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(54) **Title:** METHOD AND APPARATUS FOR OBTAINING SOFT SWITCHING IN ALL THE SWITCHING ELEMENTS THROUGH CURRENT SHAPING AND INTELLIGENT CONTROL

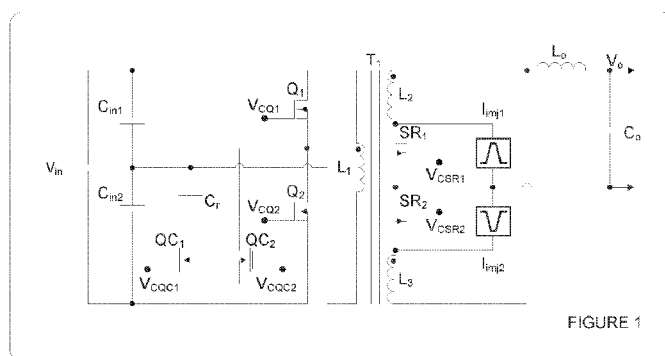


FIGURE 1

(57) **Abstract:** Create soft transition in selected topologies by preserving leakage inductance energy (ELI) during dead time (Td). Using several techniques to supplement energy required to discharge parasitic capacitance (Cp) of primary switchers and obtain zero voltage switching. First technique: Current pulse injection across synchronous rectifiers during and prior to Td turn off. Second technique: Tailoring magnetizing current through frequency modulation to increase ELI and use it to discharge Cp of primary switchers. At lighter load, have magnetizing current exceeding output inductor current at end of Td. Third technique: interleaving two converters, sharing coupled inductance to lower current through each output inductor below magnetizing current level at its lowest amplitude. Fourth technique: controlling turn-off timing of primary switchers and turn-on timing for secondary synchronous rectifier, thereby control ELI during Td to build enough ELI to discharge Cp of primary switchers to zero. Any/all of these techniques can be used for any application.



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/22235

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H01F 29/02, H02M 3/337 (2016.01)

CPC - H02M3/3376, H02M3/33576, H02M3/33546

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - H01F29/02, H02M3/337 (2016.01)

CPC - H02M3/3376, H02M3/33576, H02M3/33546

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - Y02B70/1491, H02M2001/0058

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Electronic Database Searched: Patbase, Google Patents, Google Scholar

Search Terms Used: Converter, transformer, output choke, synchronized rectifier, switching frequency, zero, negative current, current source, current pulse, drain, modulation frequency, leakage inductance, boost, overlap, conduction time, primary switcher, etc.,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0036340 A1 (Scarlatescu) 17 February 2005 (17.02.2005); entire document,	1, 2
-----	especially, Abstract, FIG. 1, 3-6, para [0006], [0037], [0038], [0041], [0043], [0046], [0052],	-----
A	[0054], [0060], [0065]-[0067], [0072], [0078]	10
A	US 5,396,410 A (Okochi et al.) 07 March 1995 (07.03.1995); entire document,	1, 2, 10
A	US 2013/0242616 A1 (Oldenkamp) 19 September 2013 (19.09.2013); entire document	1, 2, 10
A	US 2003/0142513 A1 (Vinciarelli) 31 July 2003 (31.07.2003); entire document	1, 2, 10
A	US 5,539,630 A (Pietkiewicz et al.) 23 July 1996 (23.07.1996); entire document	1, 2, 10
A	US 6,611,130 B2 (Chang) 26 August 2003 (26.08.2003); entire document	1, 2, 10

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 November 2016

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/22235

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-2 and 10 are drawn to a design and control method for a converter having a transformer and at least one output choke connected to two synchronized rectifiers wherein switching frequency of the converter is controlled.

Group II: Claims 3-4, 7-8, 11 and 12 are drawn to a design and control method for a converter having a transformer and at least one output choke connected to two synchronized rectifiers and two current sources connected to the drains of the synchronized rectifiers, and two current sources connected to the drains of the synchronized rectifiers.

Group III: Claims 5-6 are drawn to a design and control method for at least two converters

Group IV: Claim 9 is drawn to a design and control method for a converter having a transformer and at least one output choke connected to two synchronized rectifiers wherein the energy in leakage inductance is boosted by a slight and controlled overlap between the conduction time of the primary switchers.

---See Continuation on Supplemental Page---

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-2 and 10

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 16/22235

Continuation of Box No. III - Observations where unity of invention is lacking (Continuation of item 3 of first sheet) -

The inventions listed as Groups I through IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special technical features:

Group I requires wherein switching frequency of the converter is controlled in a such way that the current through the synchronous rectifiers becomes zero or slightly negative before the synchronized rectifiers are turn off, not found in the other groups.

Group II requires two current sources connected to the drains of the synchronized rectifiers, wherein the current pulses injected into the drain of the synchronized rectifiers forces the current through the synchronized rectifiers to become zero or slight negative before the synchronized rectifiers are turned off, not found in the other groups.

Group III requires wherein the switching cycles of said converters are phase shifted and the output chokes are coupled in a such way that the current through said synchronized rectifiers becomes zero or slight negative before said synchronized rectifiers are turned off, not found in the other groups.

Group IV requires wherein the energy in leakage inductance is boosted by a slight and controlled overlap between the conduction time of the primary switchers and the synchronized rectifiers and said leakage inductance energy is used to discharge the parasitic capacitances of the primary switchers towards zero and creating zero voltage switching for all the switching elements, not found in the other groups.

Shared Features:

The only technical features shared by Groups I-IV that would otherwise unify the groups are a converter having a transformer and at least one output choke connected to two synchronized rectifiers.

The only additional technical features shared by Groups I-III that would otherwise unify the groups are current through said synchronized rectifiers becomes zero or slight negative before said synchronized rectifiers are turned off.

However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 2014/0334188 A1 (Jitaru et al.) 13 November 2014 (13.11.2014), wherein Jitaru teaches a converter having a transformer and at least one output choke connected to two synchronized rectifiers (Abstract, FIG. 1, para [0023],[0024]) and further teaches current through said synchronized rectifiers becomes zero or slight negative before said synchronized rectifiers are turned off (FIG. 2, para [0024]-[0029] and [0031]).

As the shared technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Groups I-IV therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.