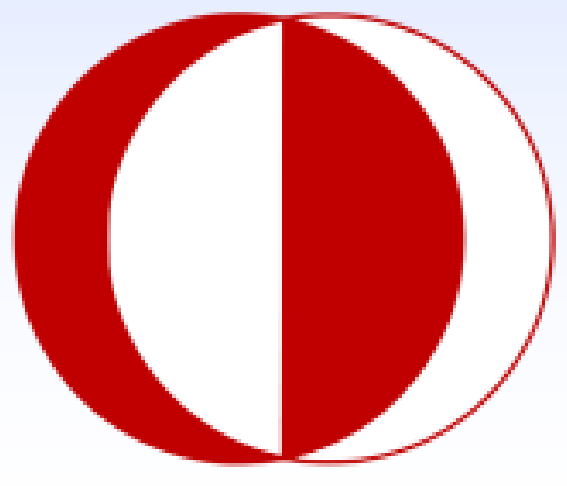


Elimination of Circulating Currents between Two Interleaved PWM Rectifiers Supplied from a Common Single-Phase AC Source



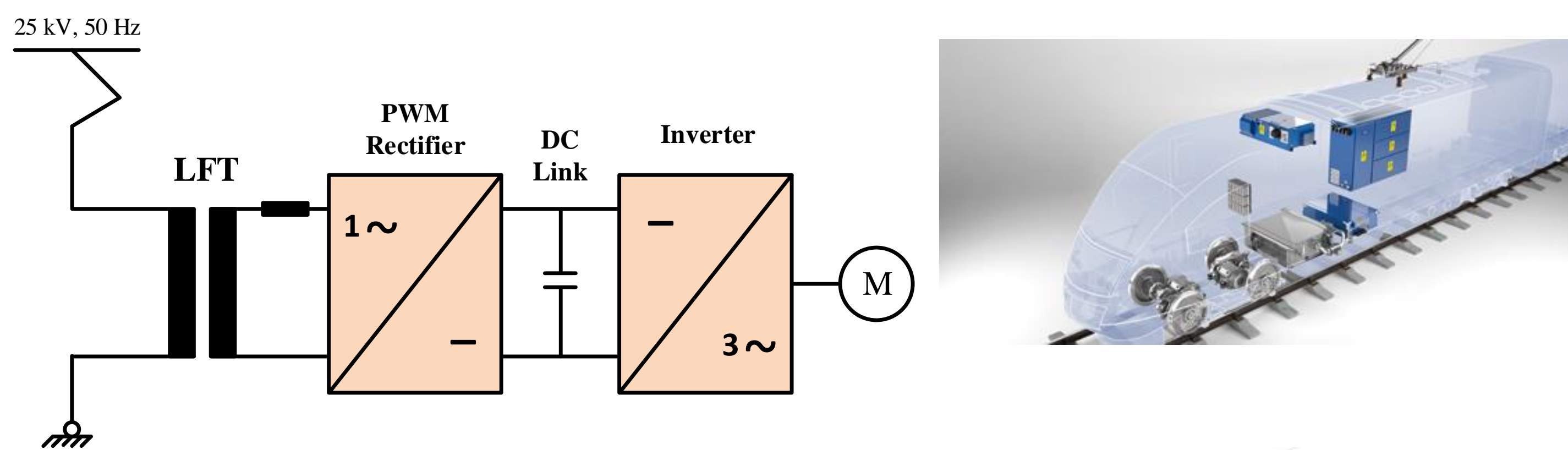
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Introduction

Most common AC locomotive traction systems have the form of a front-end step-down transformer, a single-phase PWM rectifier, a three phase inverter and an asynchronous motor as shown.



PWM rectifier is the front-end block of an AC locomotive traction system for its merits such as:

- ✓ Bidirectional active power flow (regenerative braking)
- ✓ Bidirectional reactive power flow (voltage regulation)
- ✓ Unity power factor operation
- ✓ Low harmonic distortion

Interleaving on these PWM rectifiers is usually employed for:

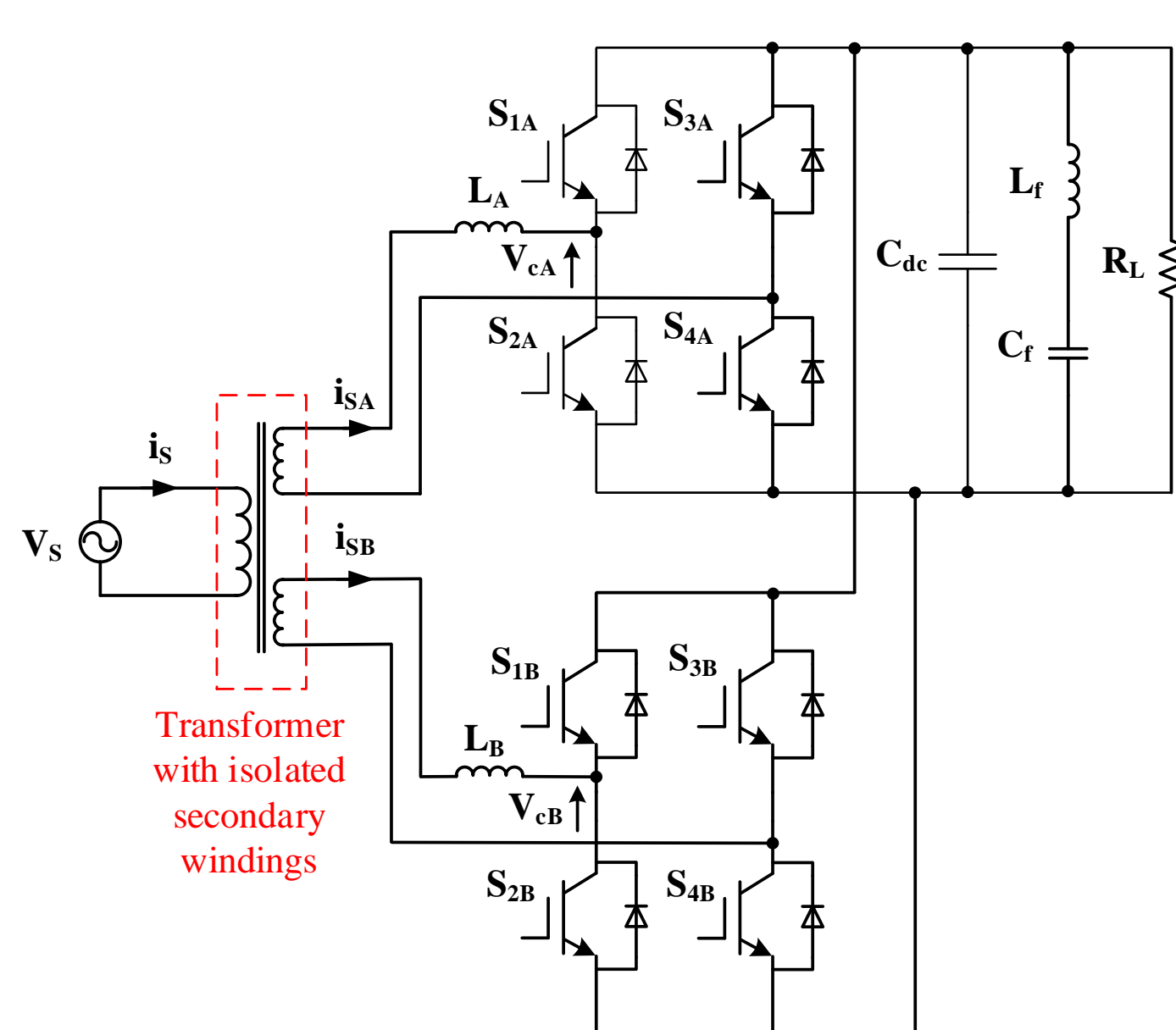
- ✓ Reduction of semiconductor device sizing (current)
- ✓ Reduction of total demand distortion (TDD)
- ✓ Redundancy

Motivation

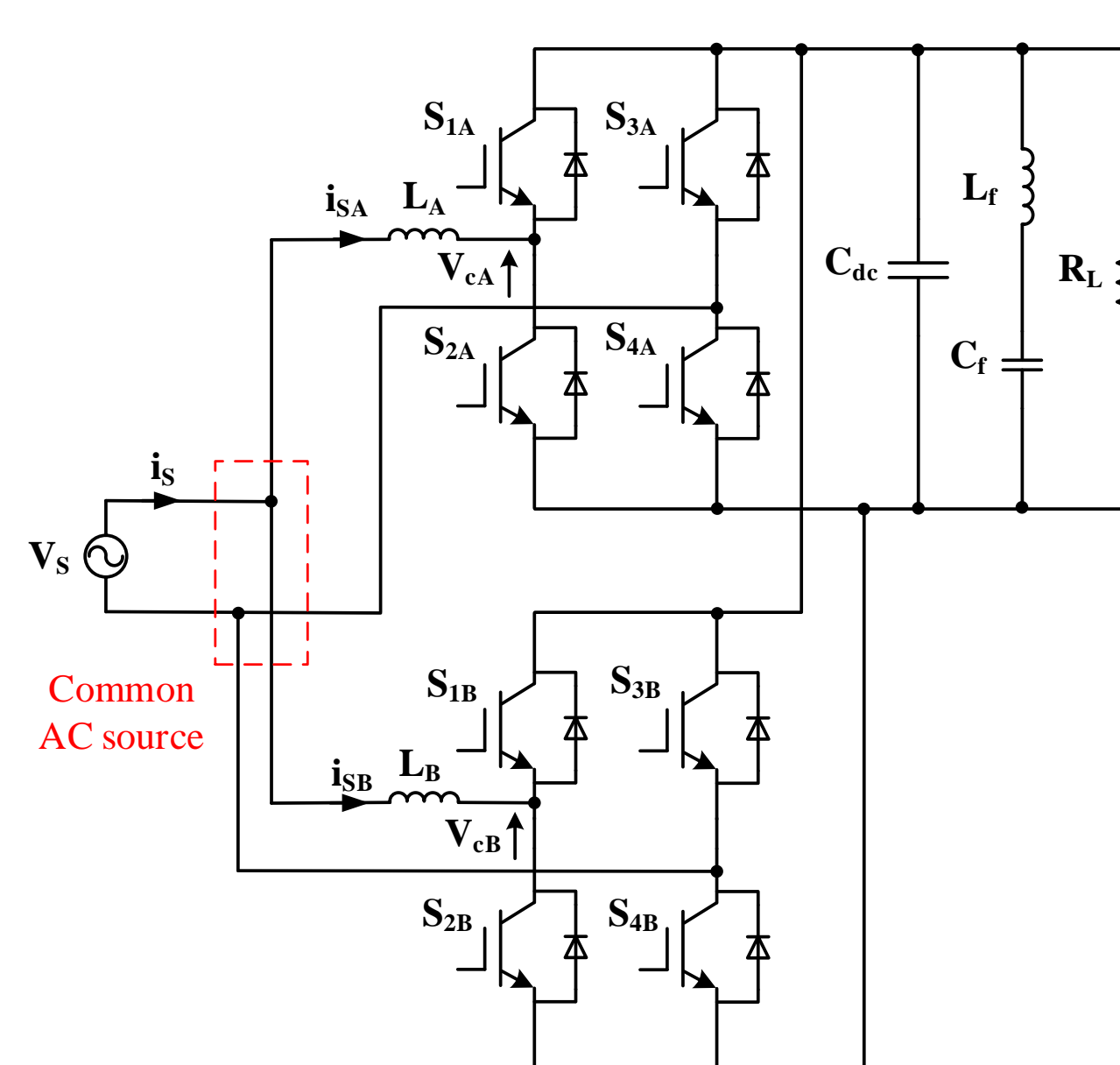
- ❑ Interleaving of two PWM rectifiers is achieved by two isolated secondary windings
- ❑ Otherwise, circulating currents start to flow with classical SPWM
- ❑ Such circulating currents would adversely affect the proper operation of the system
- ❑ They may cause malfunctioning of the power converter

In this research work, a new switching algorithm is proposed in order to eliminate the circulating currents between two interleaved single-phase, voltage-source Pulse Width Modulated (PWM) rectifiers supplied from a common AC source.

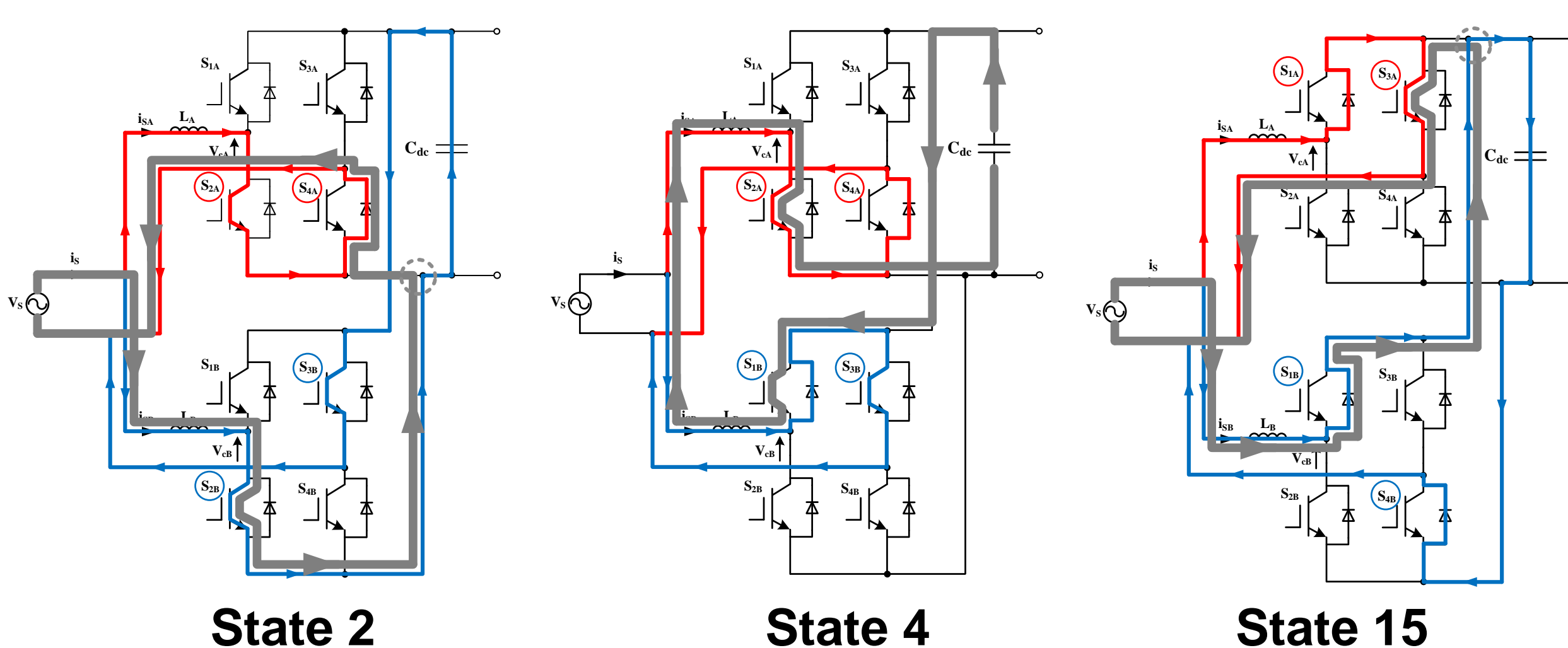
Conventional



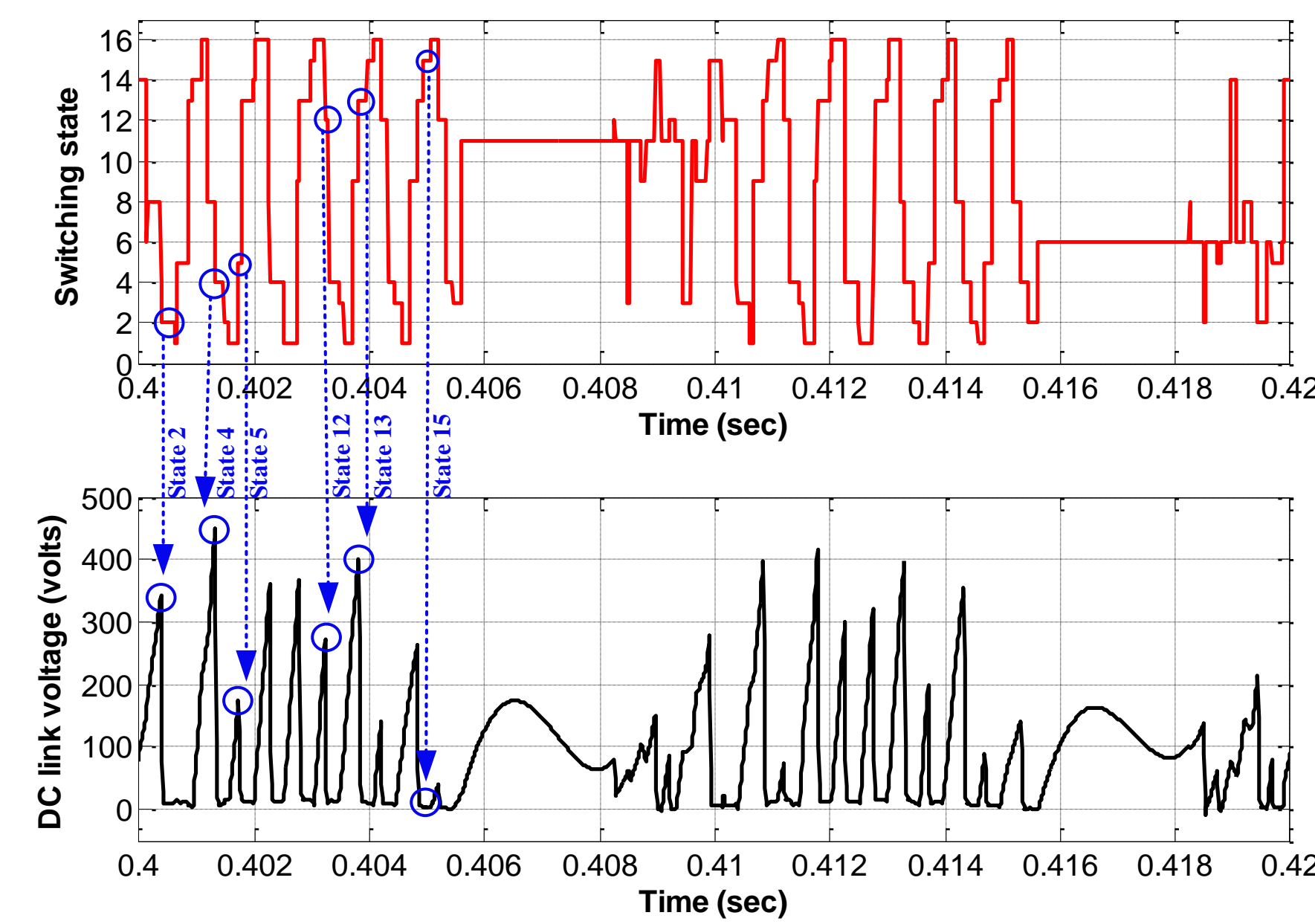
Proposed



Circulating Currents



Switching States and DC Link Voltage

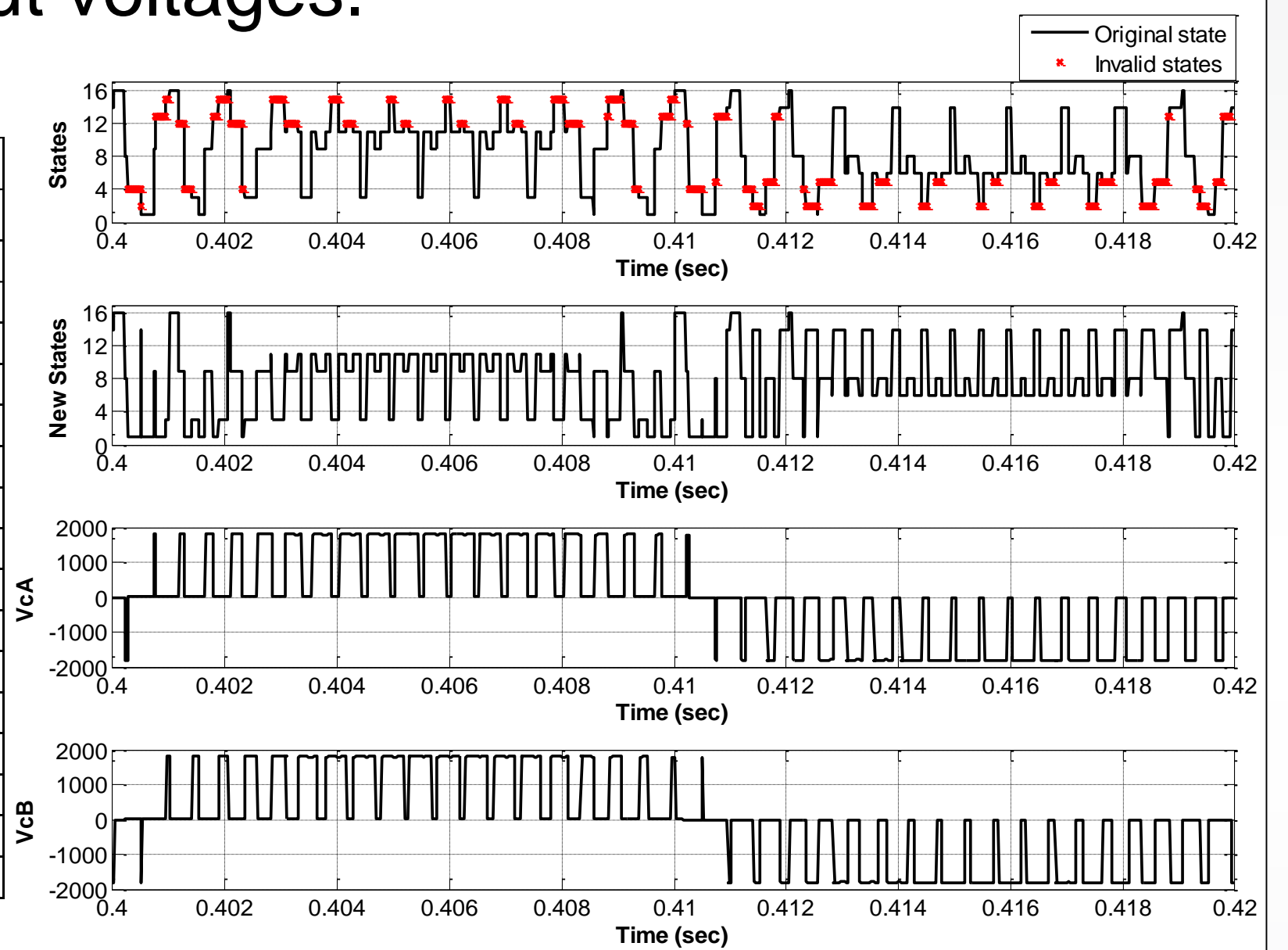


- DC Link is short circuited
- Proper operation is affected
- High currents may flow

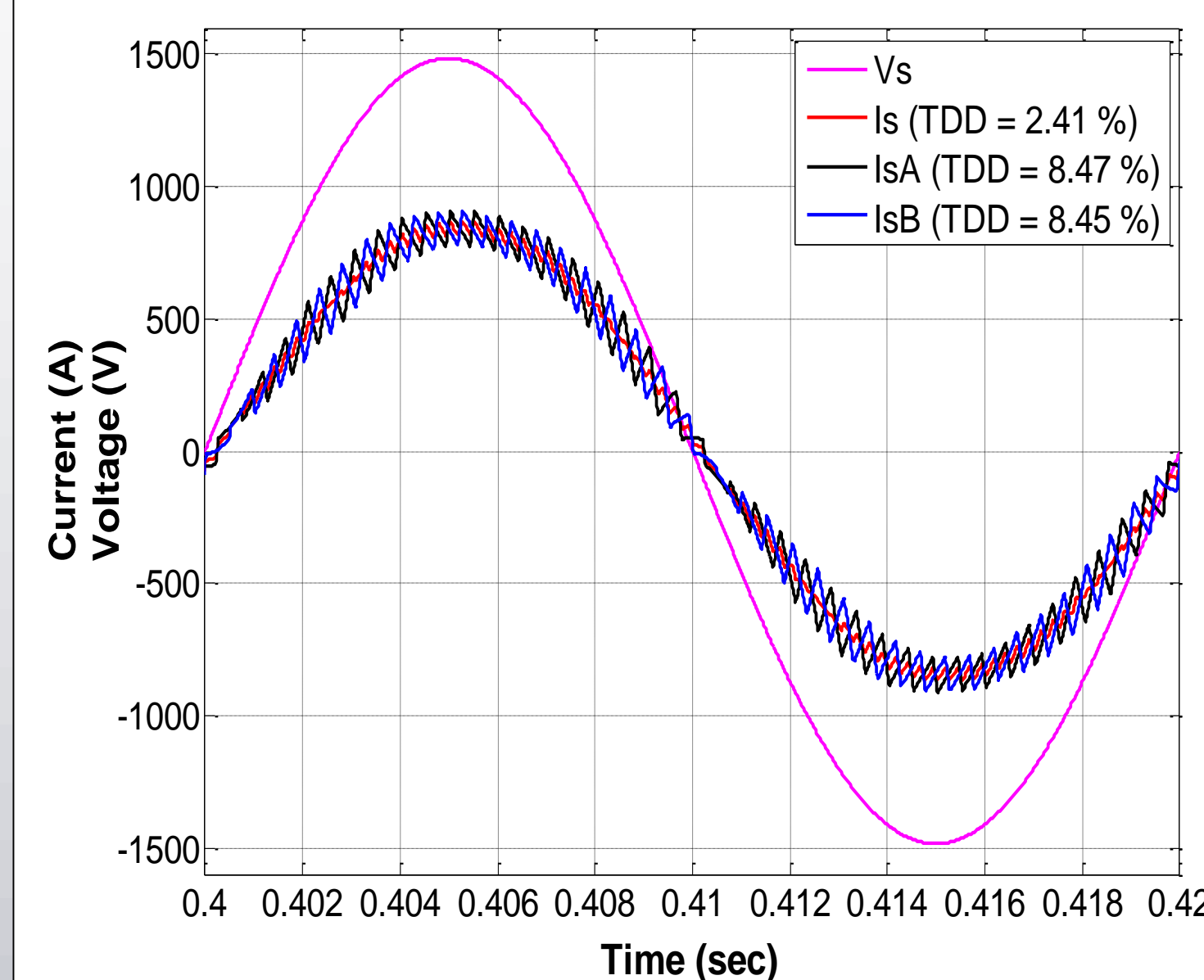
Method

Invalid states are analyzed and replaced with valid states which will yield same converter output voltages.

Original State	New State	New Switching Pattern							
		S1A	S2A	S3A	S4A	S1B	S2B	S3B	S4B
1	1	0	1	0	1	0	1	0	1
2	14	1	0	1	0	0	1	1	0
3	3	0	1	0	1	1	0	0	1
4	1	0	1	0	1	0	1	0	1
5	8	0	1	1	0	1	0	1	0
6	6	0	1	1	0	0	1	1	0
7	16	1	0	1	0	1	0	1	0
8	8	0	1	1	0	1	0	1	0
9	9	1	0	0	1	0	1	0	1
10	16	1	0	1	0	1	0	1	0
11	11	1	0	0	1	1	0	0	1
12	9	1	0	0	1	0	1	0	1
13	1	0	1	0	1	0	1	0	1
14	14	1	0	1	0	0	1	1	0
15	3	0	1	0	1	1	0	0	1
16	16	1	0	1	0	1	0	1	0



Results



- Same converter output voltages
- No circulating currents
- Unity pf operation
- Phase-shifted PWM
- THD < 5 %

Conclusions

- Interleaved PWM rectifiers to **reduce the harmonic content** of the input current, **reduce the sizing** of each power device, and for **redundancy**
- Two interleaved PWM rectifiers connected to common AC source
- No circulating currents between the converters
- Possibility of eliminating the need for a bulky, multi-winding transformer
- The number of rectifiers to be interleaved can be increased without the need of any additional secondary windings of conventional traction transformers