but what do you mean that it can reduce the temperatures? Or please explain/introduce the winding gradient for the reader.

There are some water-cooled, novel high-frequency transformer applications to increase the watt/kg performance of the machines, please mention some of them [4].

[4] Grzesik, B., Stępień, M., Nowak, A. J., & Smółka, J. (2005). Influence of cooling system on the performance coaxial transformer.

AR10: We thank the reviewer for bringing this to our notice. A new sentence has been written to clarify the issues pointed by the reviewer. The new sentence can be found between lines 582 and 583 in the new version of the paper. In addition, for addressing reviewer issues, Table 3 has been included to highlight properties of insulation materials. This table can be found after line 591 of the revised version of the manuscript. Also, the importance of cooling systems has been highlighted between lines 590 and 592 in the new version of the manuscript. The reference recommended by the reviewer has also been included, this is cited as [153].

11.- - This insulation section should be organized better.

- Application of the biodegradable oils in transformers is a current problem in the industry. These, silicon oil or ster type materials can have a lot of benefits in the future and they can reduce the footprint of biodegradable oil-based transformers [5].

[5] Fofana, I. "50 years in the development of insulating liquids", IEEE Electrical Insulation Magazine, 29(5), pp. 13–25, 2013.

AR11: We thank the reviewer for this useful information which helped to improve the insulation section. Insulation section has now been improved. New and modified sentences can be found on section 6.2.3, lines 586 to 588 in the new version of the manuscript. Furthermore, new content about biodegradable oil has been added along with the recommended reference, cited in the new version of the paper as [151].