POWER QUALITY SEMINAR OF IRAN, 2ND MARCH 2017

Power Quality Seminar

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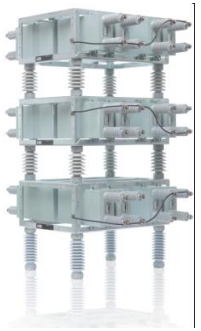


HV Capacitor Unit

Product Portfolio

Single-Phase Capacitor

- Oil immersed Capacitor Unit-AC
- Single-Phase capacitor Unit

3 types of fuse configuration protection: Internal fuse, External fuse and Fuseless

- Oil immersed Capacitor Unit-DC

Apply for DC Project

Special Capacitor

- Three-phases Capacitor

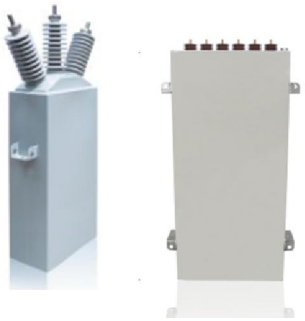
Apply in industry project, improve power factor

- Surge Capacitor

Apply in industry project, improve power factor

HV Capacitor Unit

Production Specification



Internally Fused
- Voltage Range: 1 - 14.4 kV
- Power Range: 100 - 1200kvar (50 or 60 Hz)

Externally Fused
- Voltage Range: 2.4 - 25 kV
- Power Range: 100 - 500 kvar (50 or 60 Hz)

Fuseless Units (ABB Design)
- Voltage Range: 12 - 25 kV
- Power Range: 300 - 1000 kvar (50 or 60 Hz)

Fuseless banks (Conventional Design)
- Voltage range: Min. 46 kV
- Power range: Min. 3 Mvar (50 Hz)

Standard :
- IEC60871-1 (2005)
- GB/T11024.1-2001
- DL
- IEEE
- Other standard req. by customers

HV Capacitor Unit

Oil Type 3-PH Unit

- Voltage range: 2.4 - 20 kV
- Maximum power: 500kvar (50 or 60 Hz)
- Maximum current: 180A
- Internally connection: Δ or Y
- Apply for electric motor or industrial load, improve power factor

HV Capacitor Unit

Oil Type Surge Unit

Single-phase (Europe, IEC)

- Voltage range: 1 - 36kV
- Capacitance/electrode: 0.13 - 0.65uF
- Standard: IEC

Single-phase or Three-phase(US, ANSI/IEEE)

- Voltage range : 1 - 24kV
- Capacitance/electrode : 0.13 - 0.75uF
- Standard : IEEE

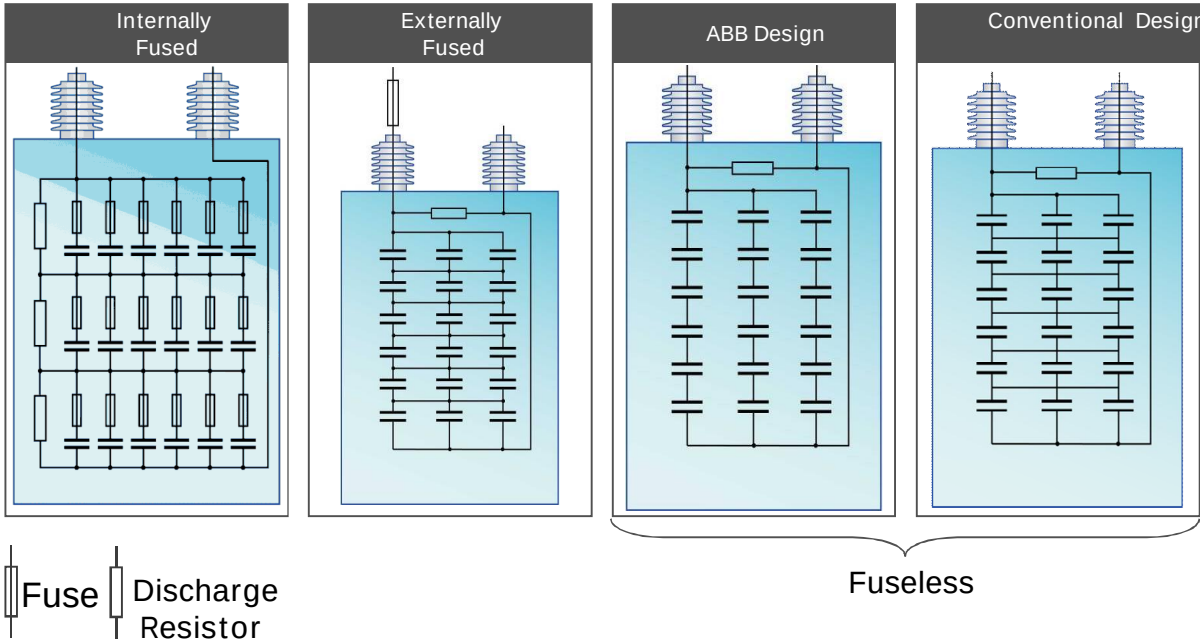
HV Capacitor Unit

Raw material

Material Name	Main Character
Aluminum Foil	Symmetric thickness and good electrical property advantages. The thinnestthickness could be reached to4.5um
Polypropylene Film	Coarsening surface, stable property, high withstand capability, 9um films and above are widely adopted.
Faradol impregnation fluid	Improving insulation strength and biodegradable advantages, non-PCB fluid.
Bushing	The connection flange is colded pressed on the bushing which not only guarantees the insulation strength but also the mechanical strength and isolation.
Internal fuse	Adopt special material, good quality, stability and high reliability.
Discharge Resistor	Good at thermal stability and ability of overload;
Tank	High strength and corrosionproof.

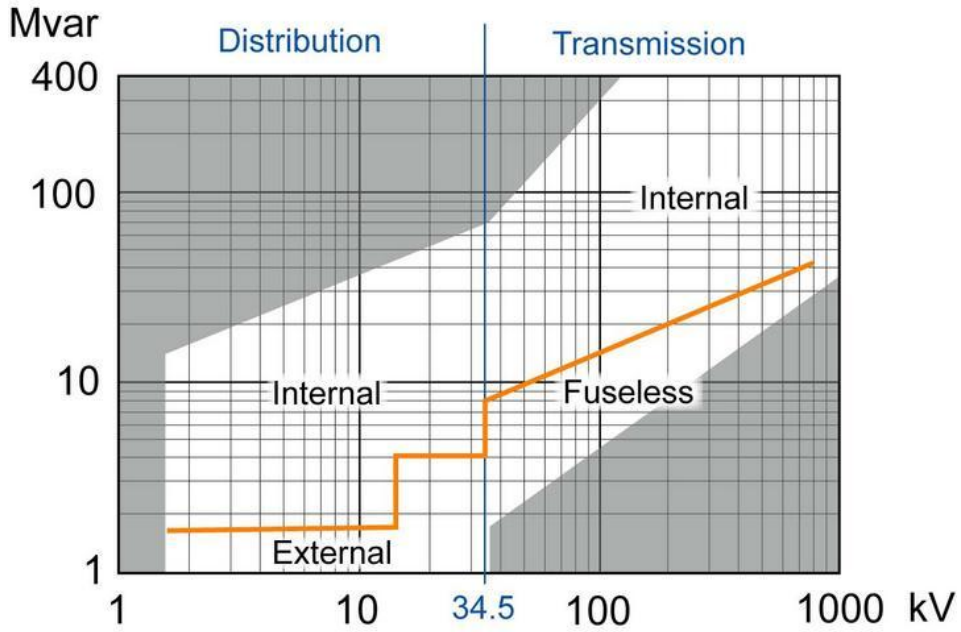
HV Capacitor Unit

Technology of Fuse



HV Capacitor Unit

Choose suitable fuse technology



How to choose fuse configuration depends on voltage and capacity

HV Capacitor Unit

Internal fuse VS External fuse

Internal fused Capacitor

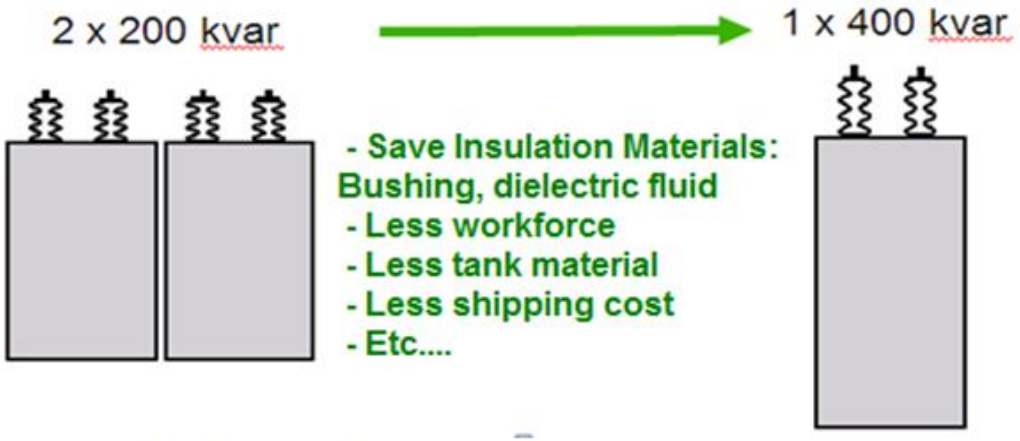
- Only one element damaged
- Less loss of capacitance
- limit current increasing
- suitable for big capacity capacitor unit
- no-direct observe for fuse disconnection
- Limited by range of voltage VS. capacity

External fused capacitor

- observe fuse disconnection directly
- fuse from outside
- cause short-circuit of parallel group
- more loss of capacitance
- can not limit current
- capacitor volume limited
- may not disconnect if high energy in parallel

Capacitor Shunt Bank

Design Comparison

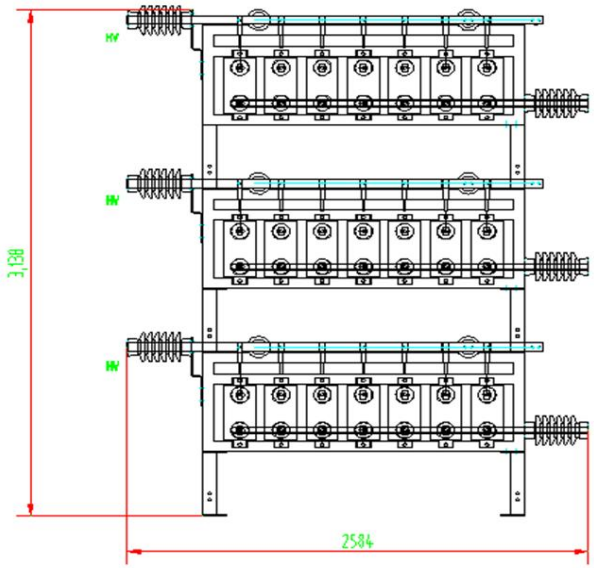


- ✓ Cost Saving for customer
- ✓ Space saving
- ✓ Enhanced system availability
- ✓ and less maintenance

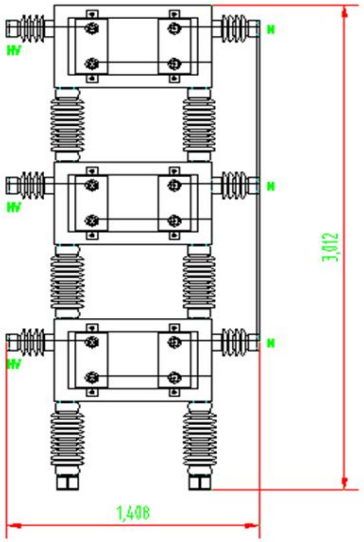
Capacitor Shunt Bank

Design Comparison

TBB 22-8400/200BLW 1S14P
Design A



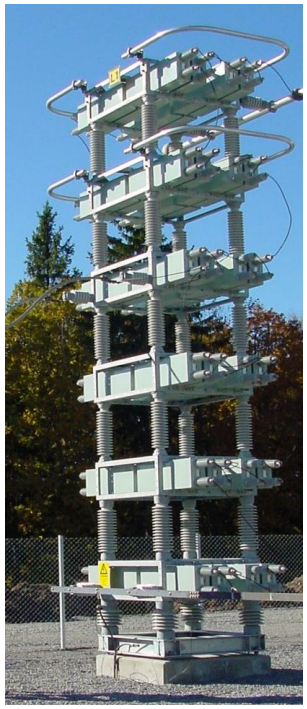
TBB 22-8400/700BLW 2S2P
Design B



	Unit	Fuse Type
Design A	BAM13.8-209-1W	External Fuse
Design B	BAM6.9-700-1W	Internal Fuse

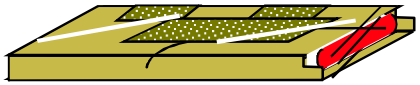
HV Capacitor Unit

Definition of capacitor unit



Capacitor bank

Capacitor unit



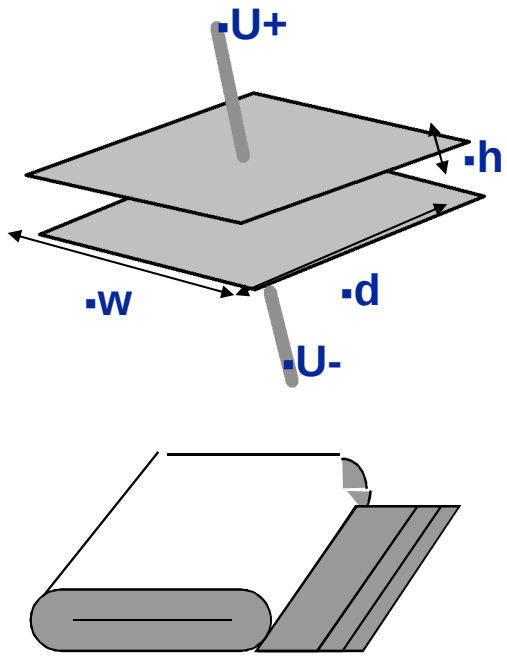
Capcitor element

HV Capacitor Unit

Capacitor Unit Construction

HV Capacitor Unit

Design principle



Available area of electrode (mm^2)

$$A = d \times w$$

Capacitance (μF)

$$C = \varepsilon \frac{A}{h}$$

Reactive power (kvar)

$$Q = \omega C U^2$$

System Specification

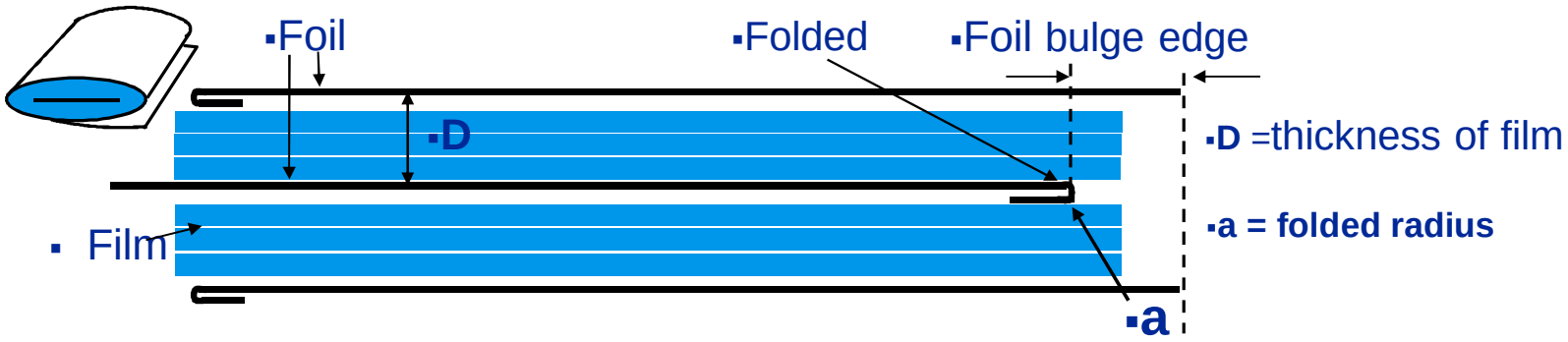
Operation condition

HV Capacitor Unit

Design principle

Consideration of safety plenty level

- Film layer (3-layers is normal)
  - Strong puncture- against ability
- **Foil auto-folding of electrode**
  - Regular edge stress;
  - Excellent partial discharge ability



HV Capacitor Unit

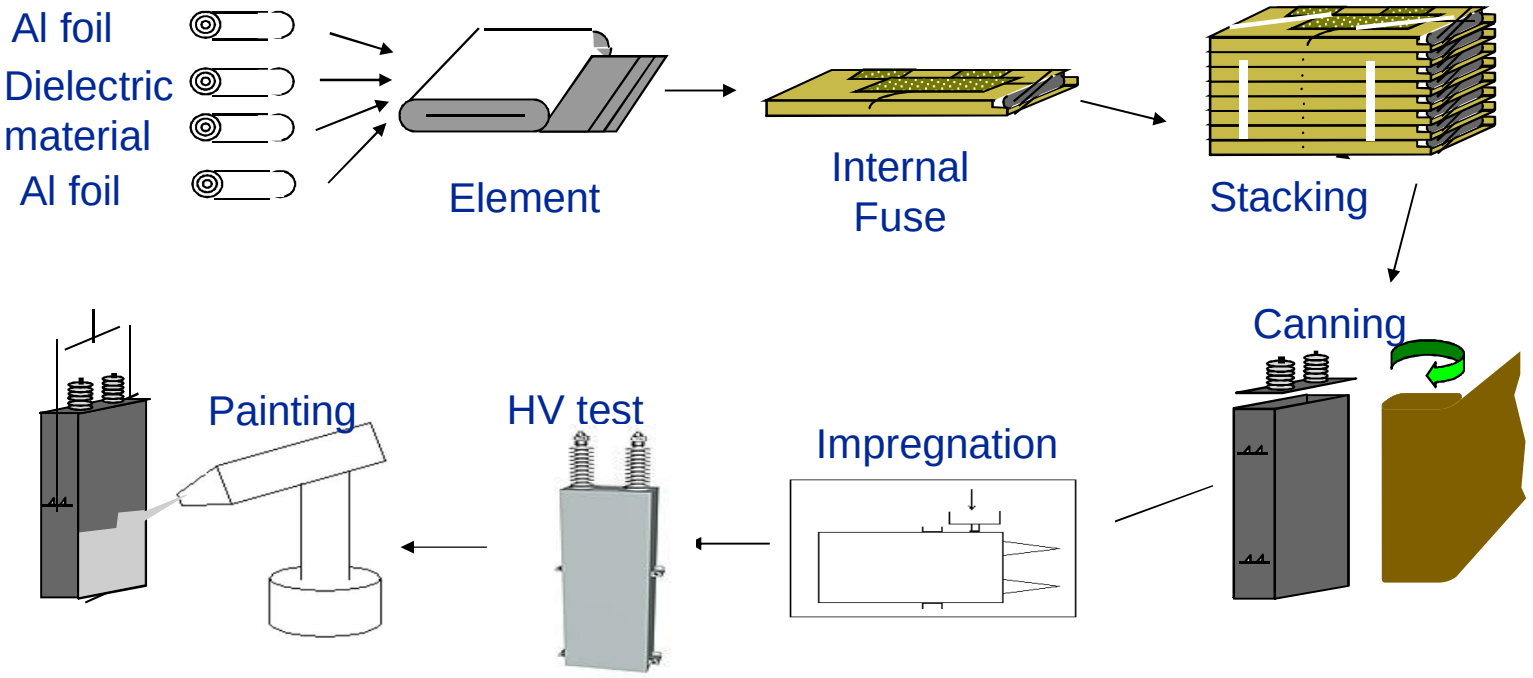
Process Control

High quality raw materials, with optimized design scheme to guarantee the product life and reliability;

Barcode System records full production process as to ensure consistent quality;

HV Capacitor Unit

Production process



HV Capacitor Unit

Module Assembly & Packing

Finish goods check for capacitor unit;
Connection assembly;
Rack assembly;
Unit packing and module packing;

Modularized packages of product, conveniences for installation and shorten working time and cost at site

HV Capacitor Unit

Characters of Capacitor unit

- Advanced internally fused technology
- Lower loss
- High reliability
- Narrow capacitance deviation range
- Better weight/per kvar ratio;
- Good sealing;
- Compared with others better ability at over voltage and over current;
- Inside discharge resistor
- Wide temperature range
- Suitable for varies of climate condition and frequent operations
- Tank painting gives a good reflection of ultraviolet, aging slowly, high anti-corrosion;
- Strict selection and control of auxiliary material to guarantee the quality stability of capacitor;
- Two-dimension ID nameplate, long term quality tracing and easy for follow-up purchasing

HV Capacitor Unit

Characters of Capacitor unit

IEC60871-1 standard requirement

8.2 Loss requirements

The requirements regarding capacitor losses shall be agreed upon between manufacturer and purchaser.

The value of capacitor losses is that measured under the conditions of 8.1.

Requirement from China utility power company standard

5.2.4 损耗角正切值（tgδ）

电容器在工频交流额定电压下，20℃时损耗角正切值应符合下列值：

纸膜复合介质的电容器应不大于 0.08%；

全膜介质的电容器：有放电电阻和内熔丝的应不大于0.05%；无放电电阻和内熔丝的应不大于 0.03%。

ABB capacitor unit: 0.02% or 0.015% 40W/200 kvar or 30W/200kvar

Local company: 0.1% 200W/200kvar

HV Capacitor Unit

Characters of Capacitor unit

旭硝子 株式会社 千葉工場 御中

件　名 ：絶縁油中ＰＣＢ分析

採 取 年 月 日：平成24年10月25日

中外テクノス株式会社
関東環境技術センター
千葉県千葉市緑区大野台2丁目2番16
TEL 043(295)1101(代)

環境計量士　安並 勲

分析責任者　松本 茂之

Insulation oil for ABB capacitor

分析結果を次のとおり報告致します。

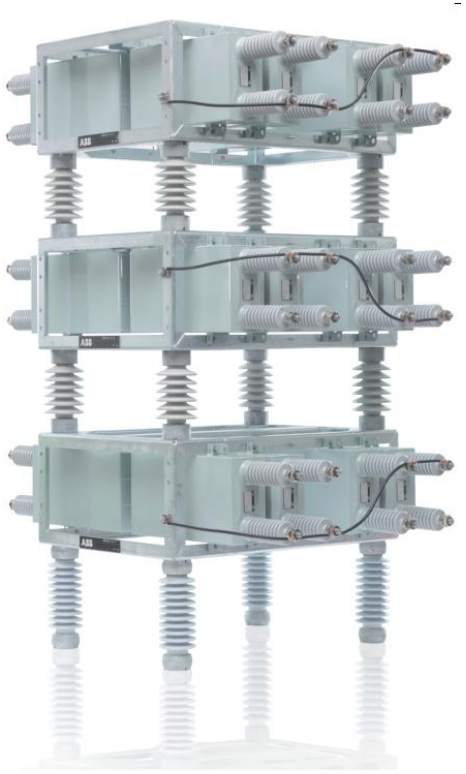
PCB(polychlorobiphenyl)

試料名	容量	製造番号	製造年	形式	製造者	ポリ塩化ビフェニル (単位：mg/kg)
ABB社 ｺﾝﾃﾞﾝｻ用 絶縁油	－	12K-01	－	－	－	検出せず Not detectable
備考	「検出せず」とは定量下限値未満のことです。 分析は持込試料にて実施しました。 mg/kgはppmと同一の濃度単位です。 0.5mg/kg以下はＰＣＢ廃棄物に該当しません。					Detection limit 定量下限値 0.15
分析方法	絶縁油中の微量PCBに関する簡易測定法ﾏﾆｭｱﾙ(平成23年5月 第3版) 2.1.2 加熱多層ｼﾘｶｹﾞﾙｶﾗﾑ/ｱﾙﾐﾅｶﾗﾑ/ﾈｷｻﾋﾞﾗﾘｰGC/ECD法					0.15mg/kg(ppm)

Contents

Capacitor Shunt Bank

Function & Parameter range



Installed in Transmission and distribution network

- Increase transmission capability
- Improve power factor
- Lower line losses
- Enhance power quality

Voltage scope: 1 - 1000 kV
Capacity range: 0.6 - 300 Mvar

Capacitor Shunt Bank

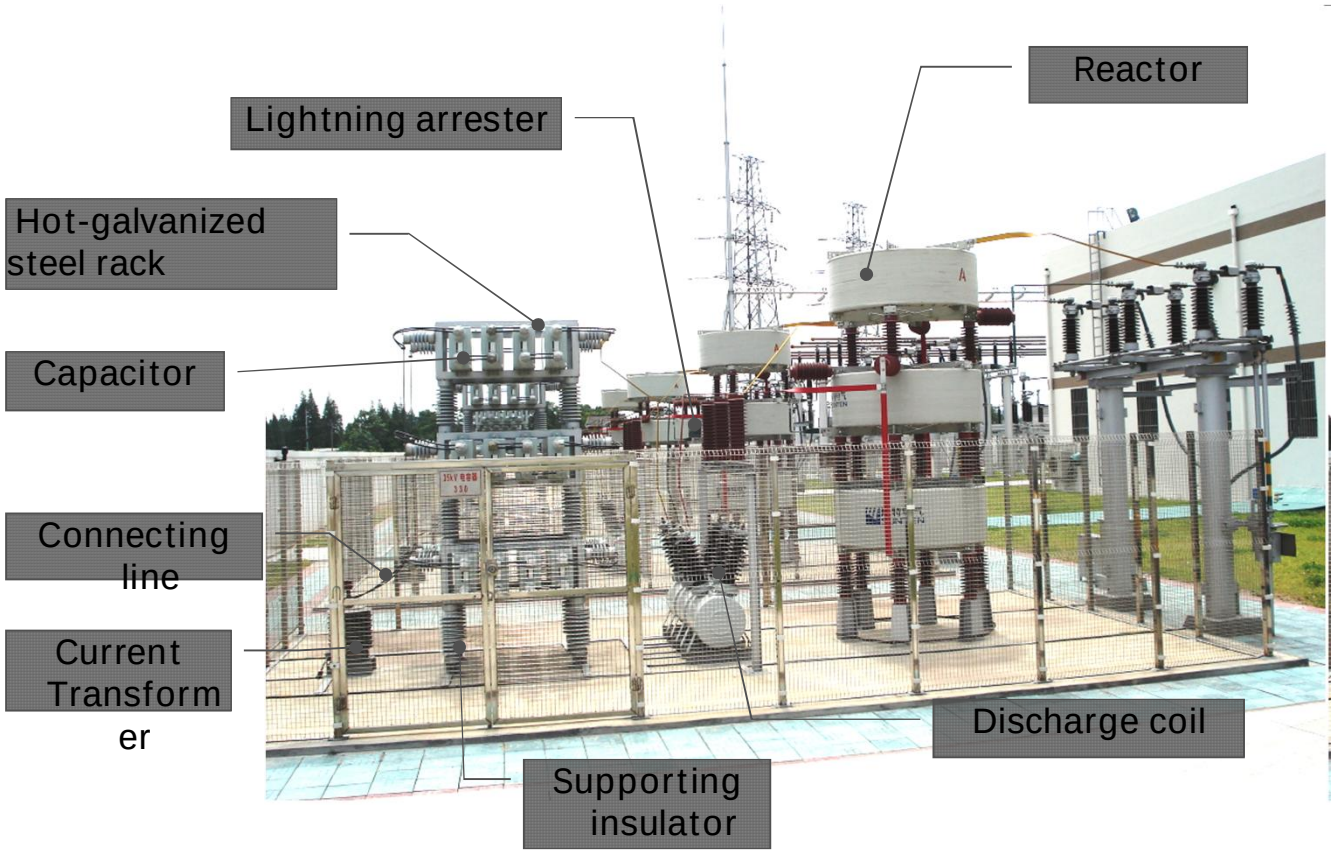
Explanation of Type

T BB A 35 - 60000/500 A QW

- T for bank
- BB for shunt bank
- A for QBank-A
- Bank rated voltage(kV)
- Bank rated capacity(kvar)
- Unit rated capacity (kvar)
- A for single star
- Q for bridge different current
- W for outdoor

Capacitor Shunt Bank

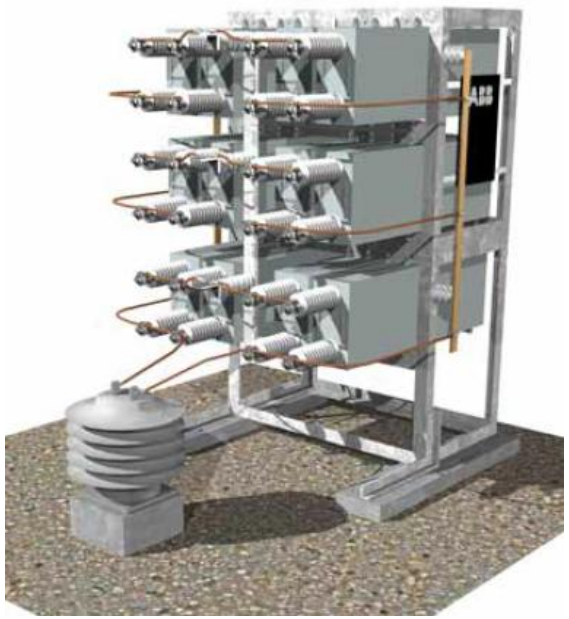
Structure



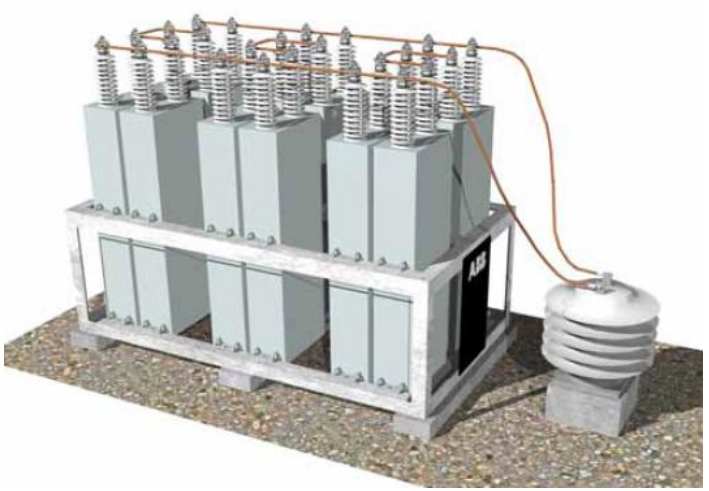
Capacitor Shunt Bank

Structure

QBANK-A



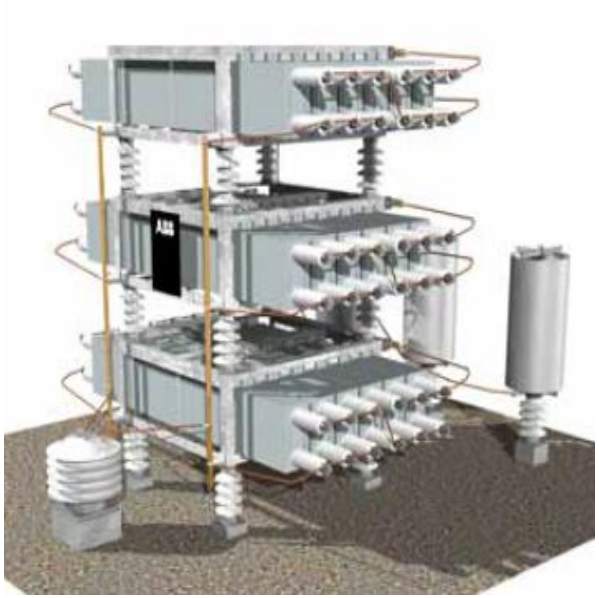
QBANK-B



QBANK-C

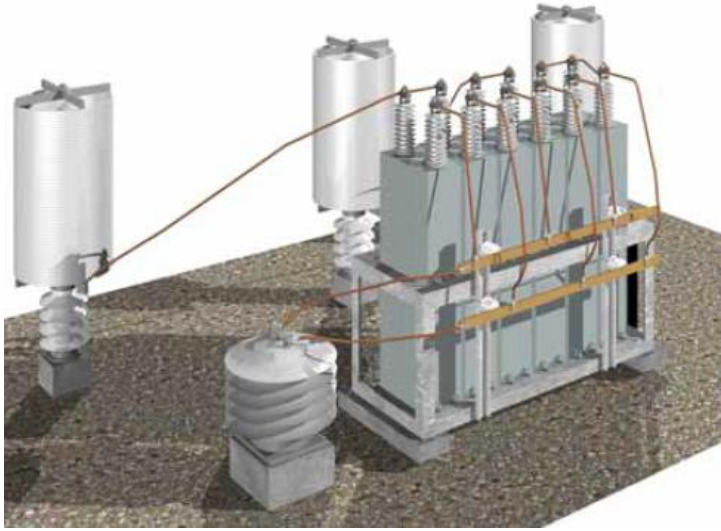
Capacitor Shunt Bank

Structure



QPLUS-A-Example

QPLUS-B-Example



QPLUS-C-Example

Capacitor Shunt Bank

Features

May choose stainless, Hot dipped galvanized rack;

Low failure rate, annual failure rate is lower than 0.1% by statistic.

Easy to install. Capacitor unit & rack has been installed together in the factory.

May choose ABB's disconnection switch;

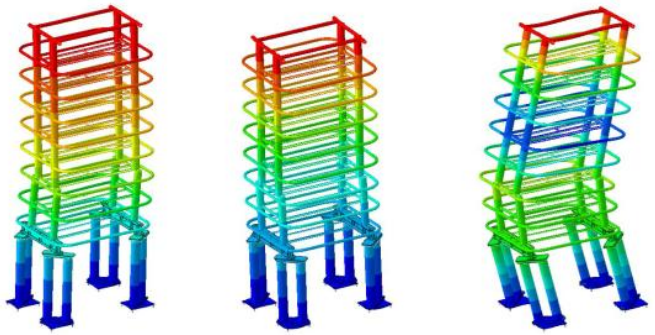
Specific connecting structure between BV cable and bushing;

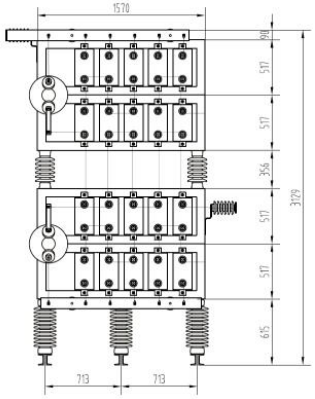
High level of standardized installation.

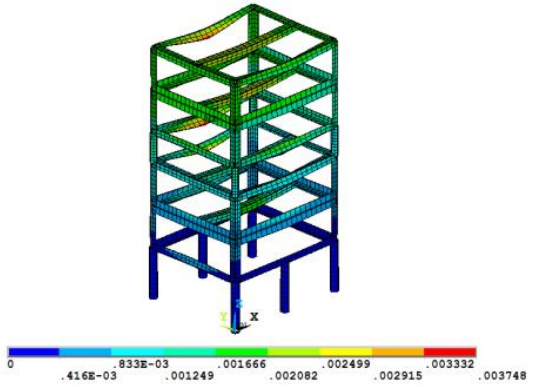
Simple structure, easy to maintain

Capacitor Shunt Bank

Anti-seismic simulation







Capacitor Shunt Bank

HVDC AC Tuning Filter

- Capacitors
- Rack
- Post Insulator
- Connection Cable
- Armour Clamp
- Current Transformer

Capacitor Shunt Bank

HVDC DC Tuning Filter

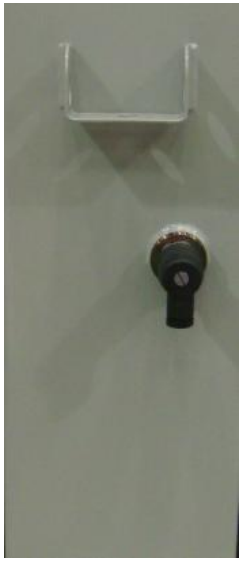
- Capacitors
- Rack
- Post Insulator
- Connection Cable
- Armour Clamp

Capacitor Shunt Bank

Test Capacitor Bank

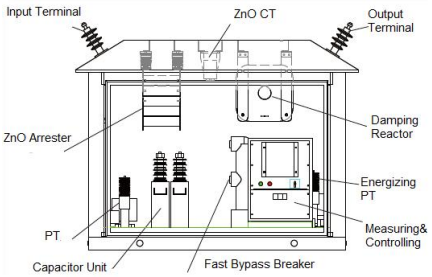
Capacitor Shunt Bank

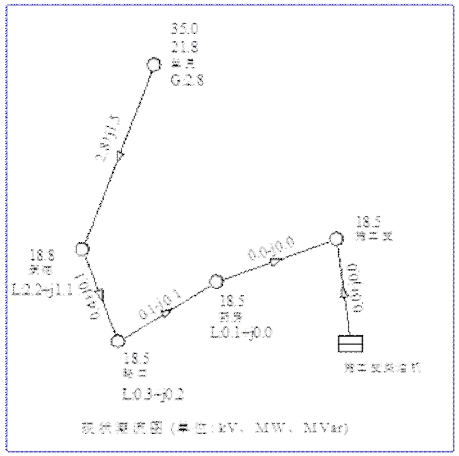
Accessary

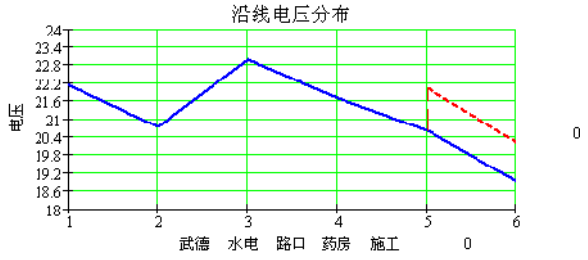


Capacitor Bank

Series Compensation Installation for Distribution Grid/Railway



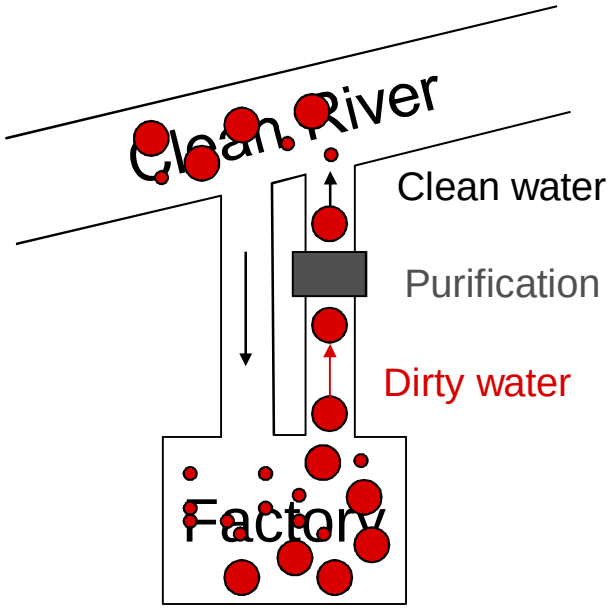


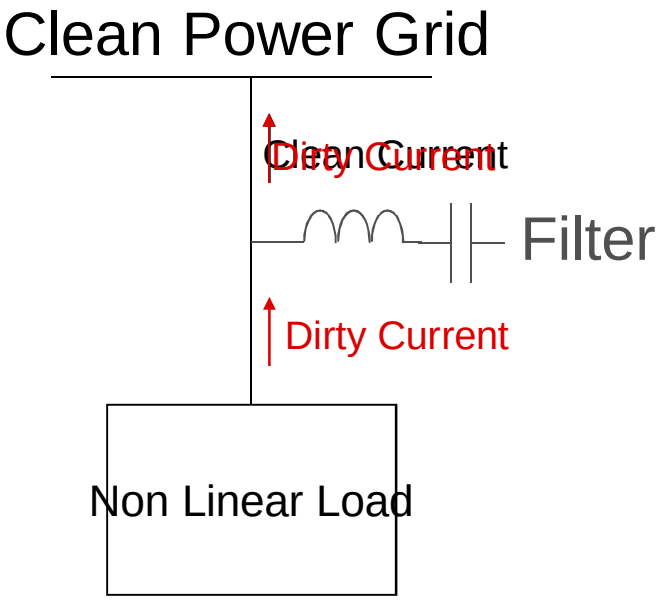


Contents

Type Solution of Filter

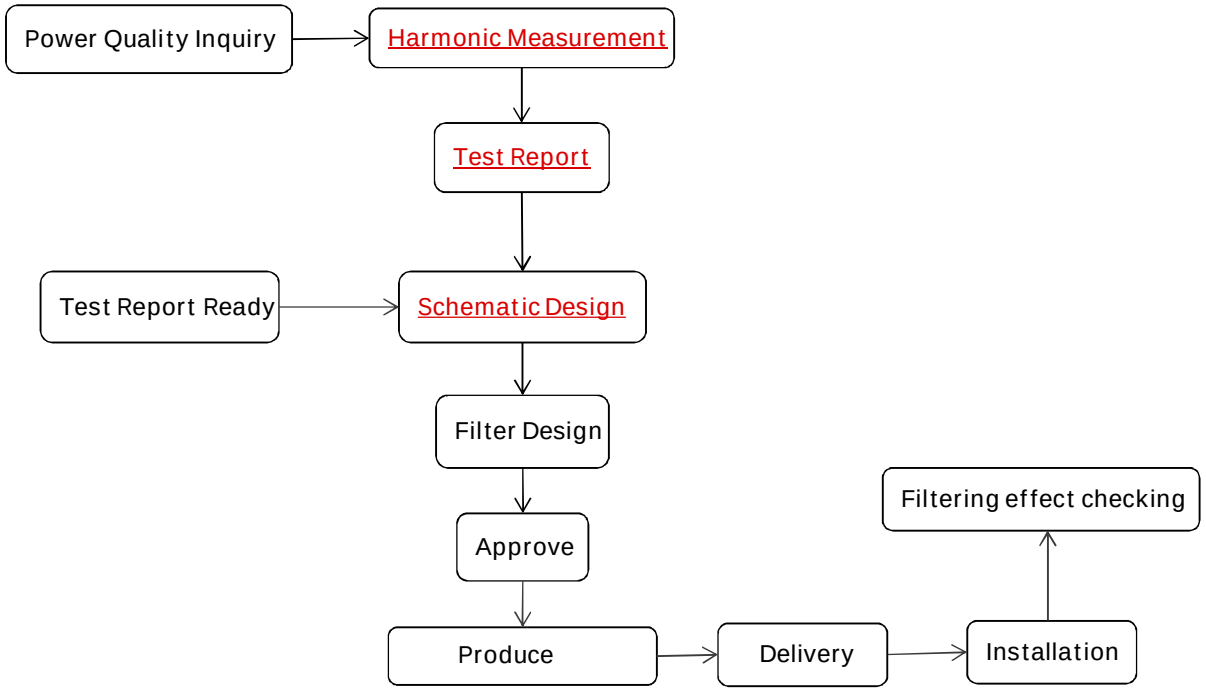
Filtering concept





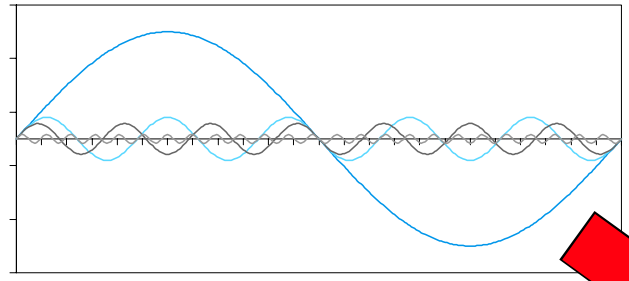
Type Solution of Filter

Project Process



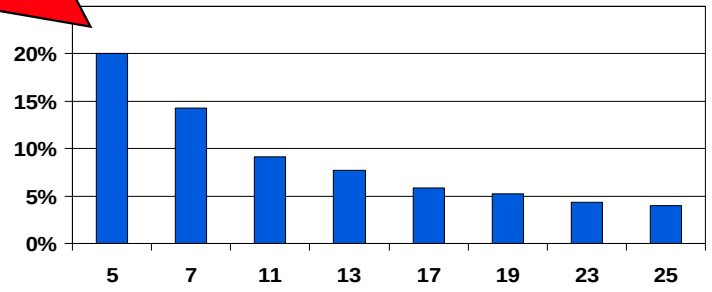
Type Solution of Filter

Harmonics representation



Time domain

Frequency domain

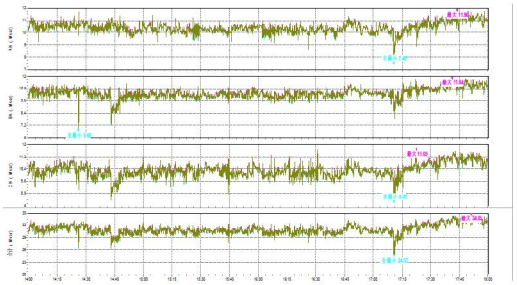


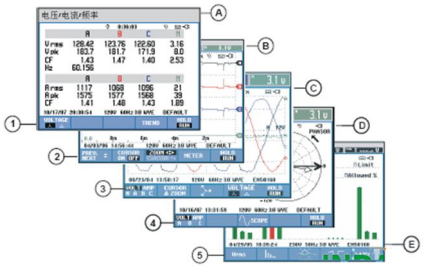
Type Solution of Filter

Power Quality Measurement

Measure unit UP-2210

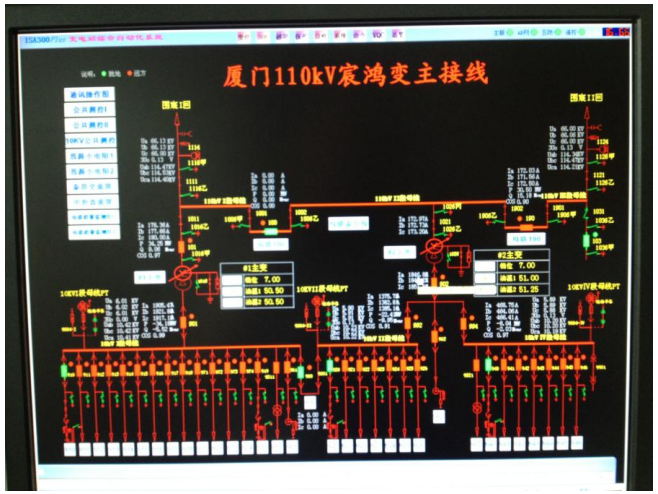
Measure unit UP-2210R



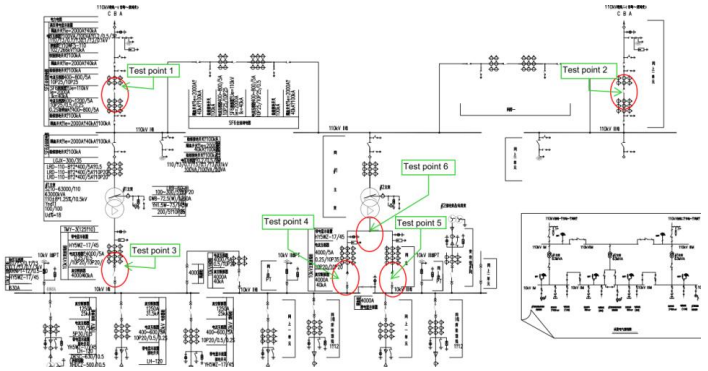


Type Solution of Filter

Power Quality Measurement



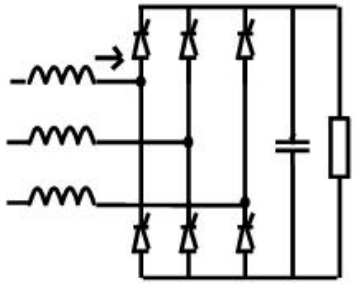
Site monitor



Connection Diagram

Type Solution of Filter

Harmonic Analysis

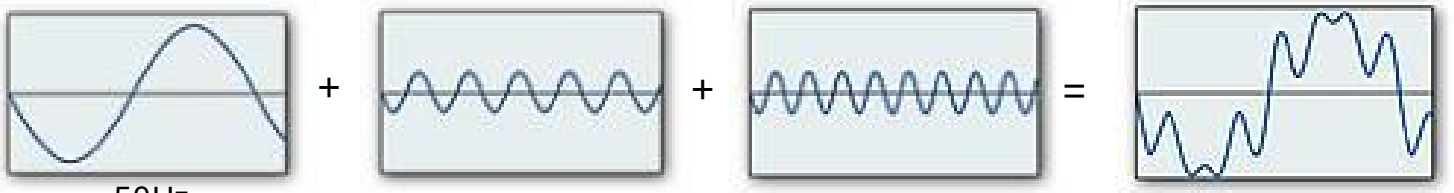


$$i_a = \frac{2\sqrt{3}}{\pi} I_d [\sin \omega t - \frac{1}{5}\sin 5\omega t - \frac{1}{7}\sin 7\omega t + \frac{1}{11}\sin 11\omega t + \frac{1}{13}\sin 13\omega t - \cdots]$$

➡ Fundermental current $I_1 = \frac{\sqrt{6}}{\pi} I_d$

➡ Harmonic current $I_h = \sqrt{I^2 - I_1^2} = 0.2965 I_a$

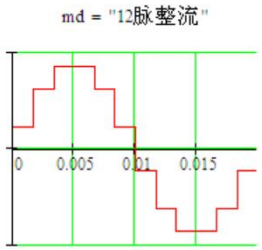
6 pulse rectifier THD I will be 29.65% !

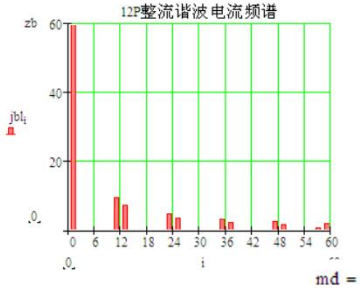


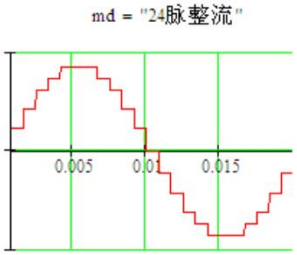
50Hz | 5 harmonic (250Hz) | 7 harmonic(350Hz) | Distortion curve

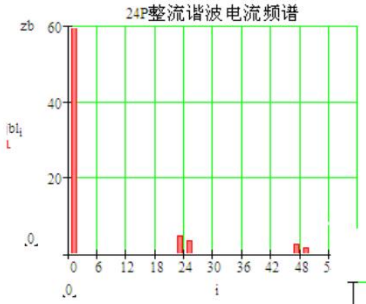
Type Solution of Filter

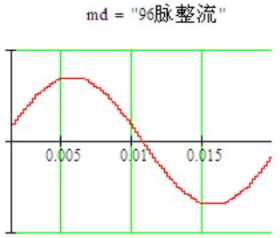
Harmonic Analysis

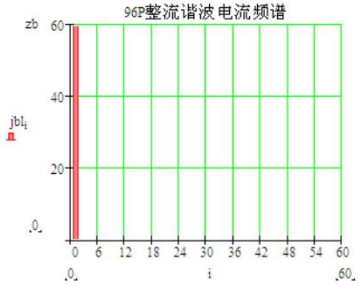






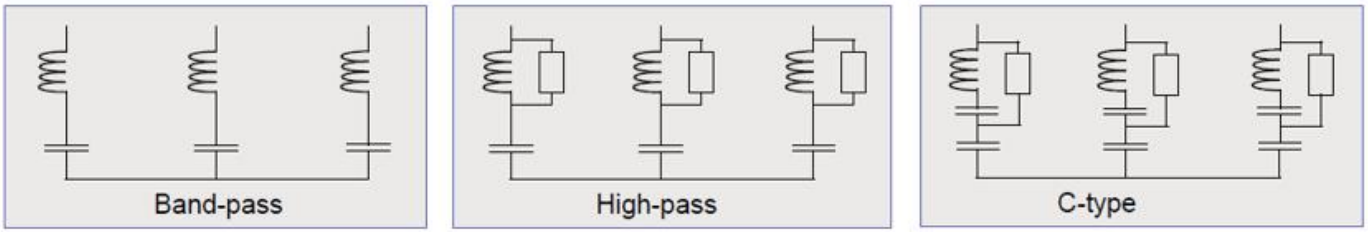






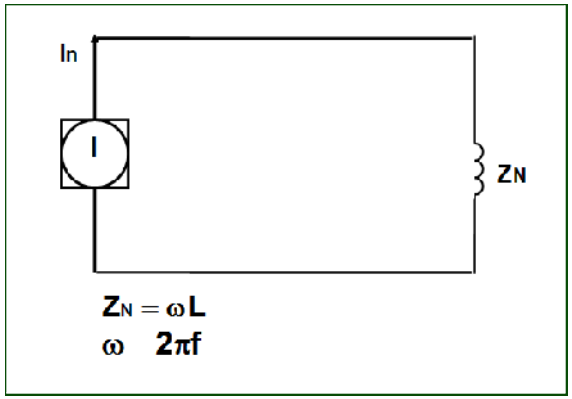
Type Solution of Filter

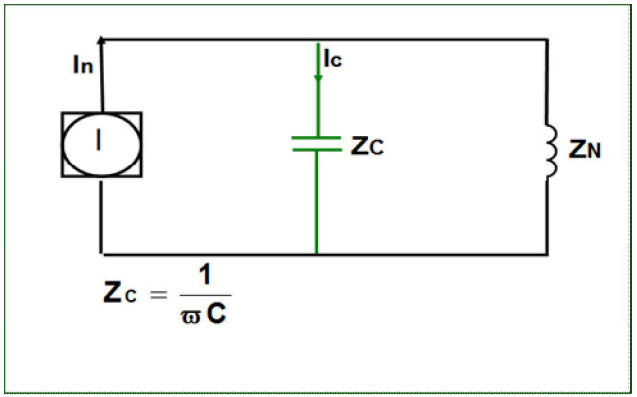
Type of Filters

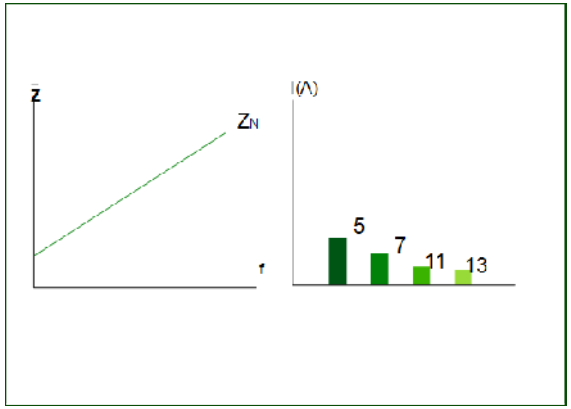


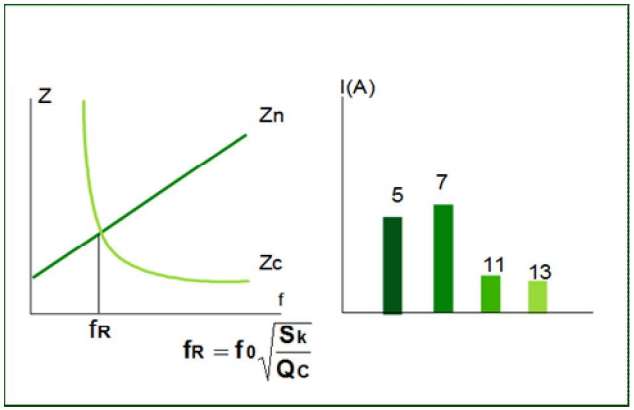
Type Solution of Filter

Type of Filters



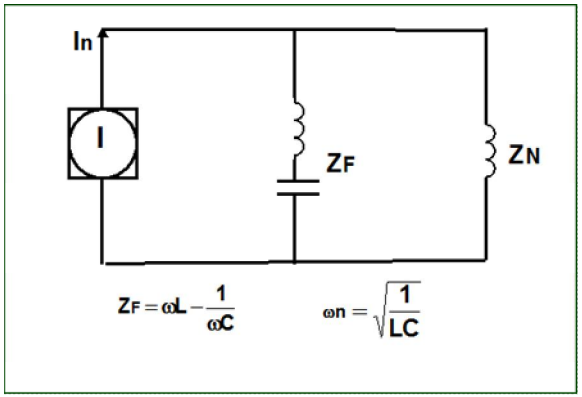


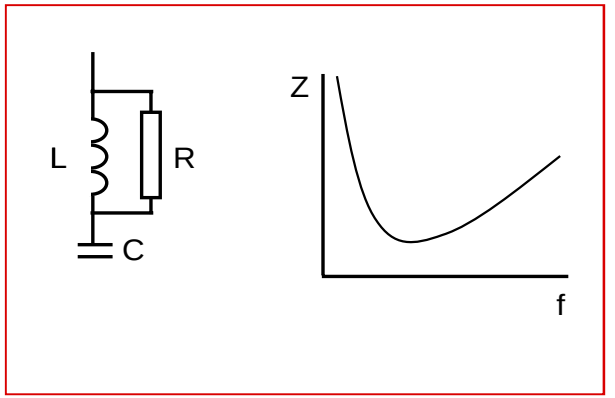


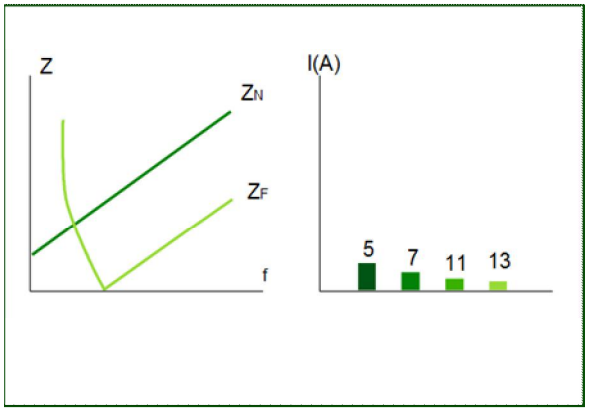


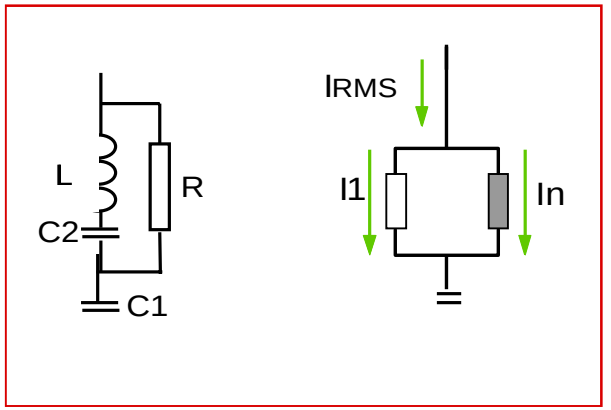
Type Solution of Filter

Type of Filters



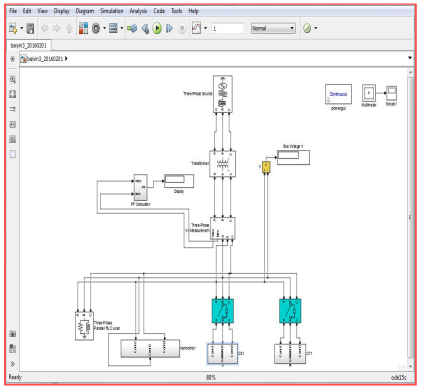






Type Solution of Filter

Harmonic Analysis



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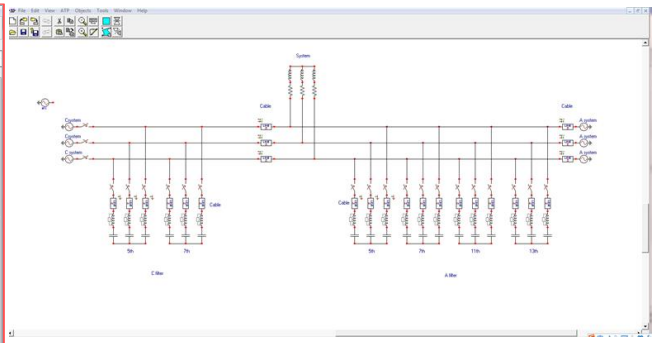

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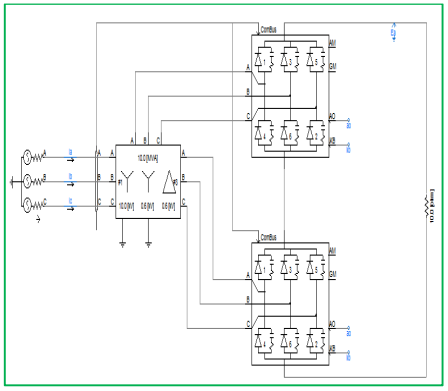

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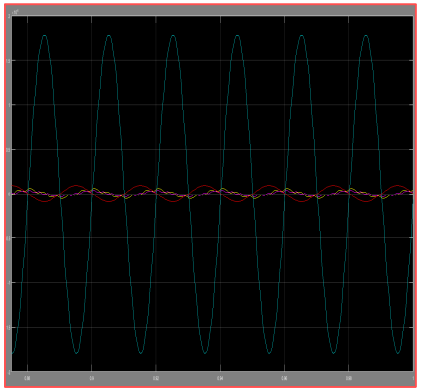
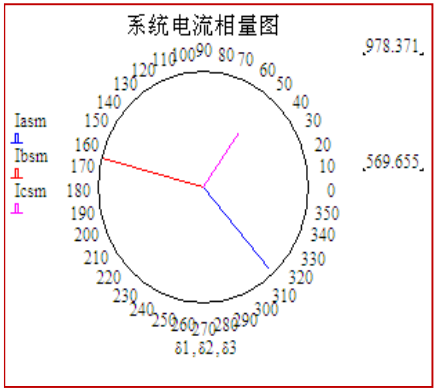
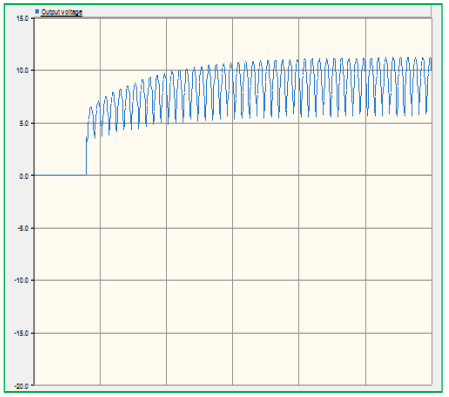
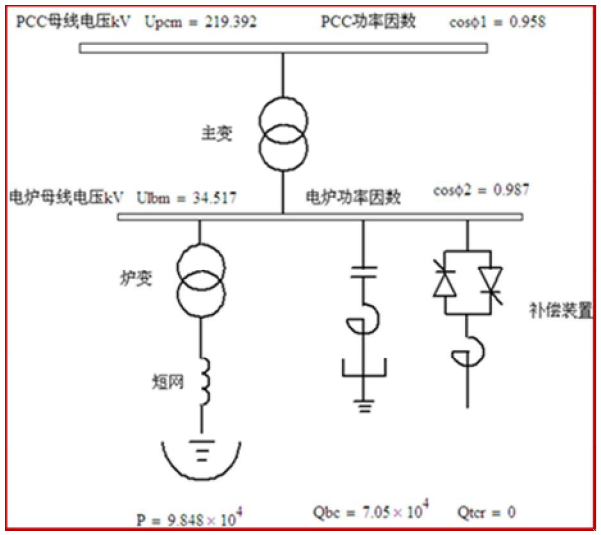


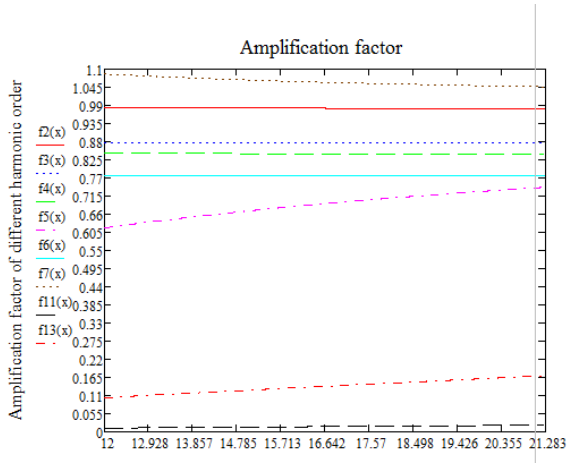


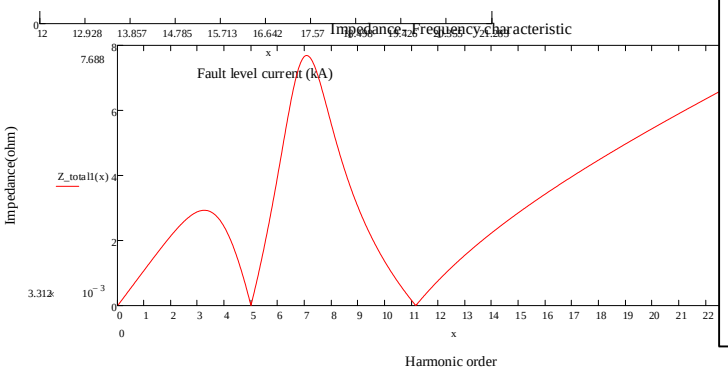


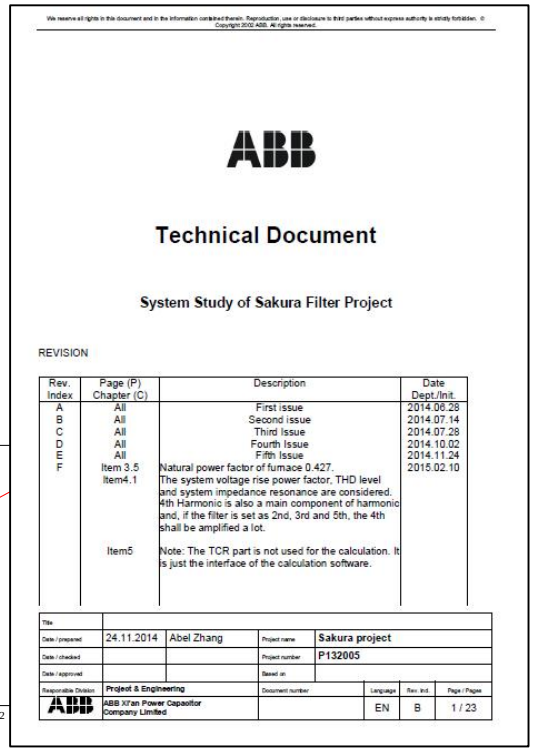
Type Solution of Filter

Harmonic Analysis









ABB

Technical Document

System Study of Sakura Filter Project

REVISION

Rev. Index	Page (P) Chapter (C)	Description	Date Dept./Init.
A	All	First issue	2014.06.28
B	All	Second issue	2014.07.14
C	All	Third Issue	2014.07.28
D	All	Fourth Issue	2014.10.02
E	All	Fifth Issue	2014.11.24
F	Item 3.5 Item4.1	Natural power factor of furnace 0.427. The system voltage rise power factor, THD level and system impedance resonance are considered. 4th Harmonic is also a main component of harmonic and, if the filter is set as 2nd, 3rd and 5th, the 4th shall be amplified a lot.	2015.02.10
	Item5	Note: The TCR part is not used for the calculation. It is just the interface of the calculation software.	

Date / prepared	24.11.2014	Abel Zhang	Project name	Sakura project
Date / checked			Project number	P132005
Date / approved			Based on	
Responsible Division	Project & Engineering		Document number	Language / Rev. ind. / Page / Pages
ABB	ABB Xi'an Power Capacitor Company Limited			EN / B / 1 / 23

Type Solution of Filter

Real Cases of Filter solution

Customer	Guiyang Aluminum
System	220kV network
Operating date	2005-2011

Power System

- Sd(min)12660.25MVAR
- DC load :

  Active 272MW

  Reactive 89Mvar
- AC load

  Active 23MW

  Reactive 12Mvar
- 5 Rectifiers,12 pulse per rectifier,totally 60pulses
- Power factor 0.87, target:0.92～0.984 (5 rectifiers) 0.91～0.96(4 rectifiers).

Type Solution of Filter

Real Cases of Filter solution

Branch	5th	7th	11th
Model	TALA22-5400/450BLW	TALA22-3600/300BLW	TALA22-5400/450BLW
Capacity kvar	5400	3600	5400
Capacitance μF	20.7	13.8	20.7
Capacity /unit kvar	450	300	450
Rated voltage kV	8.32		
Series & parallel	2 S 2 P		
Protect Type	Double-star unbalance current protection		
Inductance mH	19.68	15.14	4.21

Type Solution of Filter

Real Cases of Filter solution

Benefit to Customer

Power factor increases from 0.87 to above 0.93(meet power department requirement)

Reduce harmonic; decrease the electrolytic aluminum time, electrolyzer overhaul cycle lengthened. Electrolytic aluminum productivity increased.

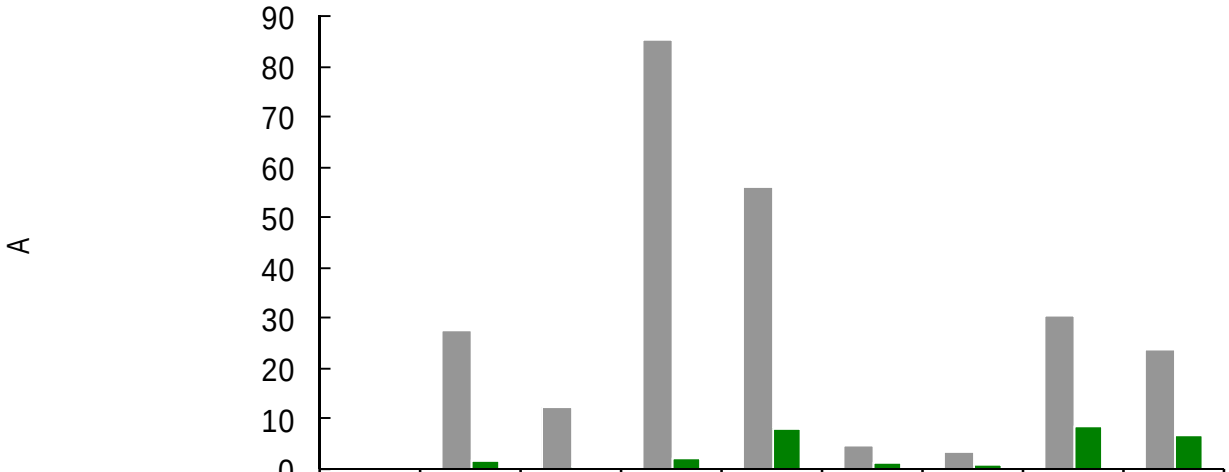
Running in later stage

- As for electrolytic aluminum electrolytic copper factory, adopt strong direct current electrolysis. So, the magnetic inductance of electro magnetic to nearby metal objects have to be taken into consideration. Magnetic metal as racks, accessories are not allowed.

Type Solution of Filter

Real Cases of Filter solution

Harmonics current comparison before and after filter



		3	5	7	11	13	17	19	23	25
Before	滤波前谐波电流	0	27.6	12.1	85.5	55.9	4.8	3.2	30.4	23.8
After	滤波后谐波电流	0	1.6	0.6	2.3	8	1.1	0.8	8.3	6.7

Type Solution of Filter

Real Cases of Filter solution

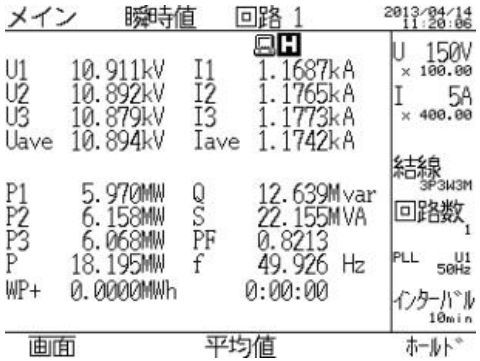
Type Solution of Filter

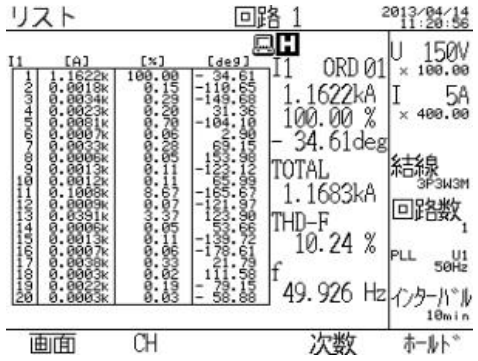
Real Cases of Filter solution

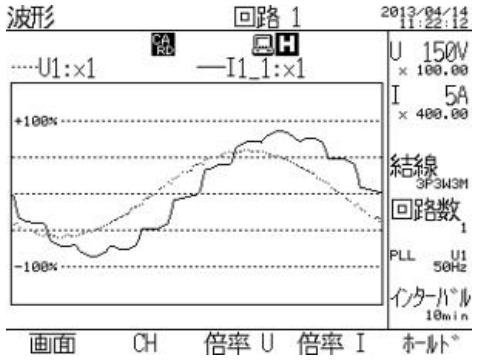
	Mode1(3-635V-19.04kA)			Mode2(4-615V-15.23kA)		
11kV voltage factor	1.05	1	0.95	1.05	1	0.95
Running branch	5,7,11	5,7,11	5,7,11	5,7,11	5,7,11	5,7,11
Stopped branch	13	13	13	13	13	13
PF	0.971	0.986	0.998	0.947	0.967	0.986
THDu%	4.449	4.532	4.613	4.308	4.388	4.464
System voltage distortion (kV)	0.31	0.27	0.23	0.31	0.27	0.23
	Mode3(3-520V-19.04kA)			Mode4(4-498V-15.23kA)		
11kV voltage factor	1.05	1	0.95	1.05	1	0.95
Running branch	5,7,11 ,13	5,7,11 ,13	5,7,11 ,13	5,7,11 ,13	5,7,11 ,13	5,7,11 ,13
Stopped branch	/	/	/	/	/	/
PF	0.98	0.984	0.989	0.953	0.96	0.968
THDu%	1.646	1.684	1.729	1.642	1.678	1.722
System voltage distortion (kV)	0.55	0.48	0.37	0.55	0.48	0.41
	Mode5(3-505V-4.08kA)			Mode6(4-505V-4.08kA)		
11kV voltage factor	1.05	1	0.95	1.05	1	0.95
Running branch	5,7	5,7	5,7	5,7	5,7	5,7
Stopped branch	11,13	11,13	11,13	11,13	11,13	11,13
PF	0.987	0.989	0.992	0.924	0.935	0.948
THDu%	1.819	1.783	1.743	2.191	2.148	2.098
System voltage distortion (kV)	0.14	0.12	0.1	0.14	0.12	0.1
	Mode7(3-435V-4.08kA)			Mode8(4-435V-4.08kA)		
11kV voltage factor	1.05	1	0.95	1.05	1	0.95
Running branch	5,7	5,7	5,7	5,7	5,7	5,7
Stopped branch	11,13	11,13	11,13	11,13	11,13	11,13
PF	0.953	0.954	0.957	0.852	0.864	0.878
THDu%	1.572	1.541	1.506	1.842	1.806	1.764
System voltage distortion (kV)	0.14	0.12	0.1	0.14	0.12	0.1
	Mode9(2-635V-19.04kA)					
11kV voltage factor	1.05	1	0.95			

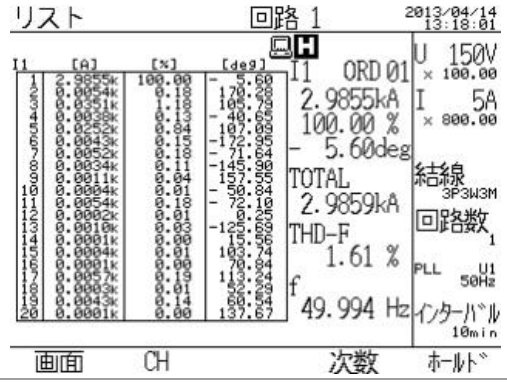
Type Solution of Filter

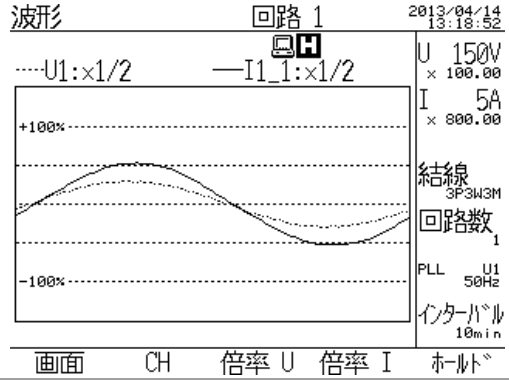
Real Cases of Filter solution







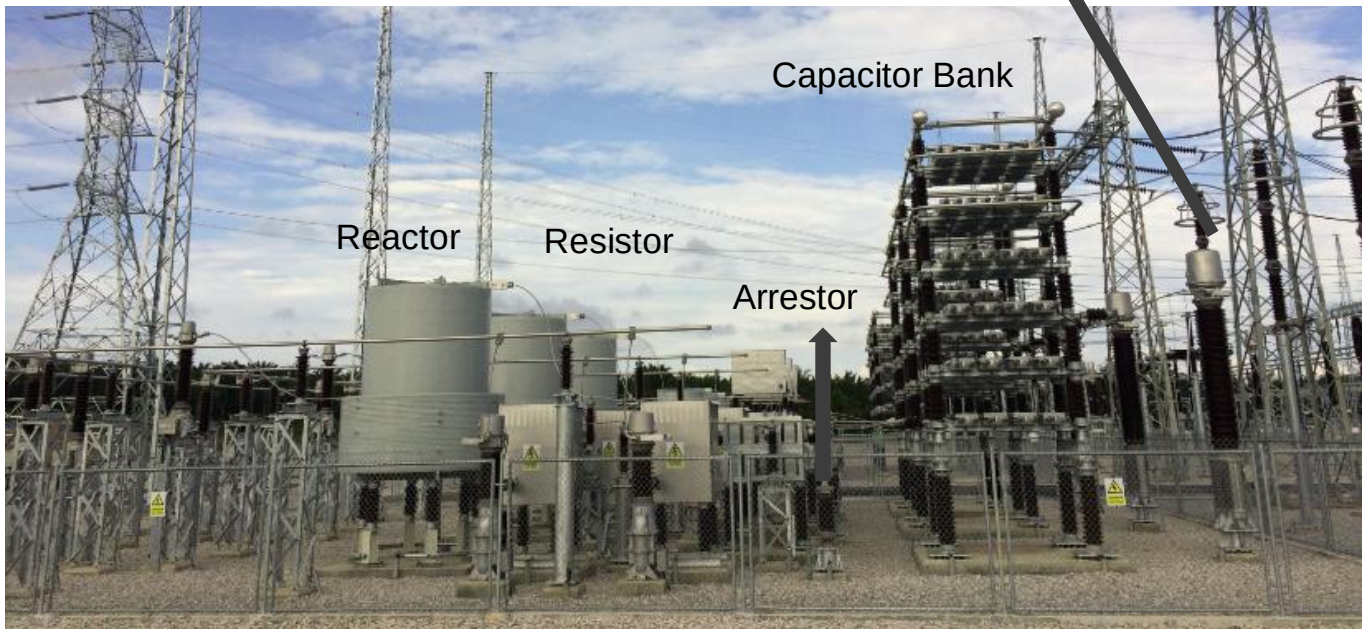




Type Solution of Filter

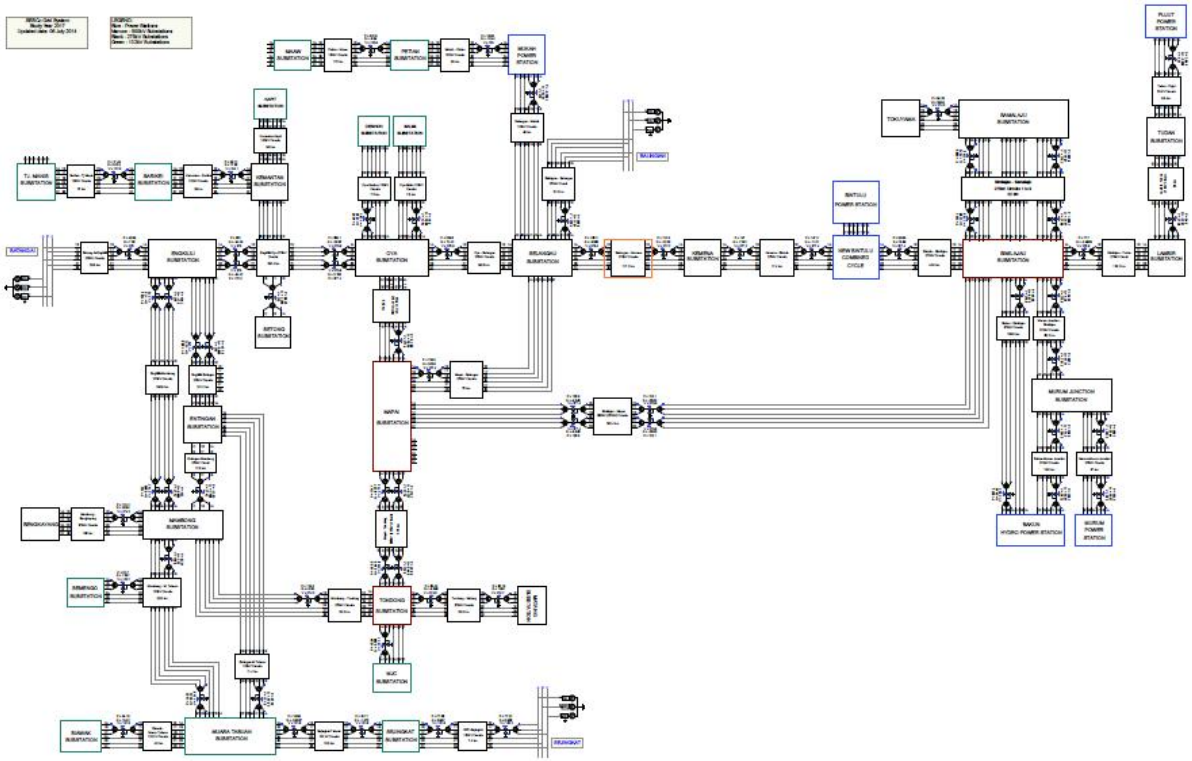
Real Cases of Filter solution

MY Samalaju 275kV Filter



Type Solution of Filter

Real Cases of Filter solution



Type Solution of Filter

Real Cases of Filter solution

1.1. For capacitor bank analysis

1.1.1. Parameters design of the components:

- Capacitor bank
- Reactor
- Arrester
- Magnetic Voltage Transformer
- Current transformer
- Earthing switch

1.1.2. Characteristic curve of MFC Frequency – Impedance

1.1.3. Modeling the capacitor bank by PSCAD

1.1.4. Inrush current analysis

1.1.5. Transient voltage analysis

1.1.6. Insulation coordination calculation

1.2. For power system

1.2.1. Power factor & Voltage rise analysis

1.2.2. Resonance analysis

- Harmonic resonance frequency calculation
- Frequency scan by PSCAD model with 4*100Mvar bank operating

1.2.3. Harmonic analysis

Type Solution of Filter

Real Cases of Filter solution

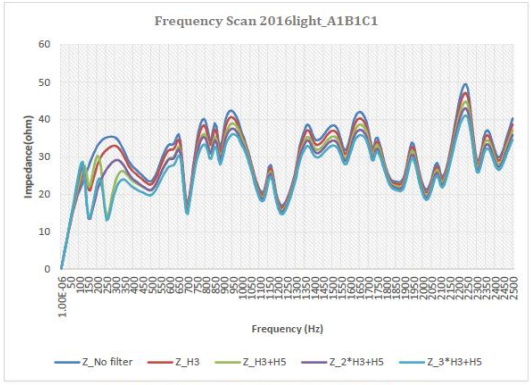


Fig 4.2 Frequency scan result of 2016light A1B1C1 case

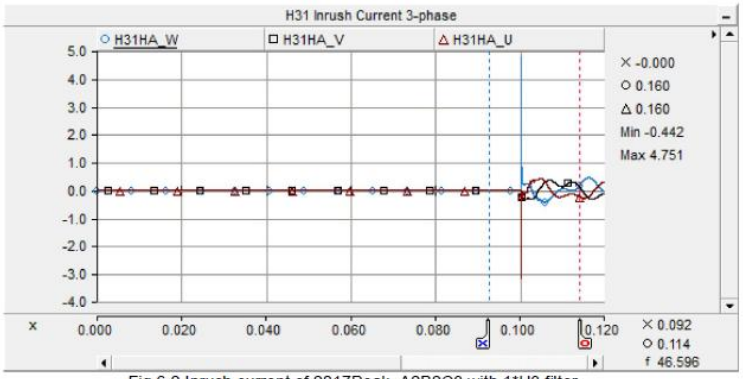


Fig 6.2 Inrush current of 2017Peak_A2B2C3 with 1*H3 filter

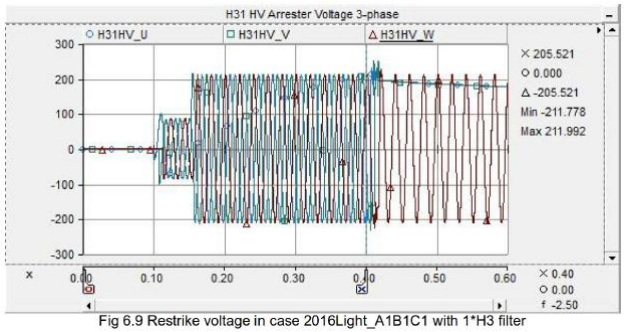


Fig 6.9 Restrike voltage in case 2016Light_A1B1C1 with 1*H3 filter

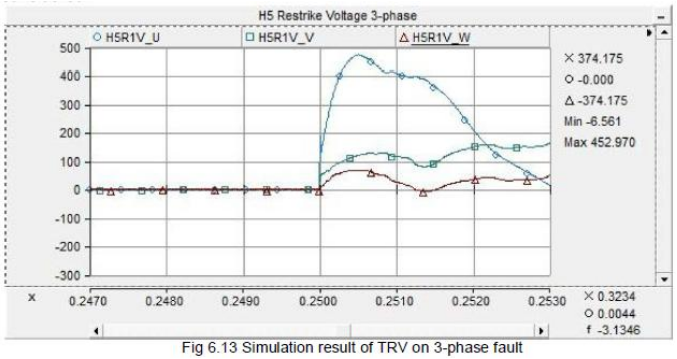


Fig 6.13 Simulation result of TRV on 3-phase fault

Type Solution of Filter

Real Cases of Filter solution

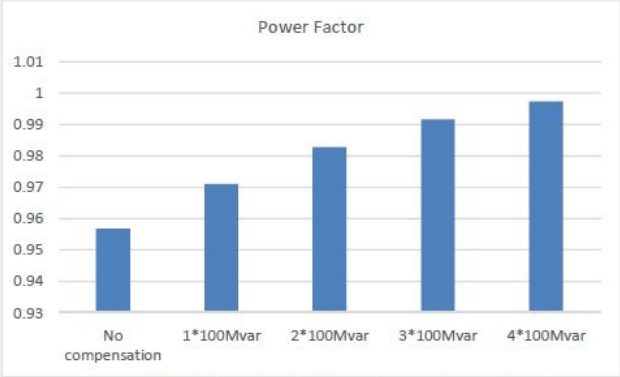


Fig 6.20 Power factor simulation result of 2016_light A1B1C1

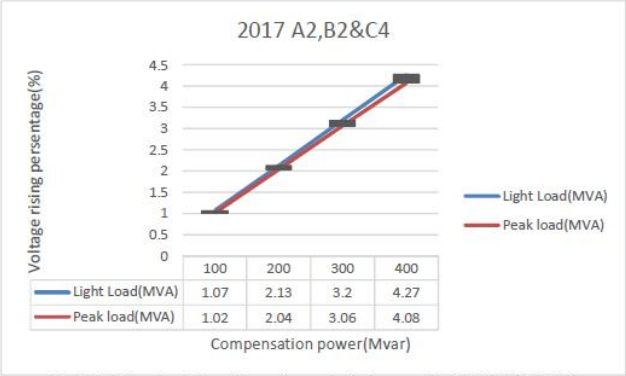
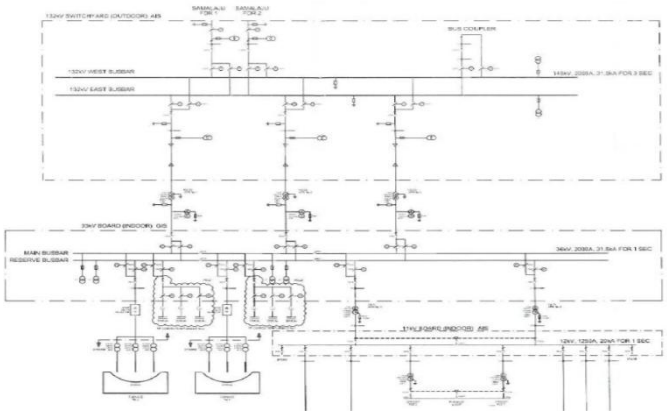


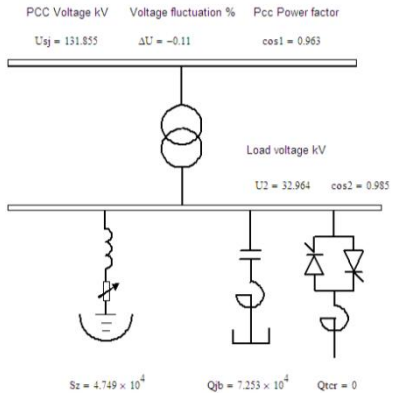
Fig 6.19 Steady state voltage rise calculation result of 2017_A2B2C4

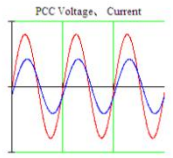
THD Total					
	ABB Xian Result	ABB PSC Result(R2)		ABB PSC Result(R3)	
Operation Case	2017-peak-A2B2C3 (BASE CASE)	2016-Light-A1B1C1 (BASE CASE)	2016-Light-A1B1C1 (CRITICAL CONTINGENCY)	2017-light-A2B1C1 (BASE CASE)	2017-light-A2B1C1 (CRITICAL CONTINGENCY)
Without filters	3.00%	3.23%	4.46%	2.96%	3.68%
1*H5 filter	2.80%	3.05%	3.84%	2.57%	3.29%
1*H3 filter	2.00%	2.80%	3.62%	2.54%	2.97%
1*H3+H5 filters	1.60%	2.35%	3.02%	2.08%	2.40%
2*H3 filters	1.71%	2.54%	3.07%	2.19%	2.49%
2*H3+H5 filters	1.40%	2.08%	2.47%	1.72%	1.90%
3*H3 filters	1.51%	2.25%	2.69%	1.93%	2.16%
3*H3+H5 filters	1.30%	1.81%	2.14%	1.47%	1.59%

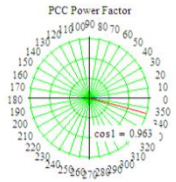
Type Solution of Filter

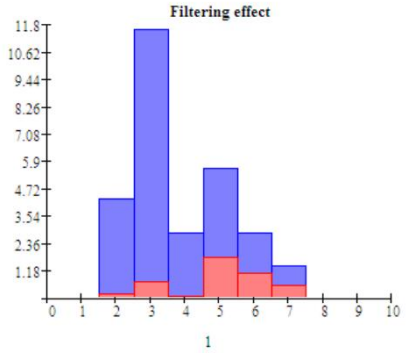
Real Cases of Filter solution







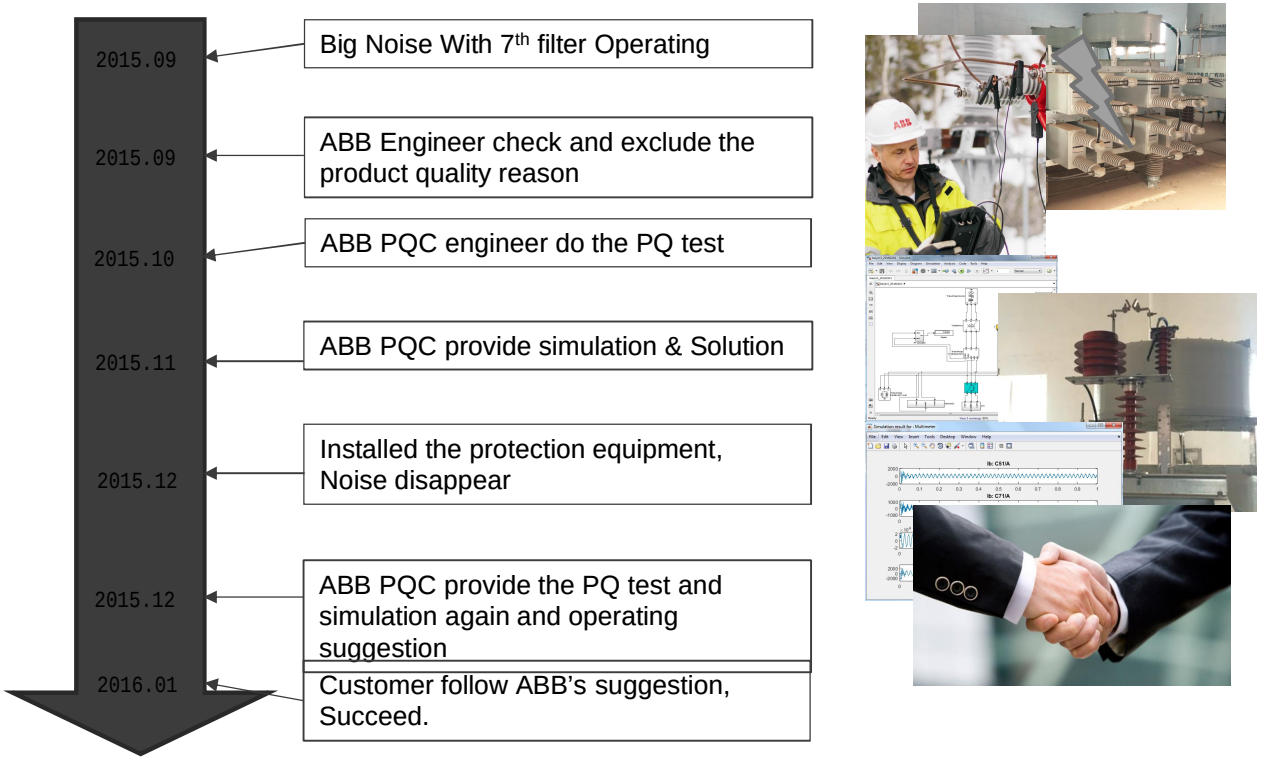




Quantity	2sets
Rated voltage(kV)	35
Rated capacity(Mvar)	
H2 Filter	54.1
H3 Filter	28.8
H4 Filter	13.4

Type Solution of Filter

Real Cases of Filter solution



Type Solution of Filter

Real Cases of Filter solution

- Variant kinds of load, DC/AC Drive, DC/AC arc furnace
- Issues with harmonic, low PF, and load-balancing
- Mixed solution with Dynacomp, MV filter, and MV SVG
- Aiming to have a standard sizing tool for future use