

621.3

..

..

SMART GRID

(Smart Grid).

,  
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 :  
 , Smart Grid,  
 ,  
 Smart Grid  
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 ,  
 ,  
 [1-5].  
 ,  
 Smart Grid (« »  
 ).  
 Smart Grid,  
 IEEE,  
 Smart Grid  
 Smart Grid  
 Smart Grid  
 5  
 [4].  
 [6-38]  
 [2].  
 Smart Grid  
 Smart Grid  
 Smart Grid.  
 Smart Grid.

**Smart Grid**

Smart Grid . 1

Network 1 Network 2  
HVDC

Microgrid 1 Microgrid 2 [3].

. 1,

Grid –

[5].

Smart Grid

(Distributed

Generation) –

« »

»

Smart Grid.

Smart Grid

(Flexible Alternating Current  
Transmission System – FACTS).

(High-  
voltage Direct Current – HVDC)

(Middle-voltage Direct  
Current – MVDC).

**FACTS**

FACTS [1, 37]. . 1

FACTS, 4 :  
(Shunt Controllers),  
(Series  
Controllers),  
(Combined  
Series-Shunt Controllers)  
(Combined  
Series- Series Controllers).

**FACTS**

( ) (Static VAR compensator –  
SVC)  
( ) (Static Synchronous Compensator –  
STATCOM).

**FACTS**

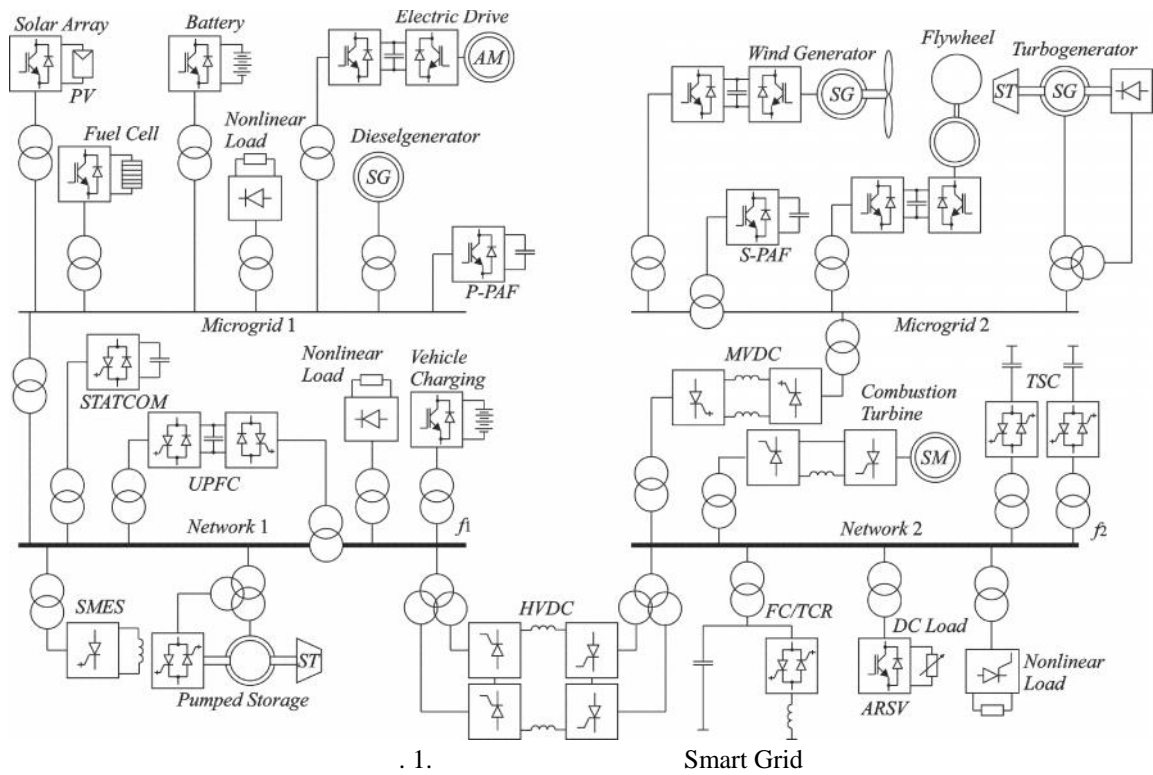
(

) [6, 7].

(Thyristor Controlled  
Reactor – TCR) ( . 2 ),  
(Thyristor Switched  
Capacitor – TSC) ( . 2 ),  
( ) (Thyristor Switched  
Reactor – TSR) ( . 3 ).

(Thyristor Controlled Braking Resistor –  
TCBR) [8, 9] ( . 3 ).

(Metal Oxide Varistor – MOV)  
(Thyristor Controlled Voltage Limiter –  
TCVL) ( . 3 ) [39].

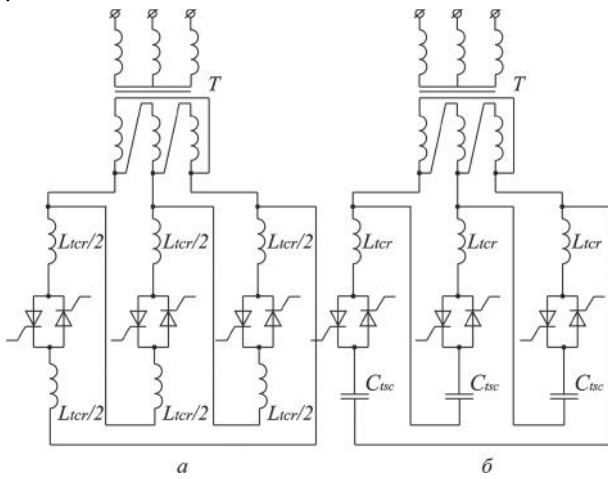


. 1.

Smart Grid

FACTS

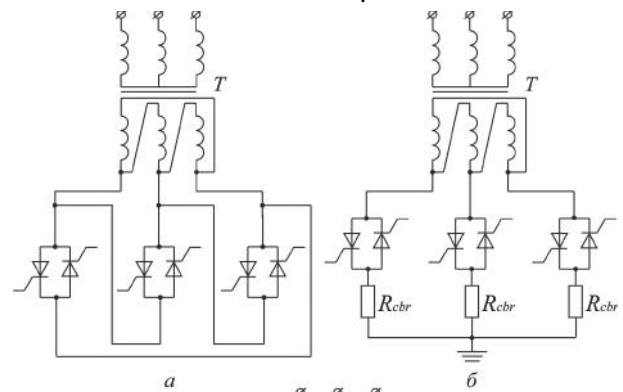
	( )	, kV			
	TCR	6-66 69-800	2-300 MVar 40-1200 MVar	Rongxin Power Electronic GE	
	TSR	6-66 110-500 123	1-60 MVar 25-160 MVar 50 MVar	Sieyuan Electric " TRENCH	
	TSC	1-1000 0.4-30 69-800	0.1-1000 MVar 1-20 MVar 40-1200 MVar	Sieyuan Electric EPRLAB GE	
	TCBR	150		Nicrom Electronic	
	STATCOM	0.48-765 0.4-36 35 4.16-138 52-765	0.1-500 MVar 1-100 MVar 100-200 MVar 5-133 MVar 50-500 MVar	ABB EPRLAB " Mitsubishi Electric Siemens	
	SSSC	220 500 345	47.8 MVar 1008 MVar 100 MVar	Ingeteam Nocian Capacitors Siemens (Marcy Project)	
		TCSC	1-1000 400 52-800	0.1-1500 MVar 394 MVar 50-800 MVar	Sieyuan Electric ABB Siemens
			TCSR	10-35	0.1-1.8 MVar
	UPFC, GUPFC	345	200 MVA	Siemens (Marcy Project)	
		TCPST	765 800	600 MVA 1000 MVA	Siemens ABB
			TCPAR	115	150
	IPS	500	370 MVar (Cap) from 1300 to 1910 MW	ABB	
		IPFC	345	200 MVA	Siemens (Marcy Project)



. 2.

[1, 38].

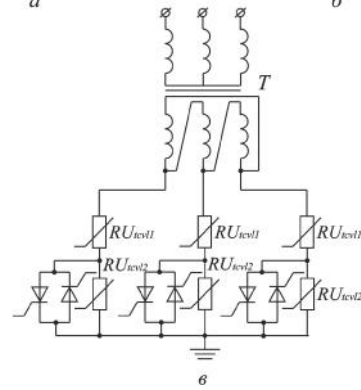
. 8



a

b

[10, 11].



6

. 3.

Smart Grid.

**FACTS**

( . . . 1)

500 MVar

756 kV.

. 4-7

( . 4) [3];

( . 5) [10];

( . 6) [11];

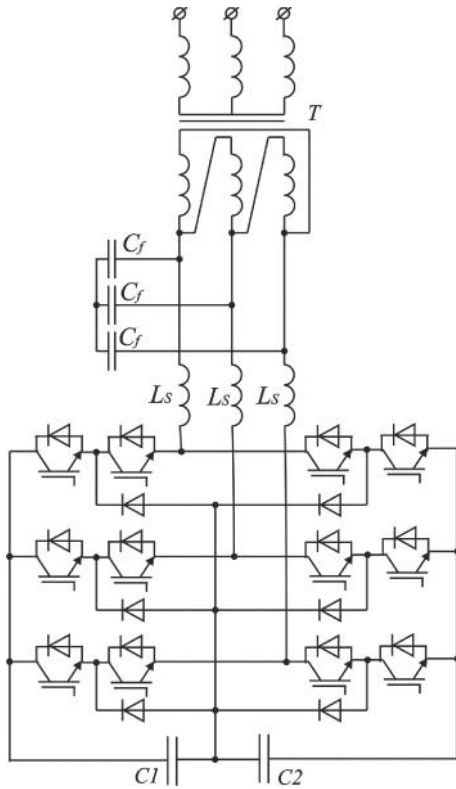
( . 7) [11].

( ) (Static Synchronous Generator – SSG),

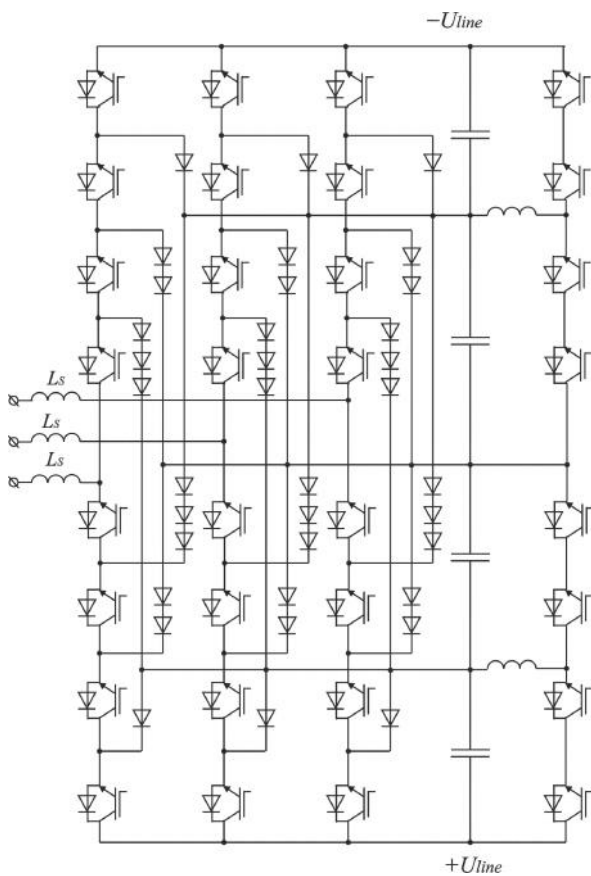
DC/DC

(Thyristor Controlled Series Capacitor – TCSC)

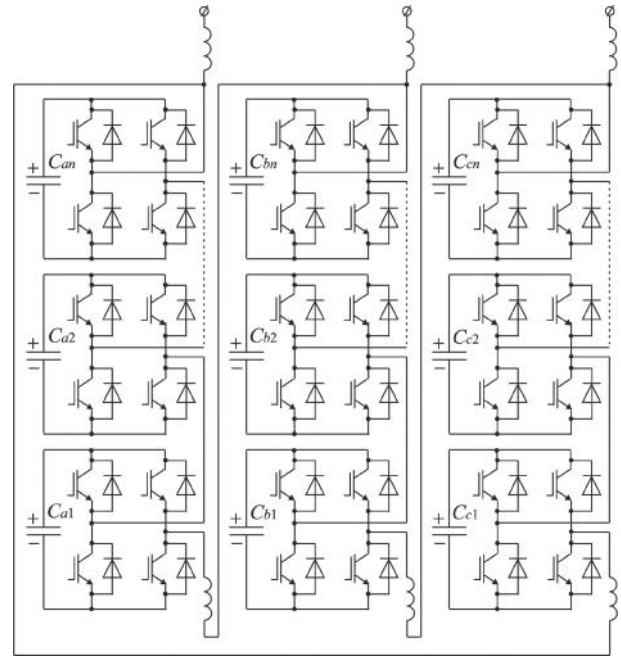
(Thyristor Controlled Series Reactor – TCSR) [6, 7]. . 9



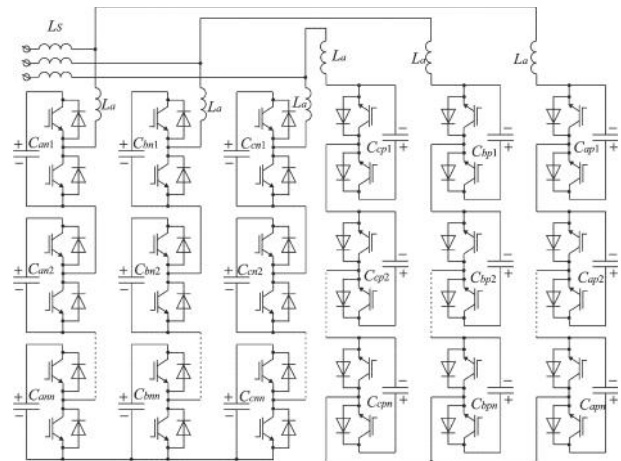
. 4.



. 5.



. 6.



. 7.

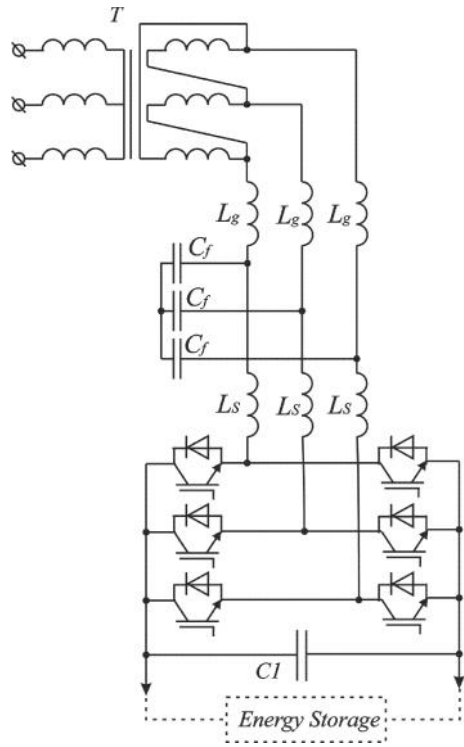
TCSC TCSR

(Thyristor Switched Series Capacitor – TSSC)

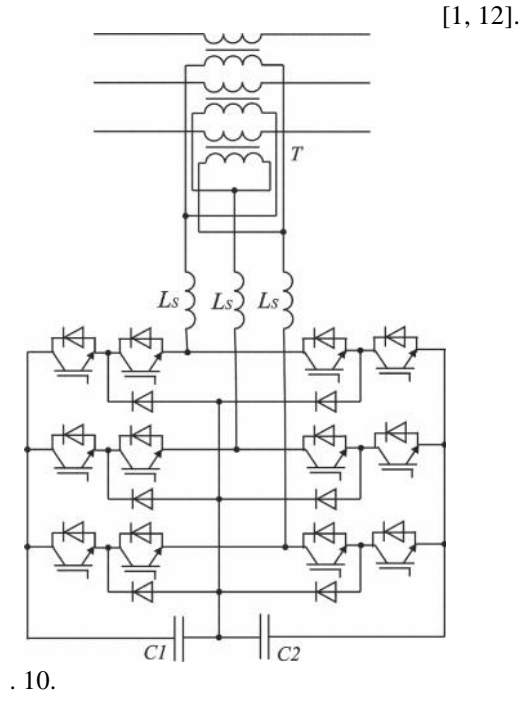
(Thyristor Switched Series Reactor – TSSR) [1].

( ) (Static Synchronous Series Compensator – SSSC)

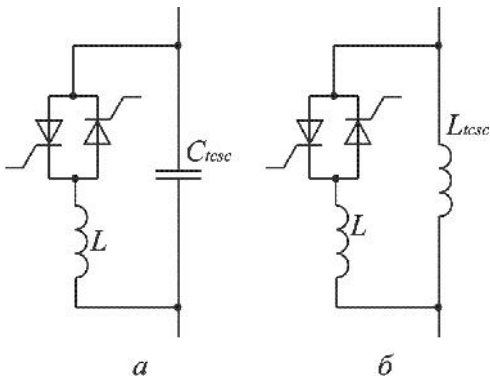
[12].



. 8.



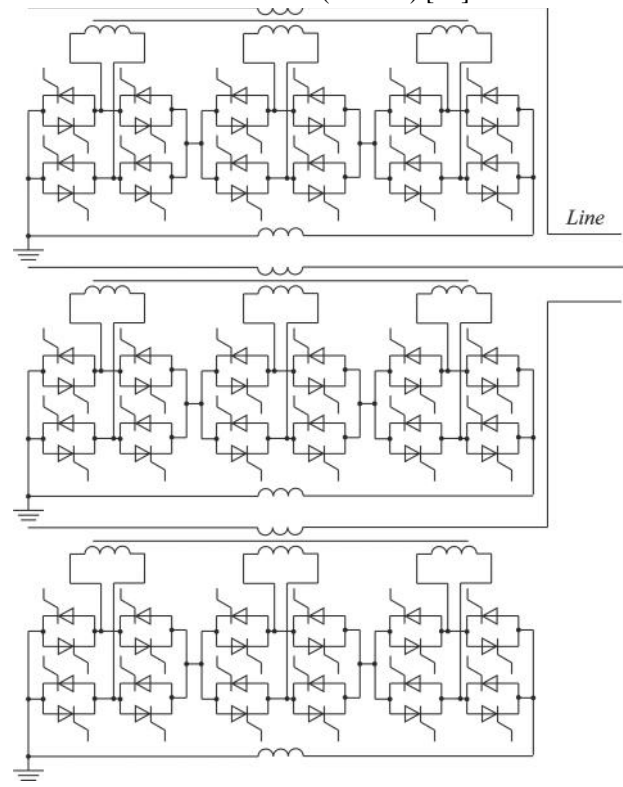
. 10.



. 9.

(Thyristor Controlled Voltage Regulator - TCVR),

( . 11) [13].



. 11.

Smart Grid,

[12].

. 10

**FACTS**

[1].

FACTS,

[1].

( ) (Unified Power Flow Controller – UPFC);

( ) (Generalized Unified Power Flow Controller – GUPFC);

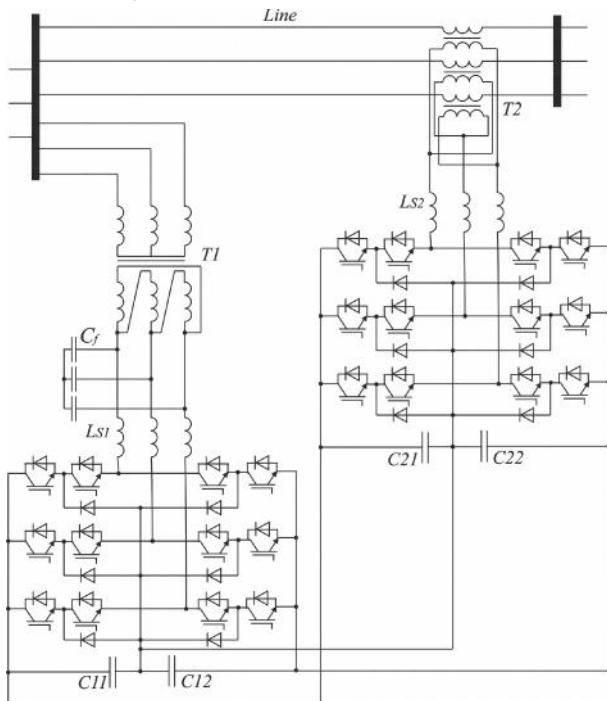
( ) (Thyristor Controlled Phase Shifting Transformer – TCPST) ( . . 13) [15-17].

(Thyristor Controlled Phase Angle Regulator – TCPAR).

( . 12) [14].

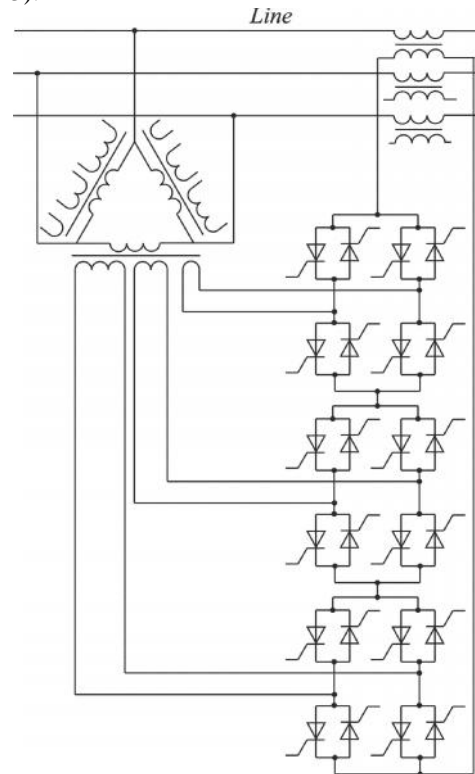
FAC S

[14].



. 12.

. 13).



. 13.

**FACTS**  
**FACTS**

( ) (Interline Power Flow Controller – IPFC)

( ) (Interphase Power Controller – IPS).

( . . 14)

[18, 19].

HVDC VDC

(HVDC)

[19].

1965

Smart Grid

165 HVDC

40

2025

[23-25].

HVDC

500  
HVDC

( . . 15) [20-22].

40 8000 W  
±25 ±800 kV

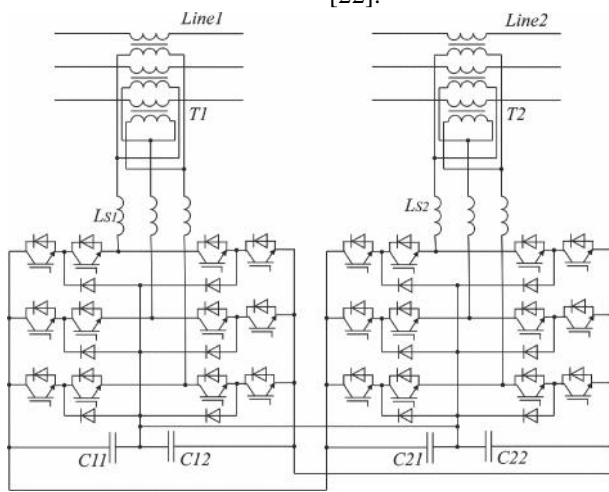
[22].

8.3 535 kV.

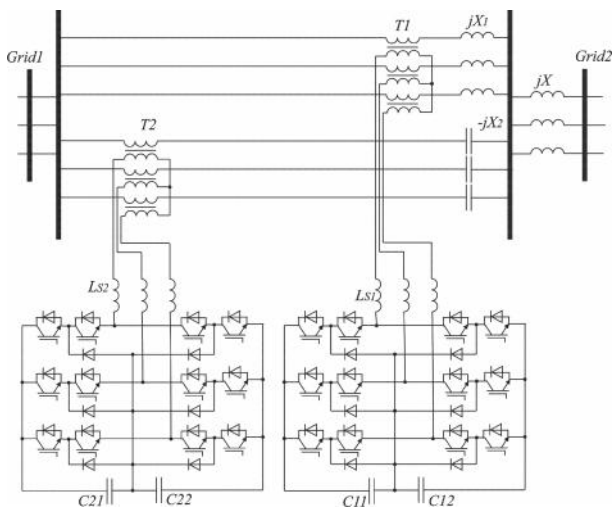
8000 MW  
±800 kV (Xiluodo – West Zhejiang Hami -  
Zhengzhou, ) [25].

. 15

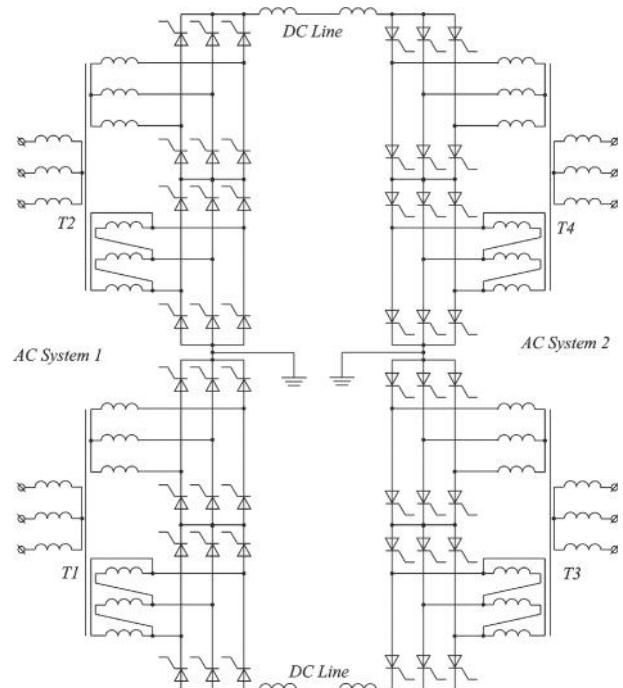
HVDC,



. 14.



. 15.



. 16.

HVDC



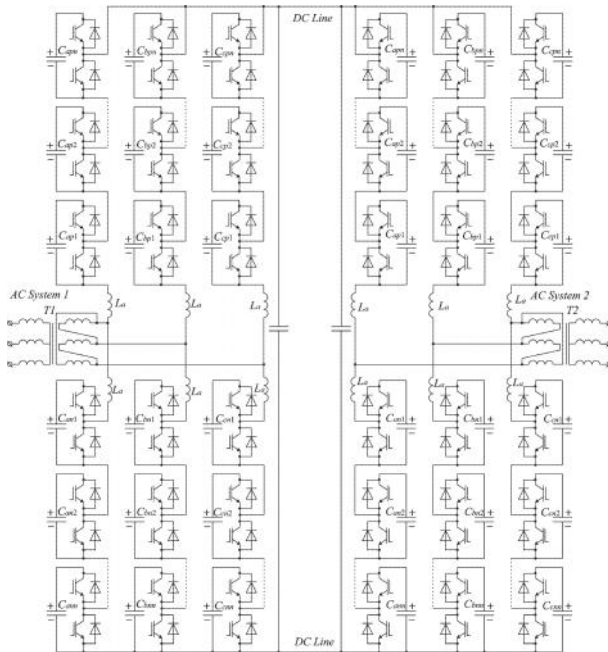
(MVDC)

MVDC  
Smart Grid.  
MVDC

.2  
Smart  
Grid : AC/DC (DC/AC), DC/DC, AC/AC.

Smart  
Grid  
2

MVDC  
0.1 20 MW ±1 80 kV  
6  
66 kV.  
. 17



. 17.  
HVDC/MVDC

		Smart Grid
		DC ;
	Voltage Source Active Rectifier (VSAR)	;
	Active Power Filter (APF)	SG;
AC/DC	( ) Voltage Source Inverter (VSI)	;
	Current Source Inverter (CSI)	;
	Z-Source Inverter (ZSI)	;
	Multilevel Inverter	;

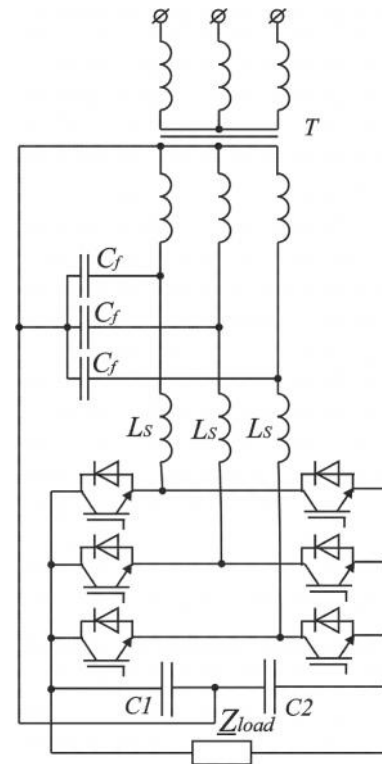
2. ( )

AC/DC

AC/DC	Multilevel Inverter	
DC/DC	Boost, Buck, Buck-Boost Converter	
	PWM Full-Bridge Converter	-DC ;
	Resonant Converters (Series, Parallel, Series-Parallel)	
	Current-Fed Two-Inductor Boost Converter	
	Bidirectional Current-Fed Converter	
DC/DC	Dual Active Bridge (DAB)	
	High Step-Up Converter	
AC/AC	Matrix Converter	AC ;

( ) (Voltage Source Active Rectifier – VSAR), ( ) (Active Power Filter – APF), (Current Source Inverter – CSI); ( ) (Voltage Source Inverter – VSI), Z- (Z-Source Inverter – ZSI), ( ) (Multilevel Inverter – MI) [35, 36].

( . 18) [3].

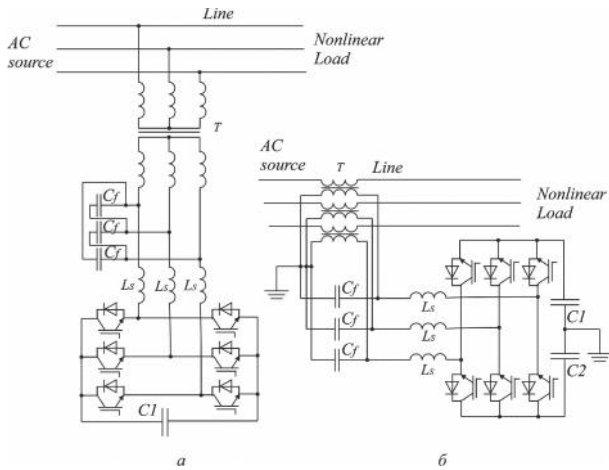


. 18.

[3, 5].

FACTS

( , , ). ( . 19 ), ( . 19 ),



. 19.

(Quasi-Z-Source, - Source, T- Source, Trans- Source, TZ-Source, LCCT-Z-Source, Cascaded MultiLevel Z-Source, Embedded ZSI) [26, 27].

( . . 4-6, 10, 12)

») (Diode-clamped) ( . 5),

» (Capacitor-clamped),

(H-bridge),

[3].

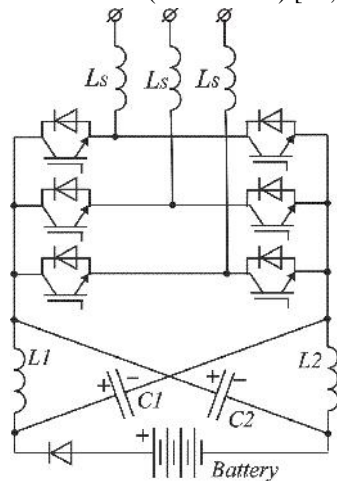
(Multi-Port, Multi-Stage Convertor) ( . 21) [3].

[1-5].

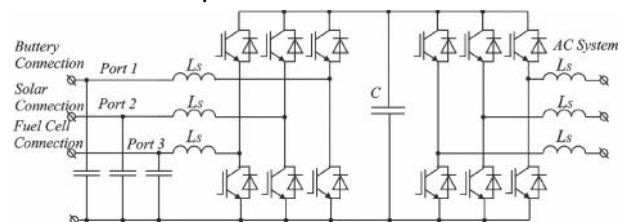
Z-

L-C

( . . 20) [26, 27].



. 20. Z-



. 21.

DC/DC

Z-

[26].  
Z. Peng),

Z-

2002 . (F.

[28-34].

Smart Grid DC/DC

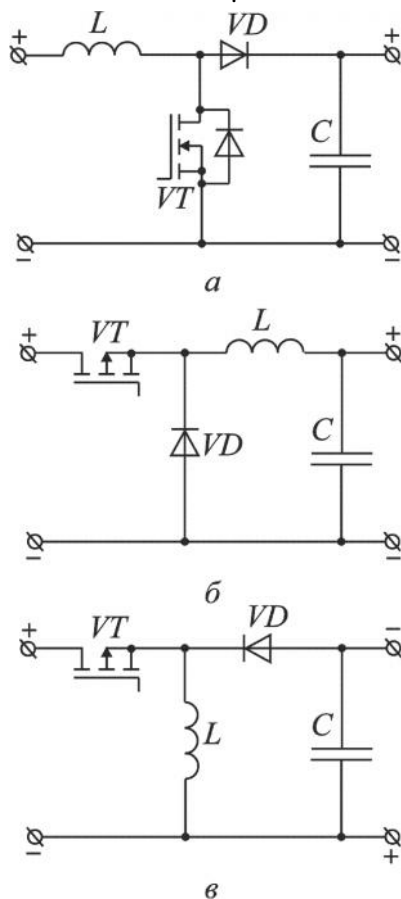
. 2.

(Boost Converter) ( . 22 ) ,

(Buck Converter) ( . 22 )

(Buck-Boost Converter) ( . 22 )

( ) [28].

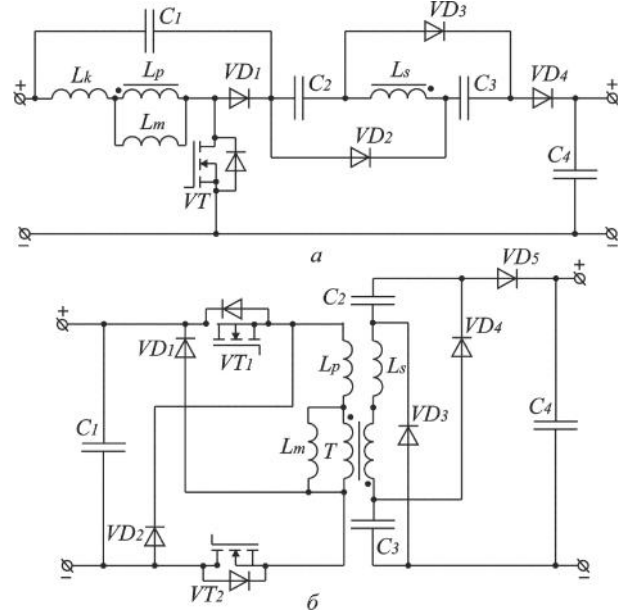


. 22.

; - ; -

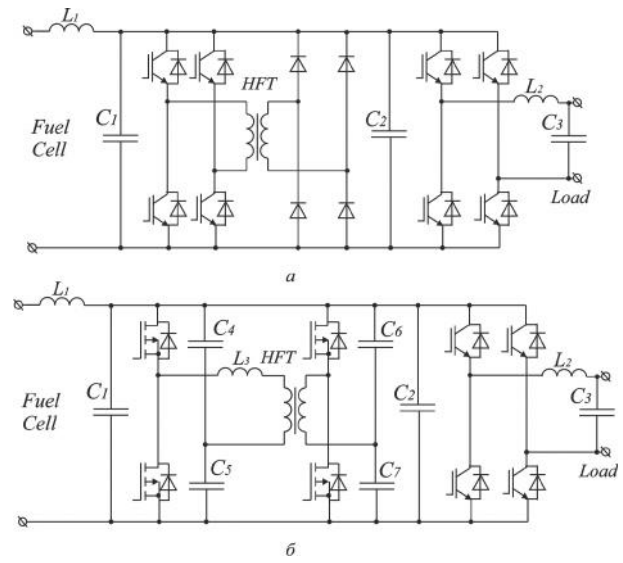
(Dual Active Bridge

- DAB) ( . 25) [31].



. 23.

DG



. 24.

[33, 34]. . 23

DC/DC Smart Grid (PWM Full-Bridge Converter).

[32]. ( . 24) ( . 26 )

DC/DC

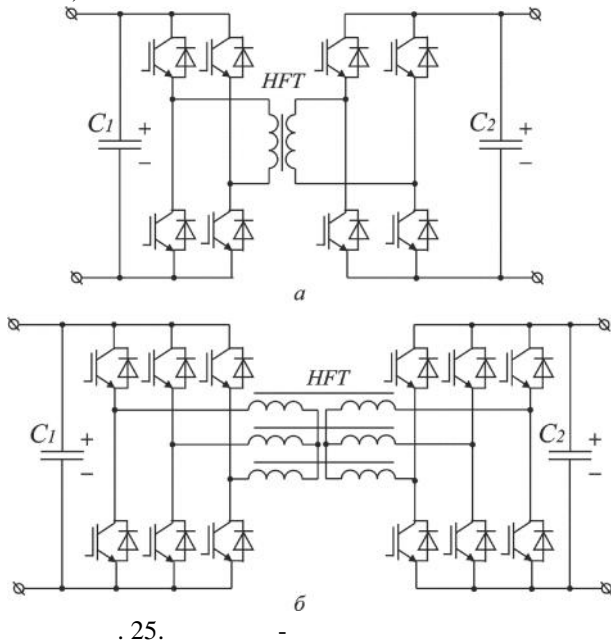
[32]. . 26

(Series Resonant Converter – SRC)

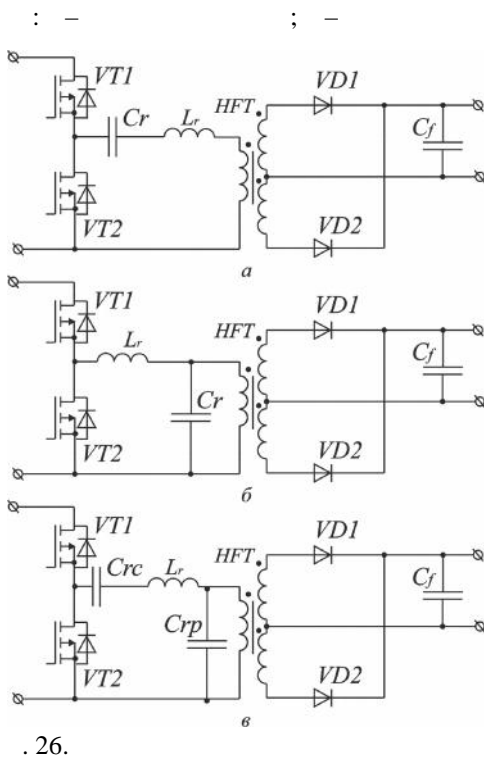
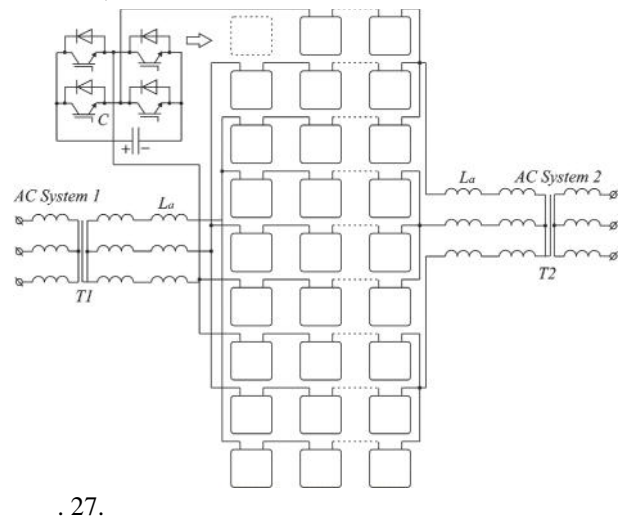
(Parallel Resonant Converter – PRC) ( . 26 )

. 26

(Series Parallel Resonant Converter – SPRC).



[5],



1.

Smart Grid

2.

Smart Grid

3.

Smart Grid.

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2.

Smart Grid /

... // ... , 2010. - 208 .

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Smart Grid [28],

( . . 27).

4. . . . -  
/ . . . // ,  
2012. - 3. - . 49-50.
5. : /  
. . . // . :  
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200 /10 [ ] -  
: URL: <http://www.matic.ru/doc/articles/article2.pdf>.
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## SMART GRID

(Smart Grid).

## POWER ELECTRONICS CONVERTERS IN SMART GRID

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The effective resolution of technical problems on the Smart Grid implementation depends on the power electronics capabilities. The goal of the article is to systematize the circuit topology of power electronics converters relating to Smart Grid application. If we consider the Smart Grid as part of an alternative to the unified energy system, it is possible to select the multiple baselines of its organization.

We have applied system analysis method for forming a three-level hierarchy of converting systems for smart grids. The first level is associated with preservation of existing network structures with electric power AC transmission. The second level is determined a connection between the networks with vary electric power parameters. The third level is formed by objects of distributed generation – alternative energy sources, consumers and energy storages.

We have presented modern converters implementation solutions for flexible alternating current transmission system, high-voltage direct current transmission and distributed generation and energy storage. The most perspective flexible alternating current transmission system for Smart Grid application such as static synchronous compensator, static synchronous series compensator, unified power flow controller, interline power flow controller, interline power flow controller are considered.

We have elucidated an issue that using advanced modular and multilevel converter structures for flexible alternating current transmission system, high voltage and medium voltage direct current transmission system would be the most appropriate solution. The third hierarchical level occupied by the most numerous converters, intended for connection of distributed generation plants with renewable energy sources, energy storages, different types of consumers and power active filters. The most perspective for Smart Grid application converters such as active rectifier voltage source, parallel and series active filter, Z-source inverter, multilevel inverter, Multi-Port, Multi-Stage Converter, Boost Converter, Buck Converter, Buck-Boost Converter, PWM Full-Bridge Converter, resonant converters, Current-Fed Two-Inductor Boost Converter, Bidirectional Current-Fed Converter, Dual Active Bridge, High Step-Up Converter, Matrix Converter are considered.

**Key words:** semiconductor converter, Smart Grid, static synchronous compensator, Unified Power Flow Controller, pulse-width converter, energy storage, fuel sell