

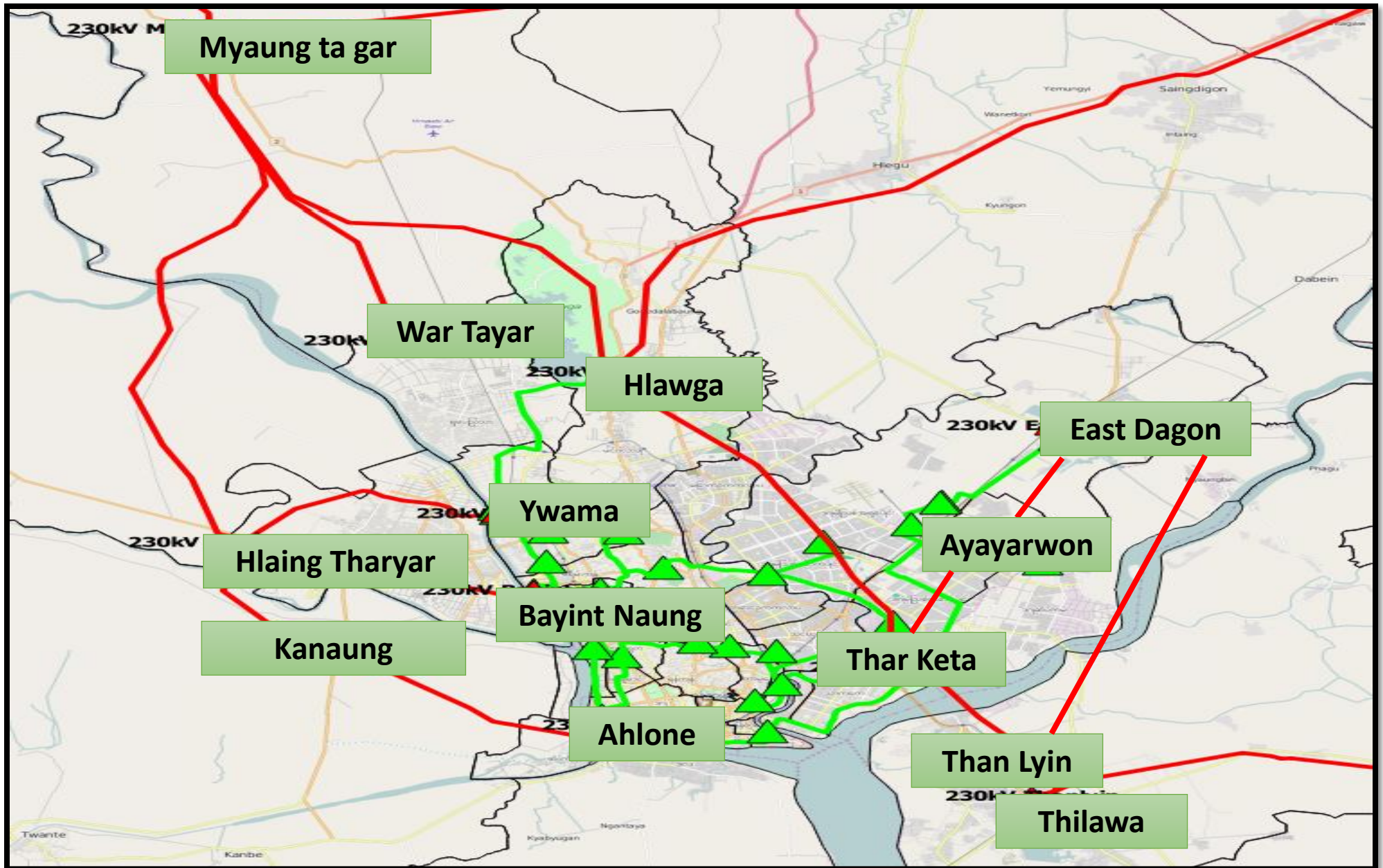
Power Quality Management

**U Maung Maung Thant Zin
P E . 1154 (Electrical Power)**

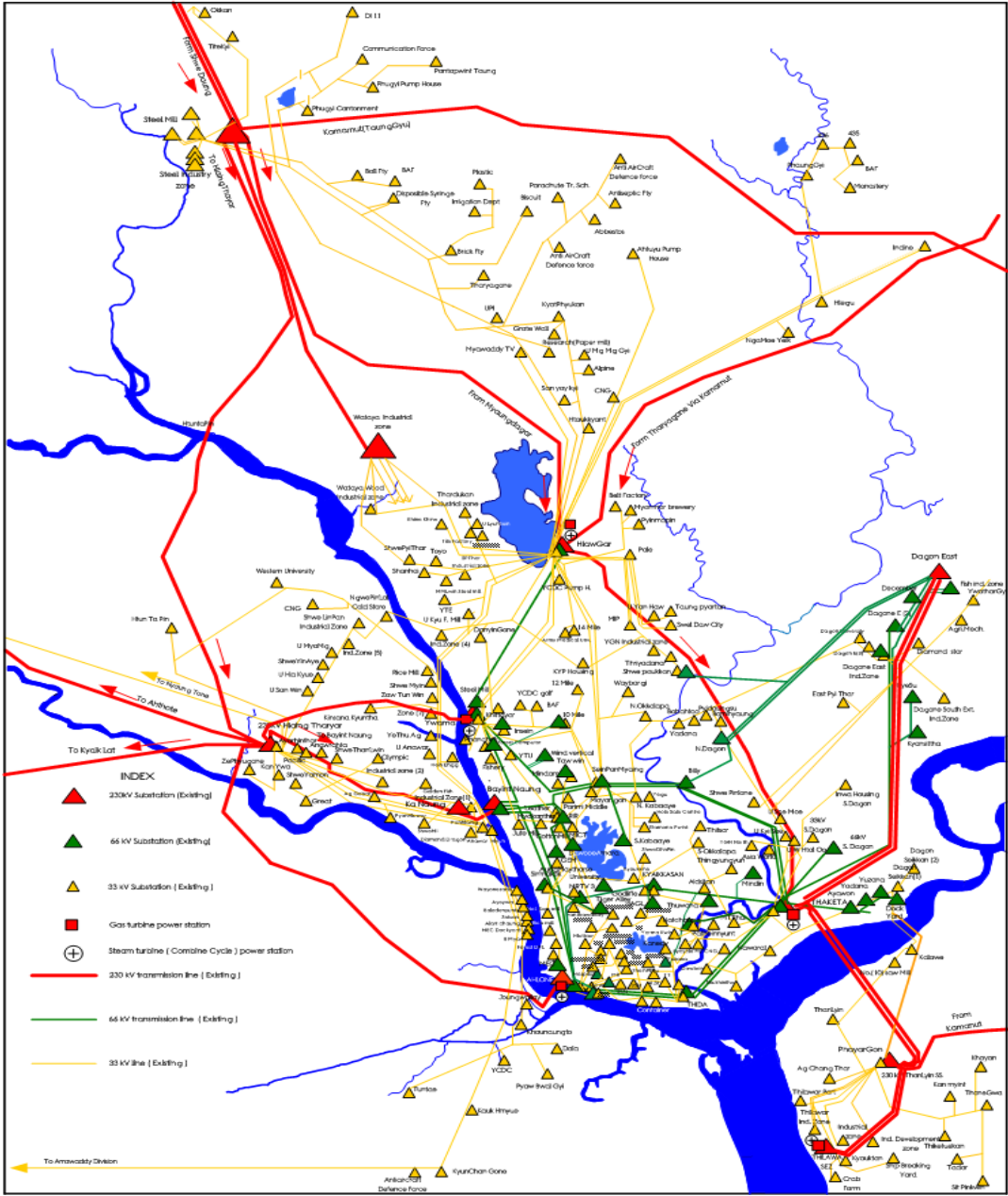
This discussion is referenced from
Training programme on
Power distribution system engineering, Management and
Technology by JICA, TICA and MEA.



(230)kV Sub Station

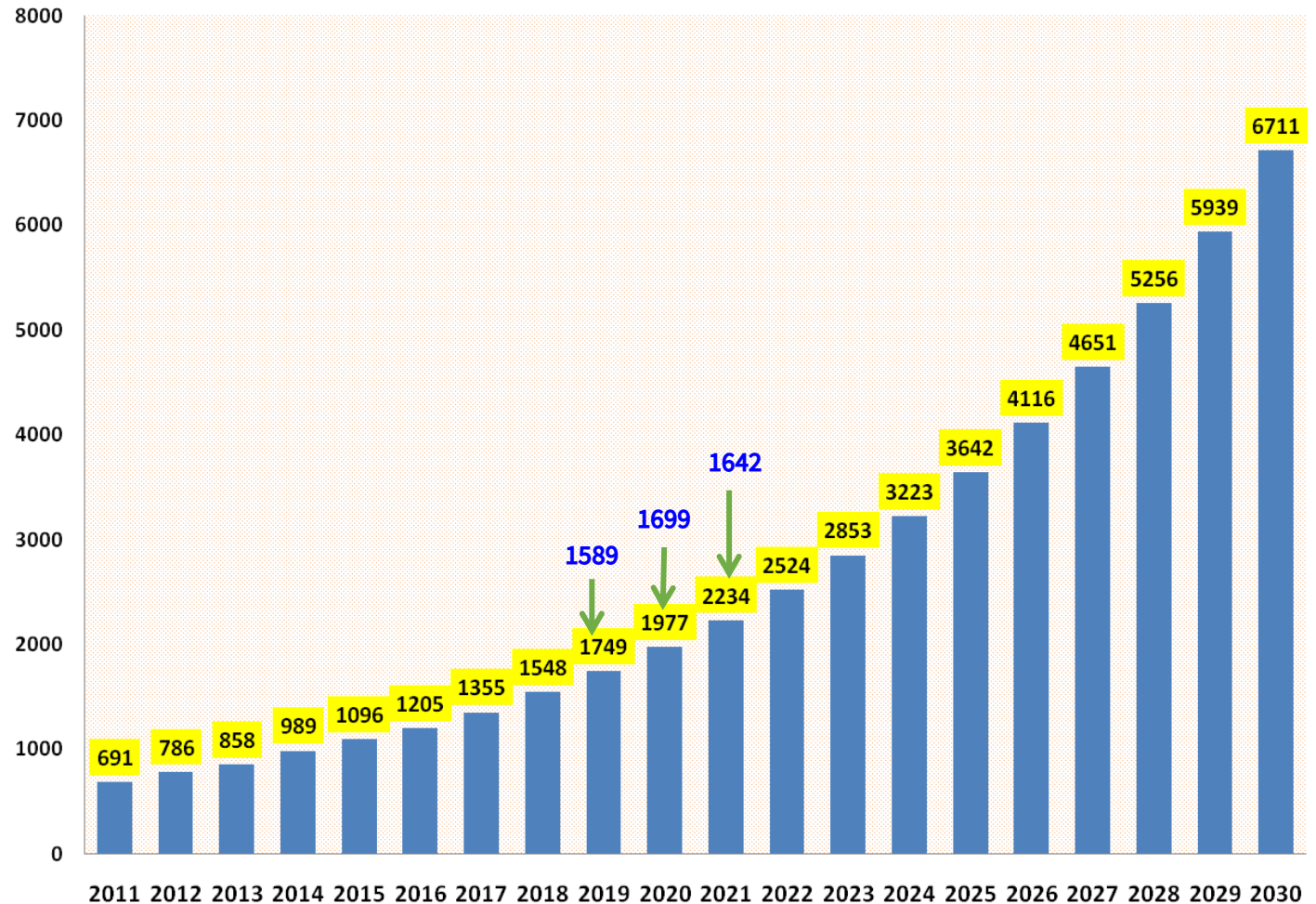


230kV , 66 kV and 33 kV Net work diagram of Yangon Distribution System



Demand Growth and Future Forecast of Yangon (MW)

Sr.	Year	Demand Forecast of Yangon Load (MW)	Increase (%)
1	2011	691	
2	2012	786	12
3	2013	858	8
4	2014	989	13
5	2015	1096	10
6	2016	1205	9
7	2017	1355	11
8	2018	1548	13
9	2019	1749	13
10	2020	1977	13
11	2021	2234	13
12	2022	2524	13
13	2023	2853	13
14	2024	3223	13
15	2025	3642	13
16	2026	4116	13
17	2027	4651	13
18	2028	5256	13
19	2029	5939	13
20	2030	6711	13



PRESANTATION OUTLINE

- ❑ Introduction to Power Quality and Bisic Principle.**
- ❑ Why do Power Quality interest?**
- ❑ Impact of Power Quality problem.**
- ❑ Types of Power Quality problem.**
- ❑ Steady-state Power Quality problem.**
- ❑ Event Power Quality problem.**

PRESANTATION OUTLINE

- ❑ Source of Power Quality problem.
- ❑ Impact of Power Quality problem and Mitigation.
- ❑ Harmonic generated equipments.
- ❑ Impact of Harmonic to Power System
- ❑ Mitigation of Harmonic problem.
- ❑ Power factor and impact of low power factor.
- ❑ Power factor correction solutions.

PRESANTATION OUTLINE

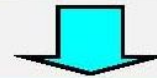
- ❑ Voltage Fluctuation and cause of Fluctuation.
- ❑ Solution of Voltage Fluctuation.
- ❑ Voltage Unbalance and it's impact.
- ❑ Voltage Unbalance mitigation.
- ❑ Reliability Indices.
- ❑ Voltage Dip (Sag).
- ❑ Voltage Dip Mitigation for Utility.

Introduction to PQ and Basic Principle

1st Era



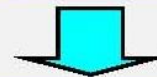
Availability : Expand power supply to all customer in the service area



2nd Era



Reliability : Improve the stability of power supply. Reduce frequency and period of interruption



3rd Era



Power Quality : Improve quality of supplied voltage. Control and reduce disturbance which can impact the operation of equipment

Power Quality = Voltage Quality



Quality Supply

1

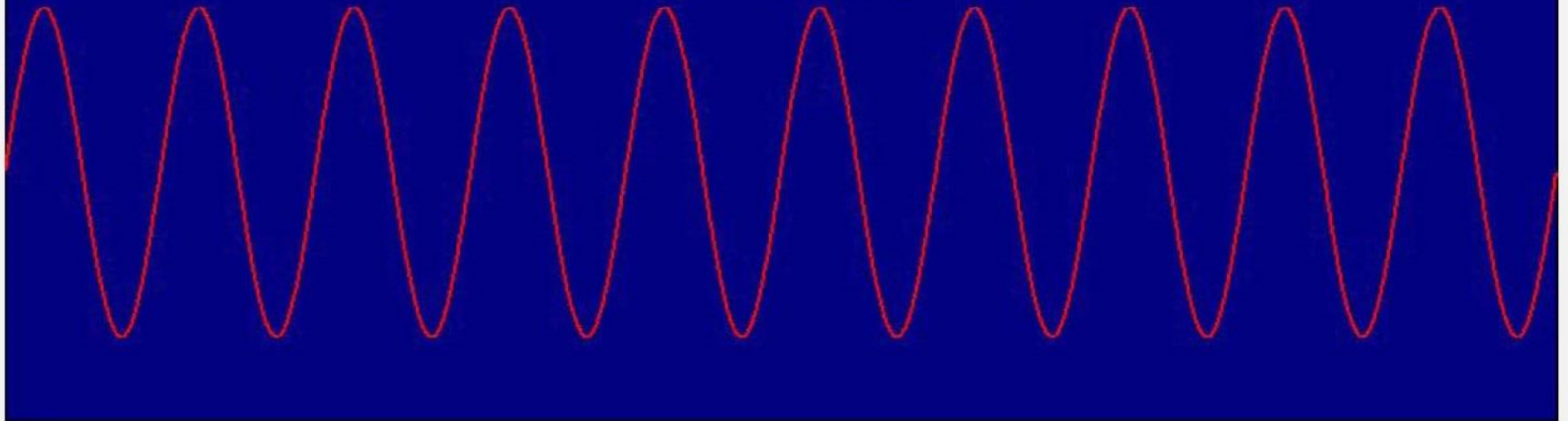


2

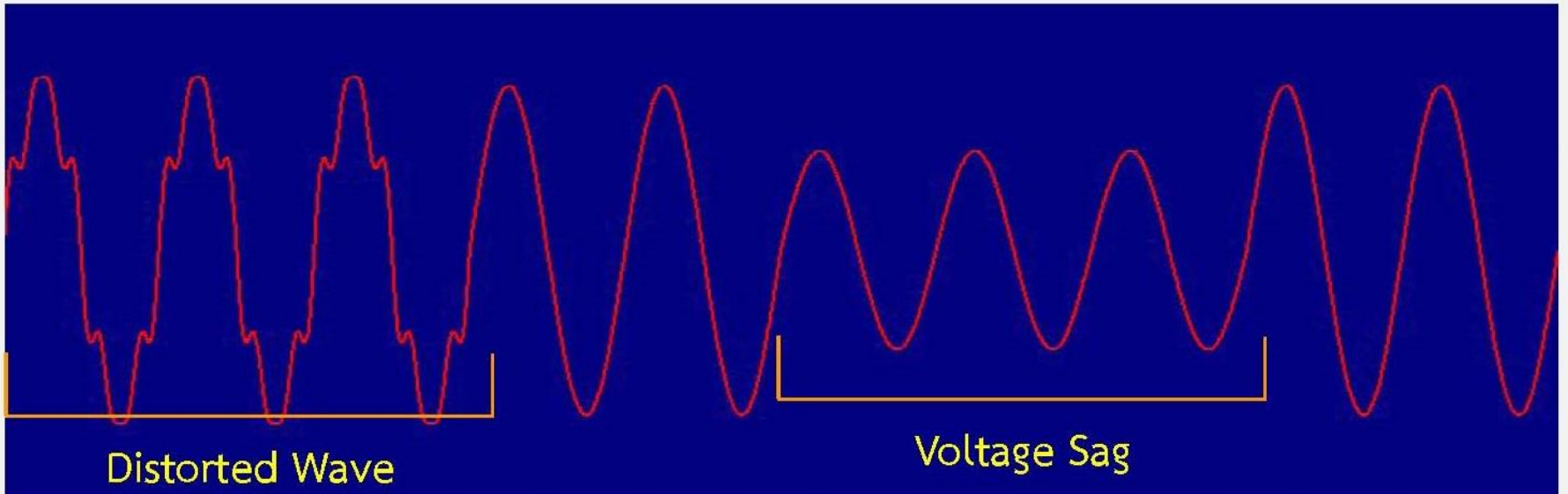
Load receive supplied voltage which having magnitude and frequency in standard range and voltage waveform does not distort from sine wave

PQ problem is “any electrical problem caused by distortion of magnitude, frequency or waveform of supplied voltage and affect equipment to malfunction or damage”

Pure Sine Wave

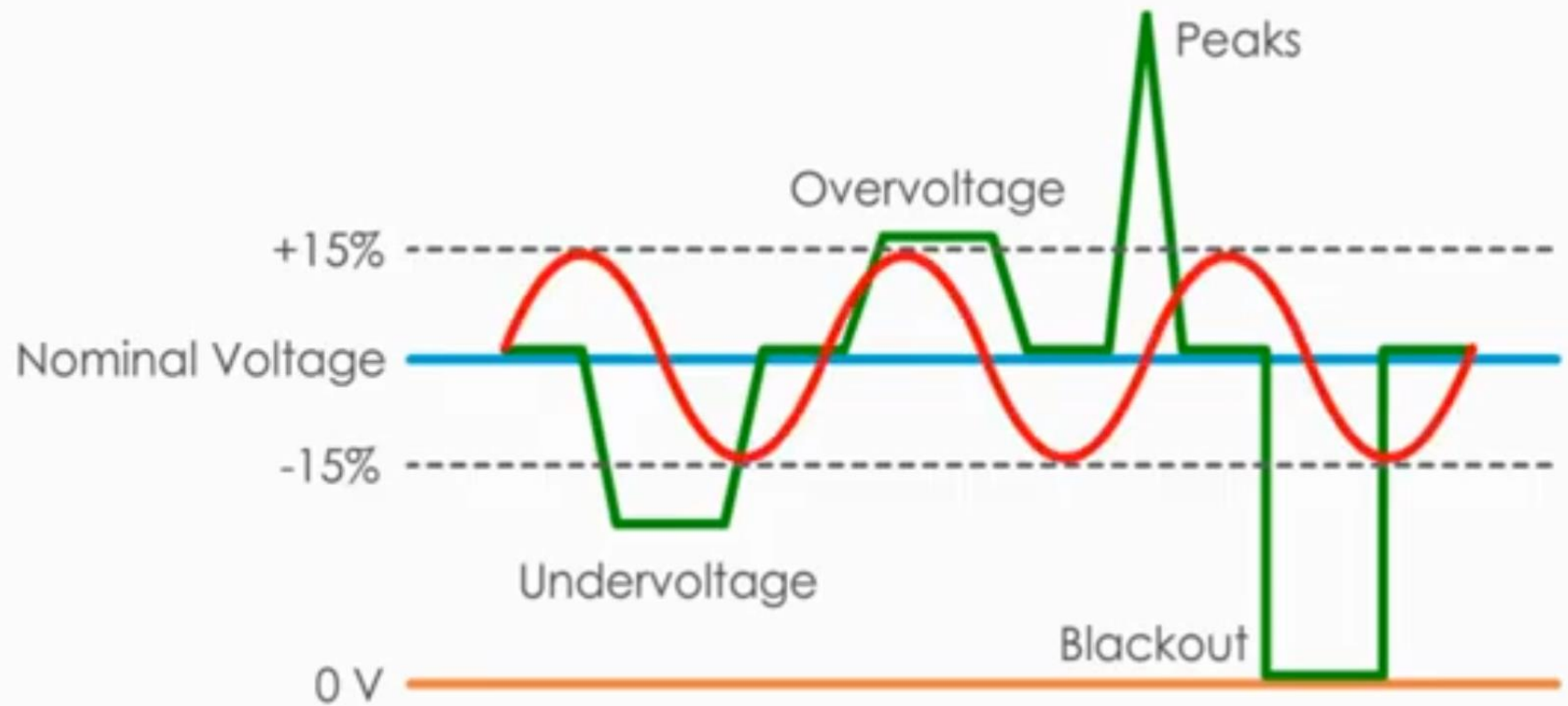


Distorted Wave



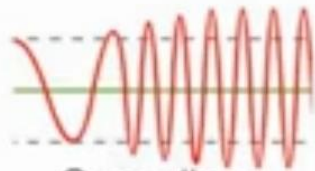
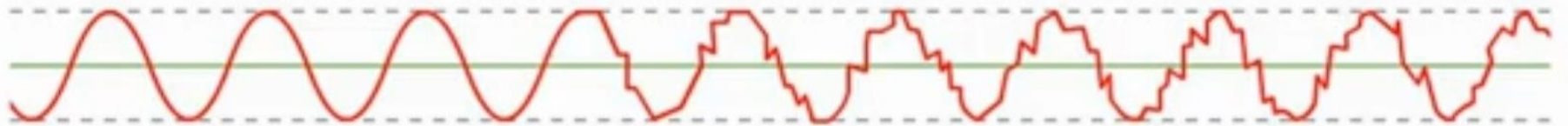
Voltage Sag

Power Quality problems

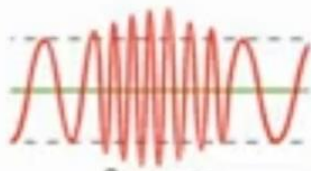


in a smooth curve waveform.

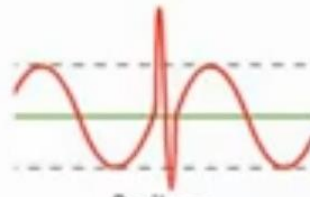
Power Quality problems



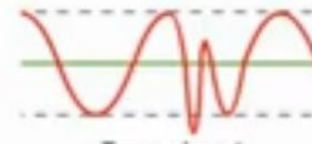
Overvoltage



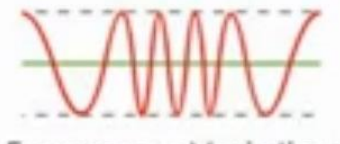
Surges



Spikes



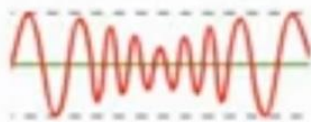
Transient



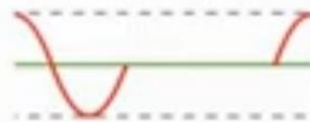
Frequency Variation



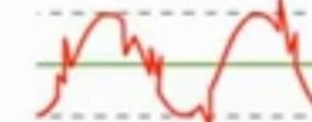
Undervoltage



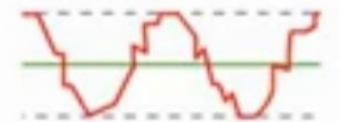
Sags



Blackouts



Noise



Harmonics

Why do Power Quality interest us?

- Modern equipments produce more power quality problems than the old ones
- In the same time, these equipments are more sensitive to power quality problems
- Increasing of electronic and computer control in industrial process

Why do Power Quality interest us?

The Advance in Microelectronics

(Approximate Sensitivity Level to Disrupt)

- 1970 : 1000 transistors per chip (0.001 J)
- 1980 : 10,000 transistors per chip (0.0001 J)
- 1990 : 1,000,000 transistors per chip (0.000001 J)
- 2006 : 100,000,000 transistors per chip (0.00000001 J)

What is the impact of PQ problem?

- Cause equipment to malfunction or trip out
- Increase losses in equipment and system
- Reduce equipment life time
- Damage equipment in some severe case
- Annoy the working environment
- Produce the noise in communication system

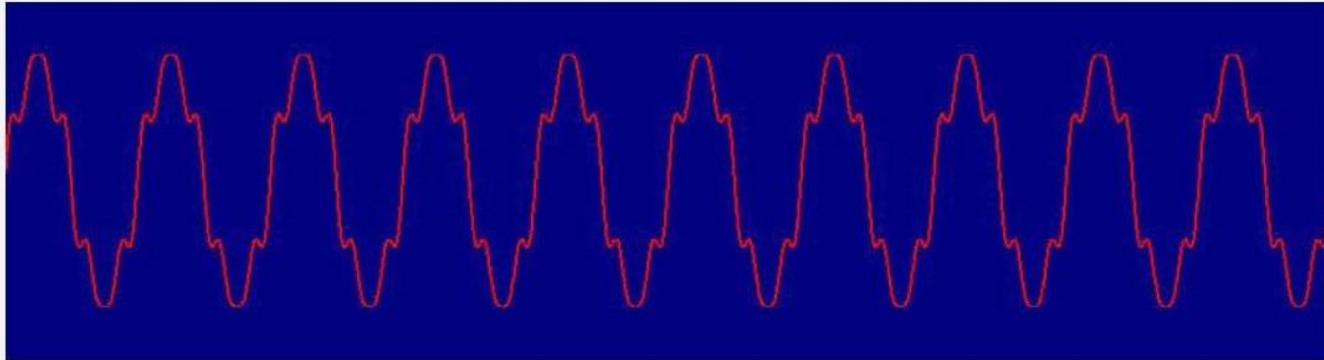
Type of Power Quality Problems

Classify by characteristic

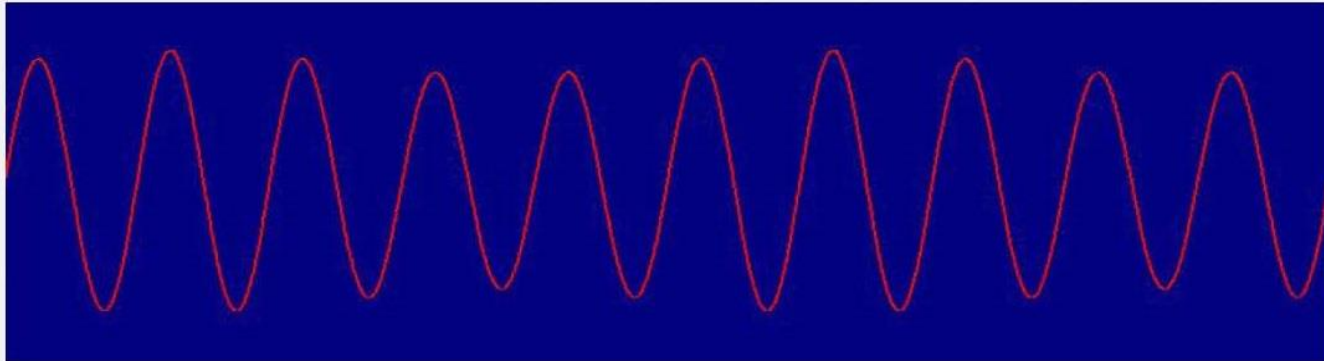
1. Steady-state Power Quality Problem

- Undervoltage and Overvoltage
- Harmonics
- Voltage Fluctuation
- Voltage Unbalance

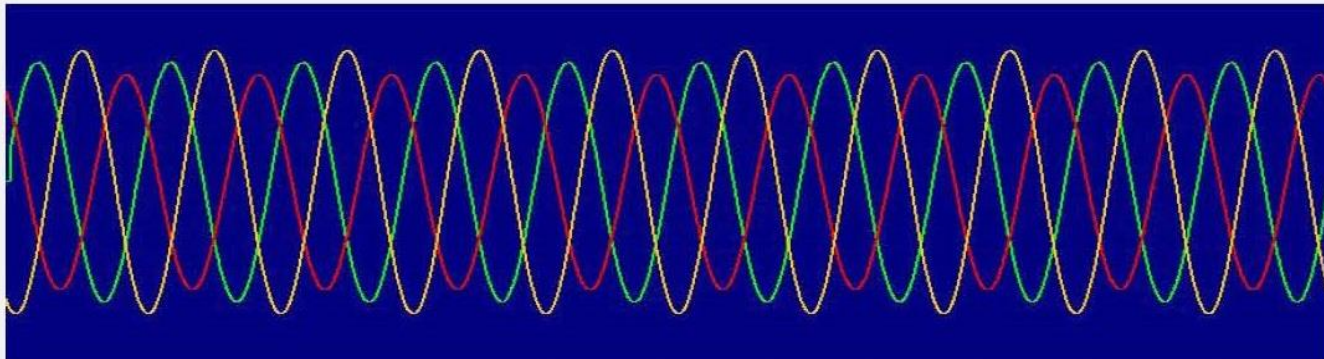
Steady State Power Quality Problem



Harmonics



Flicker



Unbalance

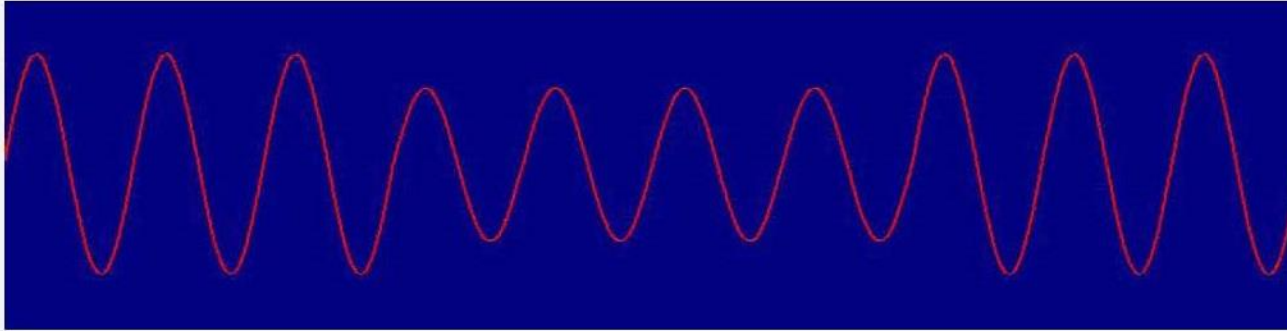
Type of Power Quality Problems

Classify by characteristic

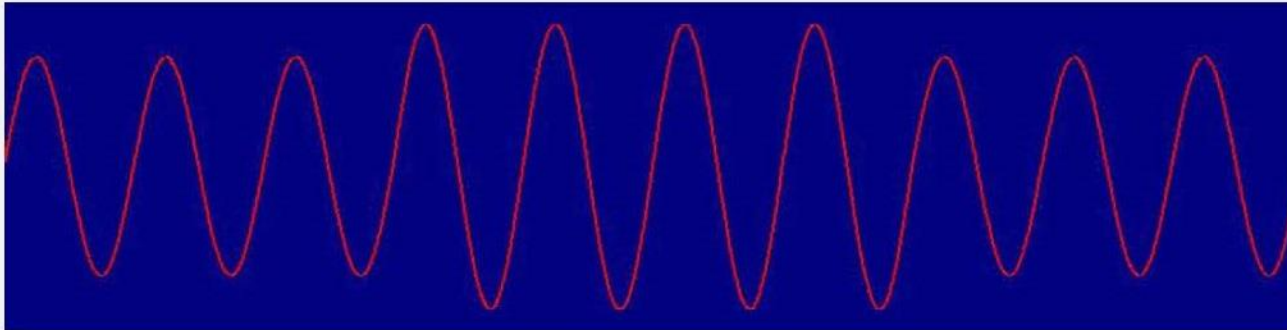
2. Event Power Quality Problem

- Short Interruption
- Voltage Dip (or Sag)
- Voltage Swell
- Voltage Surge

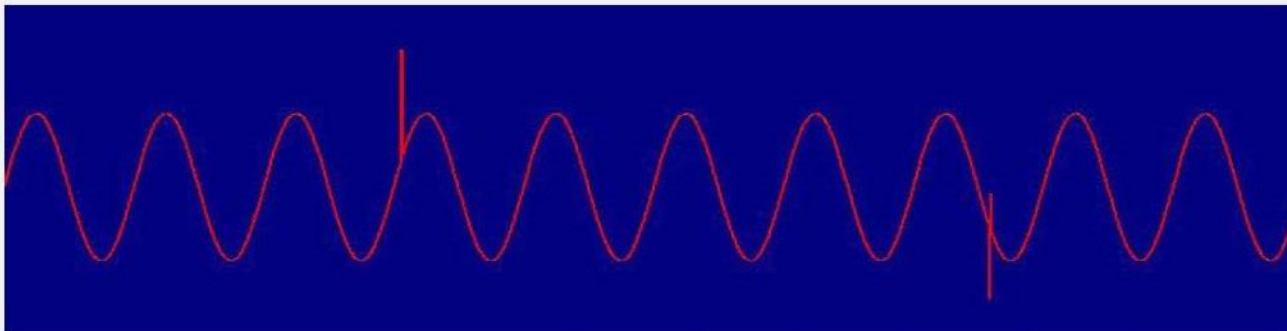
Event Power Quality Problem



Voltage Dip



Voltage Swell



Voltage Surge

Source of PQ Problem

Customer Equipment

- Harmonics
- Flicker
- Unbalance
- Voltage Dip

Abnormal Event in Power System

- Voltage Dip
- Voltage Swell
- Voltage Surge
- Interruption

Improper System Control

- Overvoltage
- Undervoltage
- Unbalance

Abnormal Current and Voltage Quality

- The product of abnormal current and system impedance cause supplied voltage to deviate or distort from sine wave

I distorted --> V distorted

I fluctuated --> V flicker

I unbalance --> V unbalance

I fault --> V dip

I lightning --> V impulse

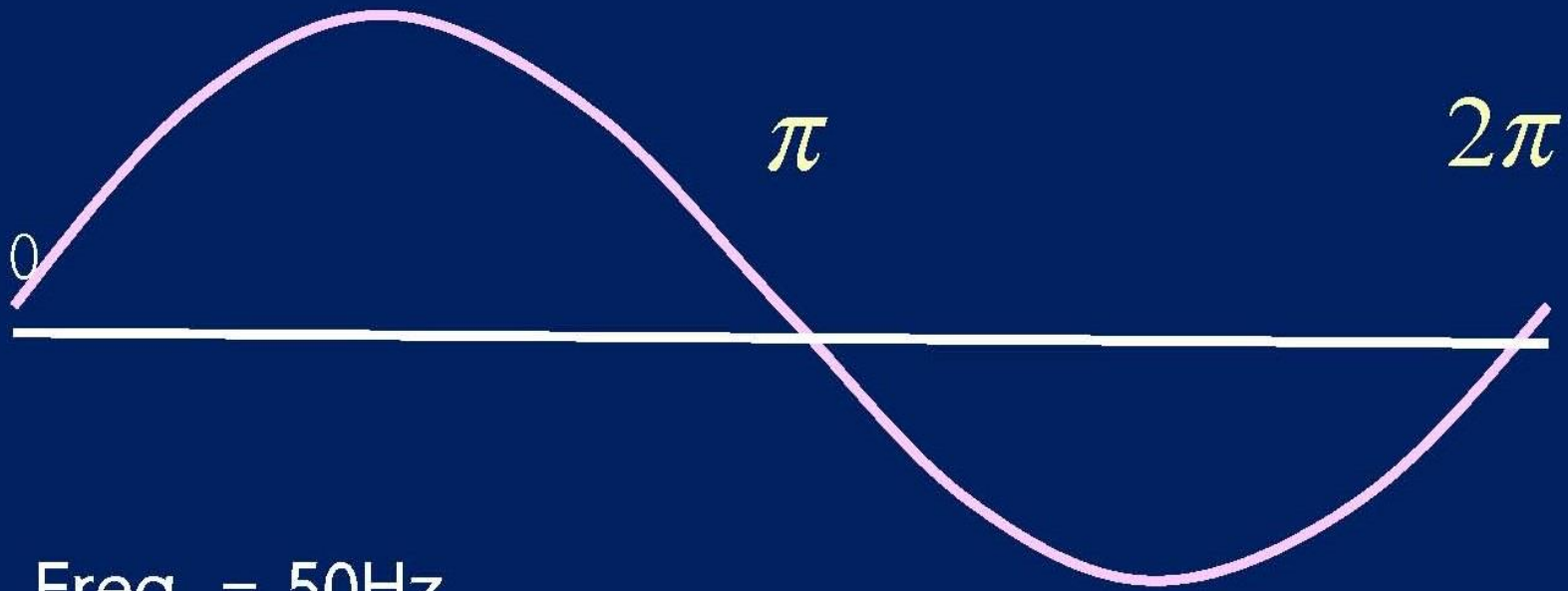
Impact from PQ Problem and Mitigation

What are Harmonics?

- Harmonics are **components in sinusoidal** voltages or currents having frequencies that are **integer multiples** of the frequency at which the supply system is designed to operate (termed the **fundamental frequency**)
- In Thailand, fundamental frequency is 50 Hz then
 - 100 Hz component is **2nd** harmonic
 - 150 Hz component is **3rd** harmonic

Fundamental Wave

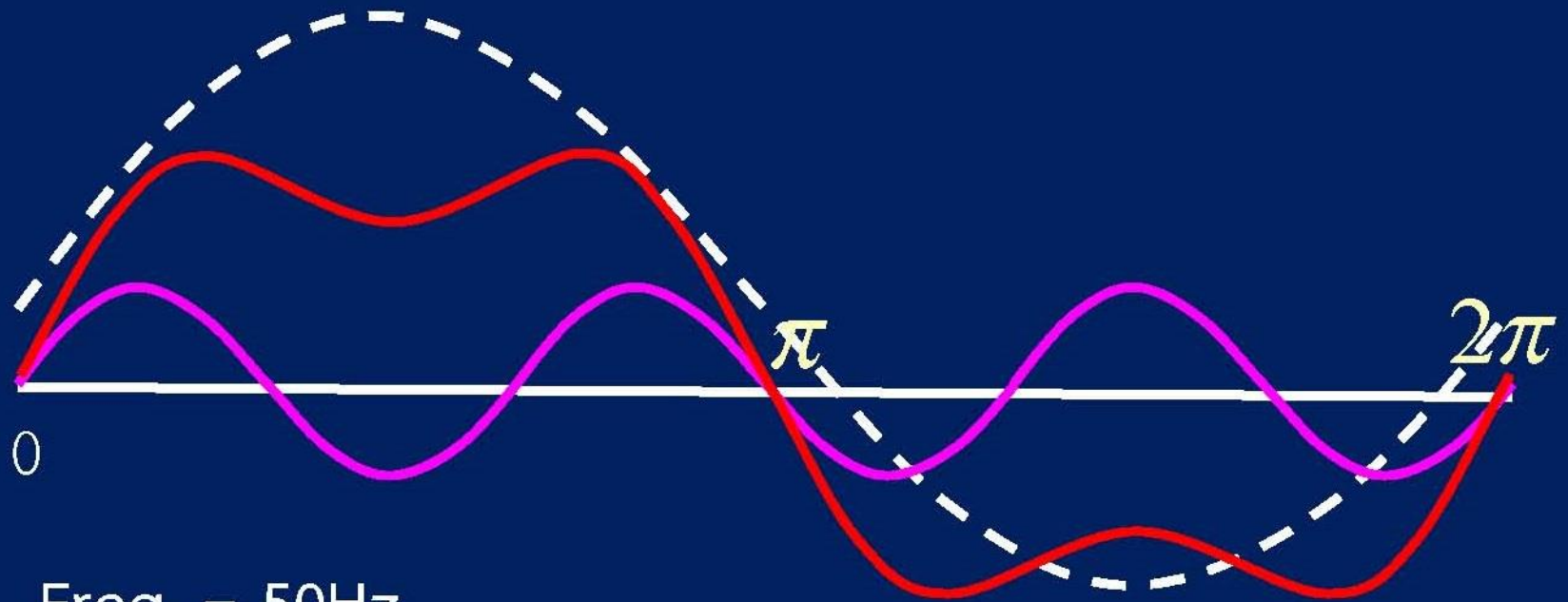
- Fundamental sinusoidal wave



Freq. = 50Hz

Third Harmonic

- Fundamental and 3rd harmonic waves

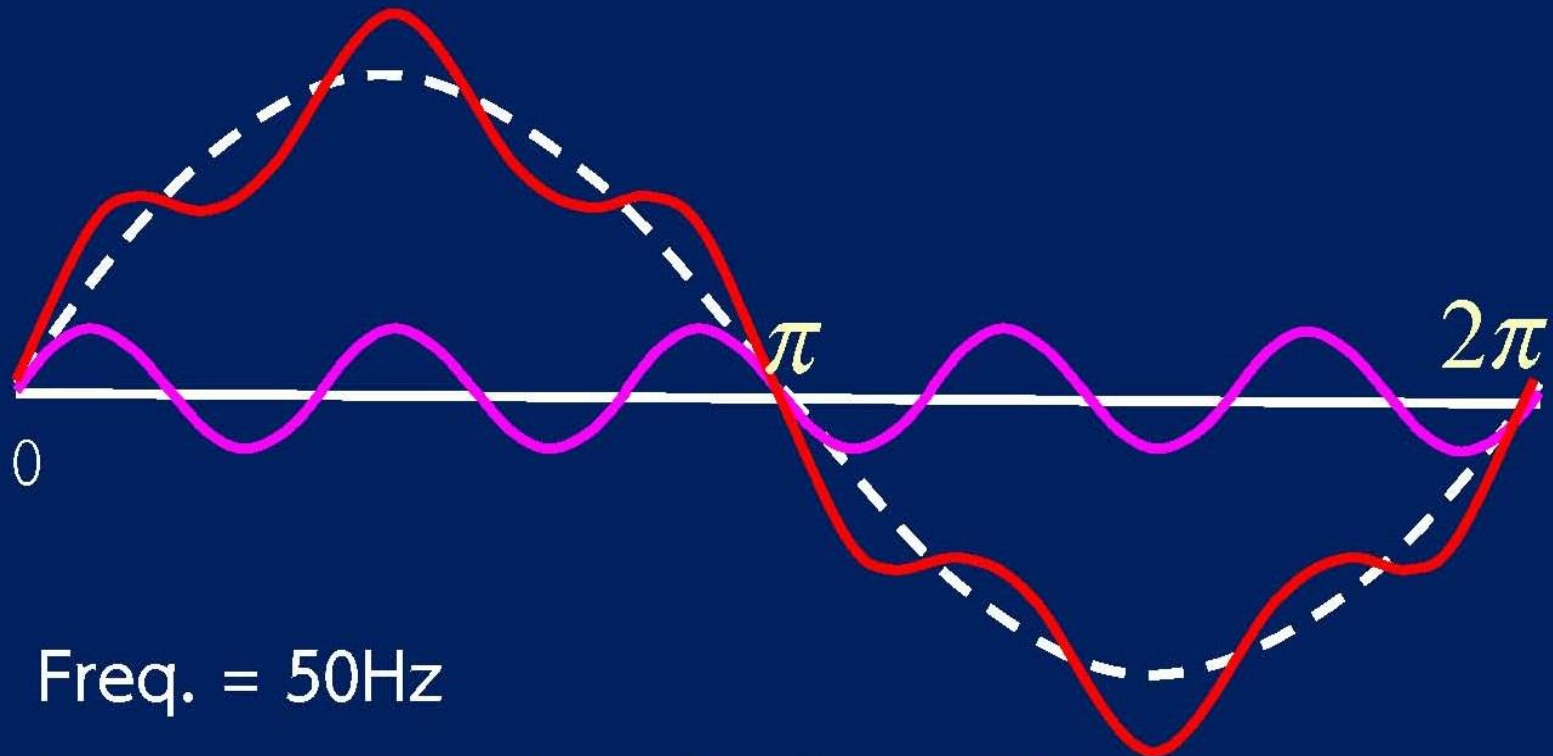


Freq. = 50Hz

Freq. = 150Hz, Amplitude = 33%

Fifth Harmonic

- Fundamental and 5th harmonic waves



Freq. = 50Hz

Freq. = 250Hz, Amplitude = 20%

How does harmonics occur?

- Harmonics are produced from the operation of non-linear loads
- Non-linear loads are loads which although they are supplied with pure sine wave voltage, they draw distorted current (non sine wave current)
- By using Fourier Series, we can analyze this distorted current in to fundamental component and harmonic components

Harmonics Generated Equipments

- Converter or Inverter
- Adjustable Speed Drive
- Switching Mode Power Supply
- Uninterruptible Power Supply (UPS)
- Arc Furnace
- Arc Welder
- Discharge Lamp
- Saturated Transformer

Causes of harmonics

❖ Nonlinear loads



Effects of harmonics

❖ Damage power factor correction capacitors

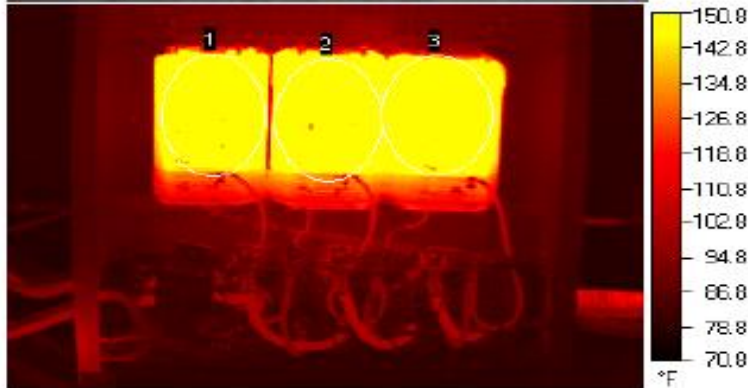


Effects of harmonics (cont.)

- ❖ Over temperature causes damages, reduces lifetime and efficiency of equipment (transformers, generators, motors, cables...).



Load 100%
Harmonics



Effects of harmonics (cont.)

- ❖ Because of high harmonic current, it is required to use larger cable size, this increases the investment cost.



Effects of harmonics (cont.)

- ❖ Cause damages of computer power supplies, power electronic equipment, and programmable logic controllers (PLCs),...



Standards on harmonics



IEEE Std 519 -1992 Harmonic Limits

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5
NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.		

Standards on harmonics



IEEE Std 519 -1992 Harmonic Limits

Current Distortion Limits for General Distribution Systems (120 V Through 69000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
$<20^*$	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits above.						
Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.						
* All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L .						
Where						
I_{sc}	= maximum short-circuit current at PCC.					
I_L	= maximum demand load current (fundamental frequency component) at PCC.					
TDD	= Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand).					
PCC	= Point of common coupling.					

Impact of Harmonics to Power System

- Increase Skin Effect and Proximity Effect
- Increase Eddy Current and Hysteresis Loss in transformer
- Generate Negative and Zero sequence in power system
- Lead to Resonance condition in power system
- Cause a noise in communication system

Eddy Current and Hysteresis

- Transformer supply a lot of non-linear load at their rated power may face an overheat problem
- In other word, transformer supplying a lot of non-linear load must be reduce their capacity (Derating)

Harmonic Problem Mitigation

- Can be implemented as followings:
 1. Decrease system impedance
 2. Change location and resize capacitor
 3. Install harmonic filter

Decrease system impedance

- Level of Voltage Distortion depends on system impedance
- Power system having high Short Circuit level will have low system impedance. Even though there is a high degree of harmonic current flowing in the system, voltage distortion in the system still be in acceptable level
- Decreasing system impedance is done by selection of low impedance transformer and larger conductor

Install harmonic filter

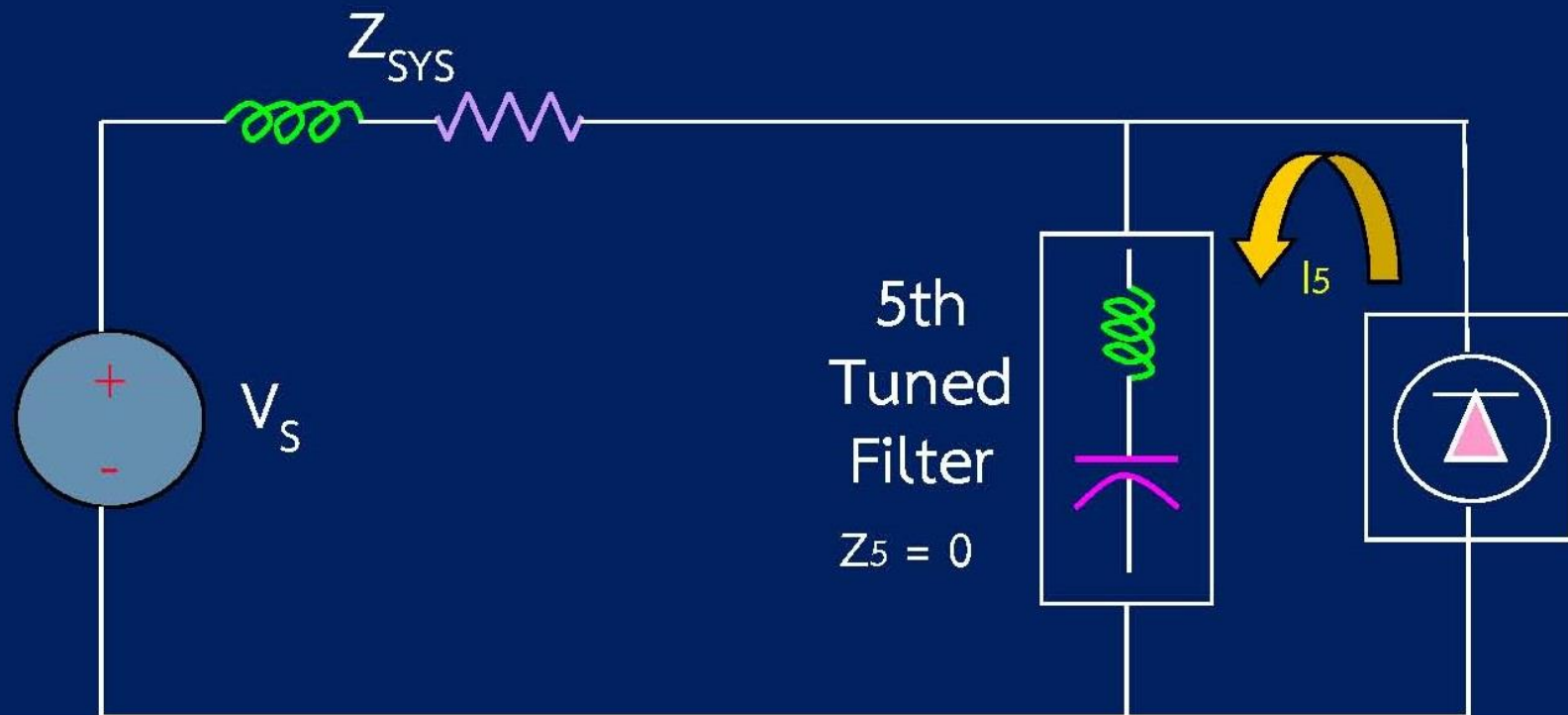
Can be divided as followings:

- Passive Filter
 - Tuned Filter
 - Detuned Filter
- Active Filter

Tuned Filter

- Tuned Filter comprise of Inductor and Capacitor which connected in series and tuned to harmonic frequency that needed to be filtered
- Proper size of capacitor and inductor is selected so reactance of capacitor and inductor are equal (at harmonic frequency that needed to be filtered) and total impedance is equal to zero
- This filter will capture most harmonic current flowing to it and will not flow to the other part of the system

Tuned Filter



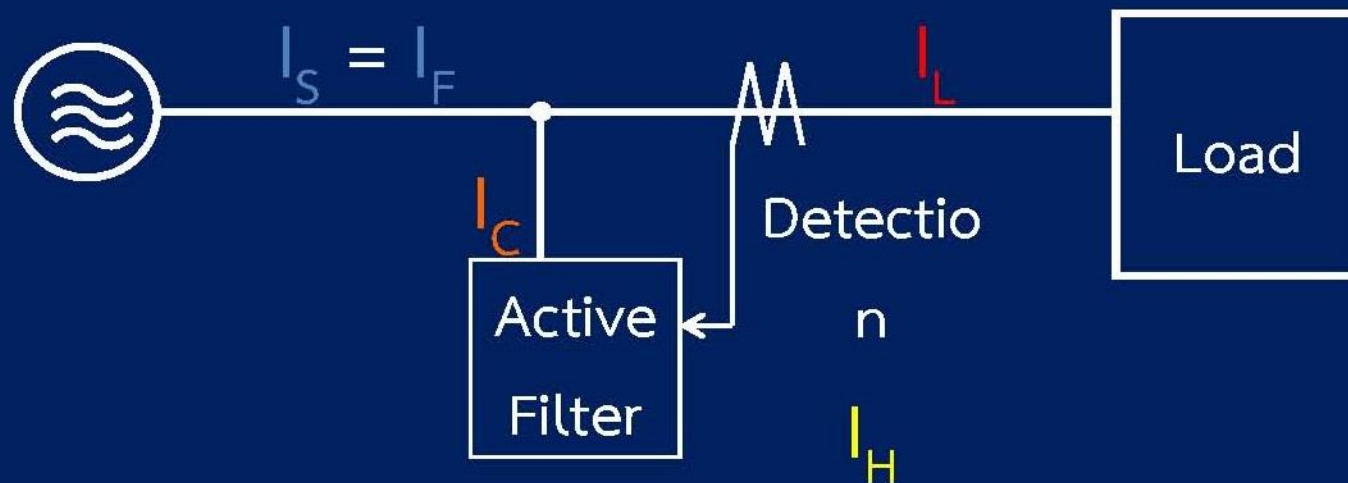
Detuned Filter

- Detuned Filter comprise of Inductor and Capacitor connected in series just like Tuned Filter but having a different objective
- Detuned Filter is usually a modification of existing capacitor bank to adjust the resonance frequency of system to be lower than lowest harmonic order in the system
- To avoid the risk of resonance condition which can create overvoltage and overcurrent

Active Filter

- Active Filter is a power electronic device that detect the harmonic content of load current and produce these current feeding to load directly
- So load current supplying from utility have only Fundamental component which is truly pure Sine Wave

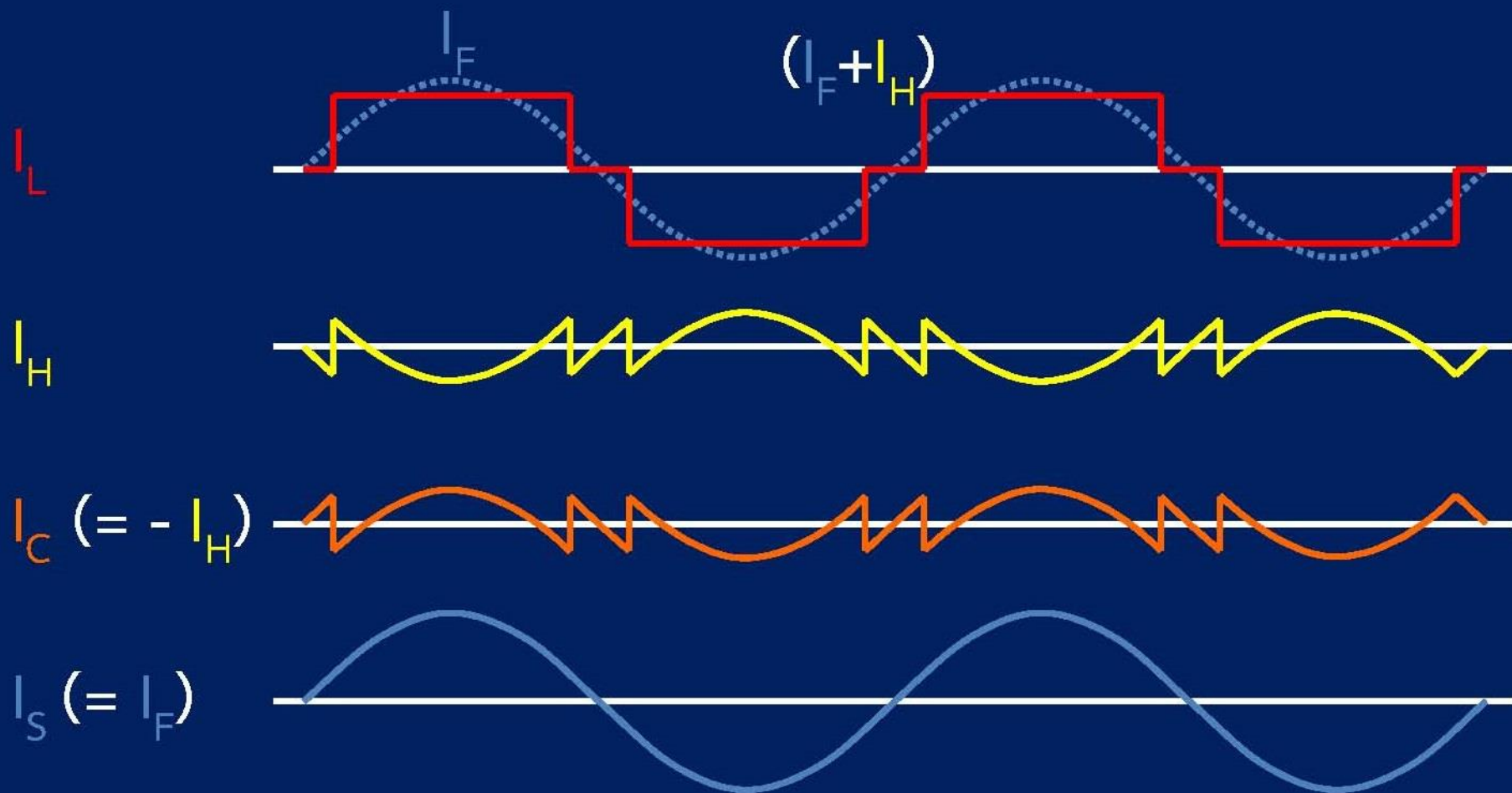
Active Filter



$$I_L = I_F + I_H$$

$$I_C = -I_H$$

$$I_S = I_L + I_C = (I_F + I_H) + (-I_H) = I_F$$



Harmonic filter solutions

- ❖ Passive harmonic filter (PHF)
- ❖ Active harmonic filter (AHF)
- ❖ Combined PHF and AHF



Passive harmonic filter equipment



Active harmonic filter equipment

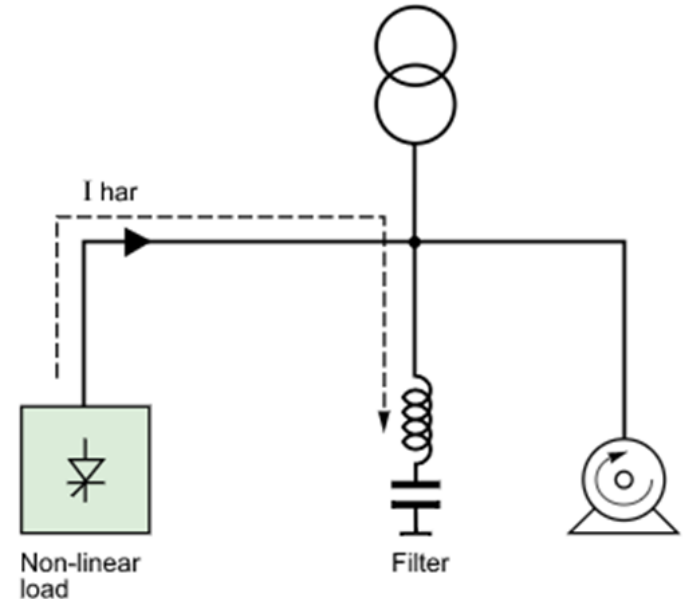
Passive Harmonic Filter (PHF)

Components and operation principles:

A harmonic passive filter is a combination of capacitors and inductors that are tuned to resonate at a single frequency, or a band of frequencies to filter out the harmonics at these frequencies

Application:

- Install in industry with total power of nonlinear loads (VFD, UPS, Battery charger.....) **higher than 500kVA**.
- Install at the places where it is required to **eliminate voltage harmonics** to reduce disturbances on sensitive loads.
- Install at the place where it is required to **reduce harmonic current** to prevent overload.



Passive harmonic filter principle

Active Harmonic Filter (AHF)

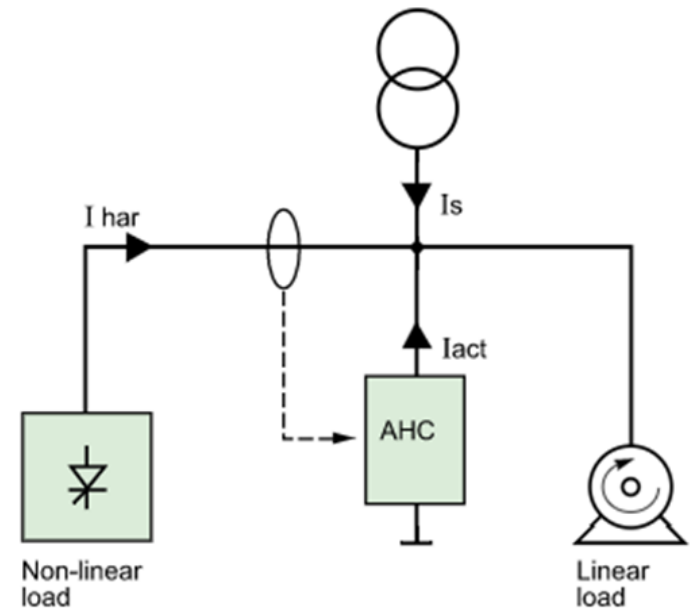
Components and operation principle:

An active harmonic filter consists of power electronic components connected in parallel or series with nonlinear loads to compensate the harmonic currents or voltages caused by nonlinear loads.

AHF generates currents which have opposite phase to the harmonic currents caused by nonlinear loads ($I_{har} = -I_{act}$) using current feedback via CTs. Thus the source current I_s is a sinusoidal.

Application:

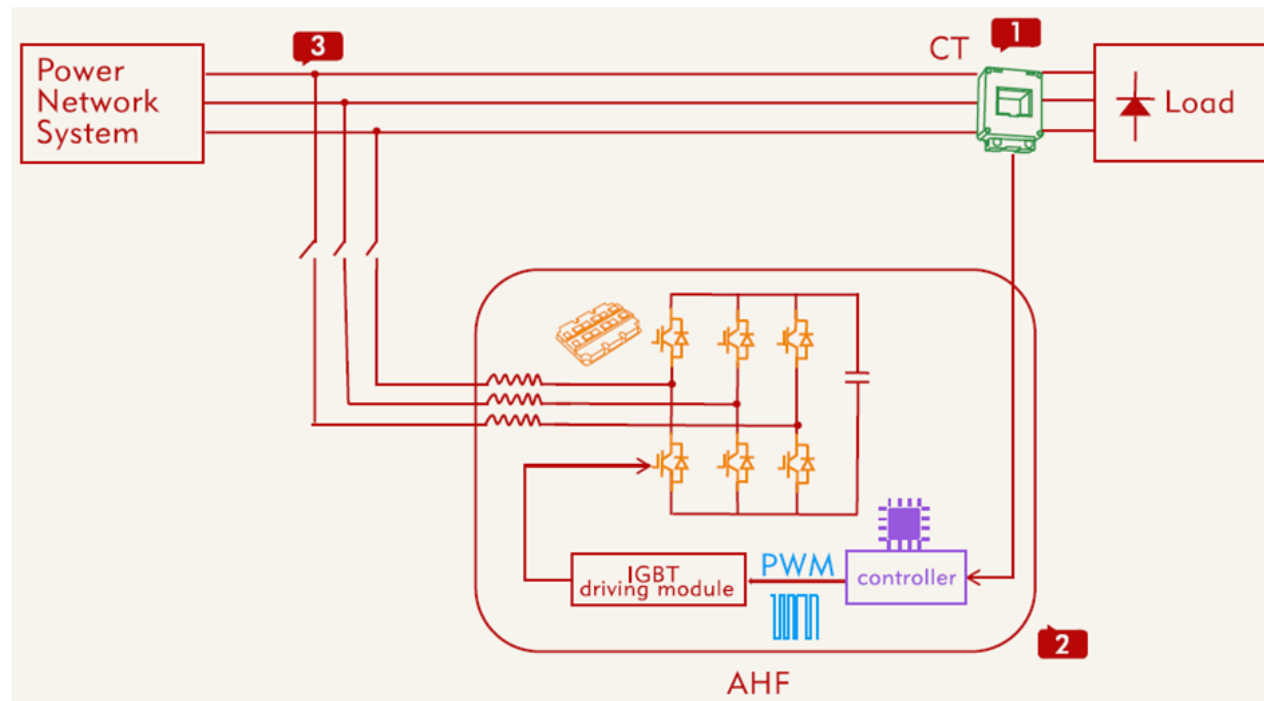
- Install in industry with total power of nonlinear loads (VFD, UPS, Battery charger.....) **smaller than 500kVA**.
- Install at the place where it is required to **reduce harmonic current** to prevent overload.



Active harmonic filter principle

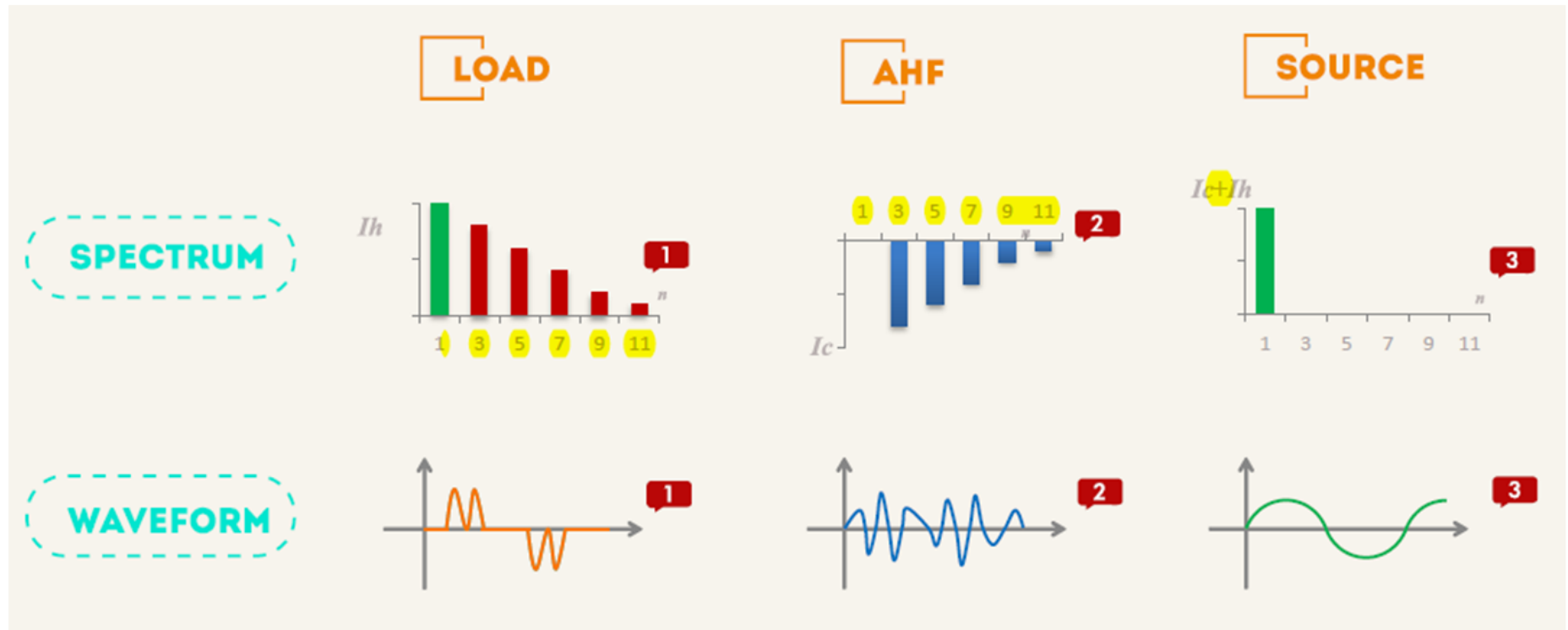
Active Harmonic Filter (AHF)

- ❖ Use DSP to control an Inverter to generate currents which have the same amplitude and in opposite phase to the harmonics.



Active Harmonic Filter (AHF)

- ❖ Spectrum and waveform of load current, AHF current and source current.



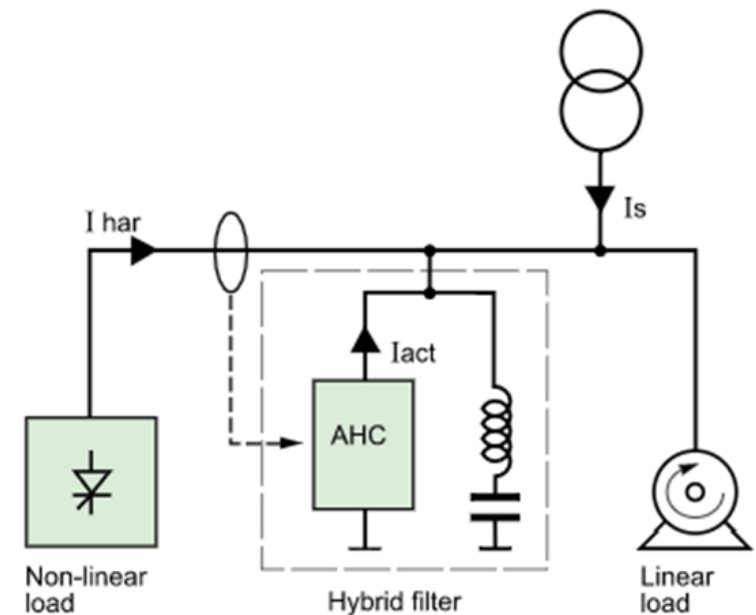
Combined PHF and AHF

Components and operation principle:

A combined harmonic filter solution has the advantages of PHF and AHF, i. e it can reduce voltage harmonics and current harmonics.

Application:

- Install in industry with total power of nonlinear loads (VFD, UPS, Battery charger.....) varied in a **wide range**.
- Install at the places where it is required to **eliminate voltage harmonics** to reduce disturbances on sensitive loads.
- Install at the place where it is required to **reduce harmonic current** to prevent overload.



Combined harmonic filter principle

AHF of Sinexcel

Đặc tính	400V				
	Sinexcel AHF 005/010/015	Sinexcel AHF 025/035	Sinexcel AHF 050/060	Sinexcel AHF075/ 100	Sinexcel AHF 150
Thông số hệ thống					
Điện áp định mức	380V/415V(228V~456V)				
Tần số định mức	50/60Hz(tần : 45Hz~62,5Hz)	50/60Hz(tần : 45Hz~62Hz)			
Số thiết bị lắp song song	không giới hạn				
Hiệu suất	≥ 97%				
Kiểu hệ thống	3P3W, 3P4W				
Biến dòng CT	50/5 ~ 10,000/5A	150/5 ~ 10,000/5A			
Thiết kế	3-level				
Chỉ số công suất					
Công suất định mức	5A/10A/15A	25A/35A	50A/60A	75A/100A	150A
Bù sóng hài	Có				
Bù công suất phản kháng	Có				
Bù mất cân bằng pha	Có				
Thuật toán	FFT, FFT Thông minh và công suất phản kháng tức thì				
Chế độ hoạt động	12 chế độ, có thể lựa chọn ưu tiên				
Tâm lọc	Bậc 2 đến bậc 61	Bậc 2 đến bậc 50			
Thứ tự lọc	Có thể điều chỉnh độc lập				
Góc lọc	Bậc 2 đến bậc 61	Bậc 2 đến bậc 50			
Hiệu suất lọc	> 95%				
Thời gian phản ứng	<15μs	<50μs			
Thời gian đáp ứng	5ms	< 5ms			
Hệ số công suất	Có thể chỉnh từ -1 đến 1				
Tần số đóng cắt	90kHz	trung bình 20kHz, tối đa 35kHz			
Lưu lượng không khí	44 L/sec	75 L/sec	151 L/sec	300 L/sec	405 L/sec
Độ ồn	<55dB	< 56dB			
Khả năng kết nối và giám sát					
Cổng giao tiếp	RS485	RS485, and network port(RJ45)			
Giao thức	Modbus	Modbus (RTU),TCP/IP(Ethernet)			
Module hiển thị	WIFI	4,3-inch HMI (module), 7-inch HMI (Giám sát tập trung)			
Chức năng bảo vệ	bảo vệ quá áp, sụt áp, ngắn mạch, nghich cầu inverter, quá bù...				
Theo dõi bảo động	Có				
Bảo động	Có, tối đa 500 bảo động				



Model: AHF-100(W) wall mount



Model: AHF-100(R) rack mount type

AHF of ABB

Model	PQFI	PQFM	PQFS
Electrical characteristics			
Connection method	3-wire		3-wire/4-wire
Network voltage ⁽¹⁾ Note: select V2 for 600V	V1: 208-480V V2: 480-600V for cULus version and upto 690V for IEC version		208-240V 380-415V
Network frequency	50 Hz/60 Hz - +/- 5%		
Line current rating per base unit (A _{sc})	V1: 300A, 450A V2: 180A, 320A ⁽²⁾	V1: 70A, 100A, 130A, 150A V2: 100A	30A, 45A, 60A, 70A, 80A, 90A, 100A, 120A
Neutral current rating per base unit (A _{sc})	-	-	3 times the line current rating ⁽³⁾
Modularity ⁽⁴⁾	Maximum 8 units can be combined		Maximum 4 units combined
Redundancy ⁽⁵⁾	Master/master or master/slave arrangement		
Equipment losses	3% of the equipment power typically		
Internal power circuit protection	Main breaker	Fuse block + Class J fuse standard incoming protection	-
Filter characteristics			
Harmonic range	2 nd to 50 th order		
Harmonics selectable simultaneously	20 orders		3-wire: 20 orders 4-wire: 15 orders
Filtering degree	Programmable per harmonic in absolute Ampere value		
Harmonic attenuation factor (I _h (source)/I _h (load))	Better than 97% at rated load		
Reaction time	< 0.5 ms instantaneous response		
Response time	2 networks cycles typically (10-90% filtering)		
Reactive power characteristics			
Target cos ϕ	Programmable from 0.6 (inductive) to 0.6 (capacitive) ⁽⁶⁾		
Load balancing characteristics			
Modes	L-L: ON/OFF		L-L: ON/OFF L-N: ON/OFF
Programming/Communication			
Digital I/O	2 digital inputs/6 digital outputs and one NO Fan contact (potential free)		
Alarm contact	1 NO/NC alarm contact (potential free)		
Programming/Monitoring	Using PQF-Manager GUI One standard Modbus TCP Ethernet or optional Modbus RTU interface PQF-Link software (optional extra)		



AHF of Schneider

Technical Specifications

Standard RMS output current ratings	60A, 120A, 200A, 300A @ 208 - 240 VAC 60A, 120A, 200A, 300A @ 380 - 480 VAC 47A, 94A, 157A, 235A @ 480 - 600 VAC 40A, 80A, 133A, 200A @ 600 - 690 VAC
-------------------------------------	--

Electrical System Characteristics

Nominal voltage	208-240 VAC; + 10% / -10% 380-480 VAC; + 10% / -15% 480-600 VAC; + 10% / -15% 600-690 VAC; + 10% / -15%
Nominal Frequency	50/60 Hz, ± 3 Hz auto sensing
Number of phases	3-phase, with or without neutral (no neutral cancellation)

Technical Product Characteristics

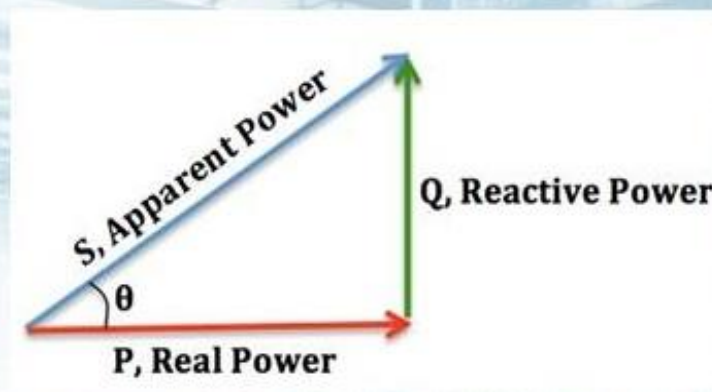
Power electronics	3-level IGBT
Topology	Digital harmonic FFT Digital reactive power
Efficiency	to 480 VAC >97%; to 690 VAC >95%
Current transformers (CT)	Any ratio with 1 or 5 ampere secondary Type 1 accuracy 50/60 or 400 Hz rated (Instrument rated or better) Grounded Can be shared with other devices
CT VA loading	40 mVA
Quantity of CT	2 or 3 for 3-phase loads 3 required for 4-wire with neutral connected loads
Spectrum cancellation	2 nd to 51 st , discrete; fully selectable per harmonic order (amplitude and on/off)
Control basis	Closed loop for new installations Open loop (compatible with AccuSine PCS for retrofit applications)
CT Position	Closed Loop Control: Source sense (at mains) CT or Load sense CT for single unit Open Loop Control: Load sense CT or source sense CT for single unit
Harmonic Attenuation	Closed Loop: <3% THD(i); max 20:1 THD(i) reduction with load harmonic current above 50% of AccuSine PCS+ rating Open Loop: <5% TDD Requires 3% or higher inductive impedance per nonlinear load

Harmonic avoidance	Output at specific harmonic order turned off if resonance or lack of impedance detected; or manually turned off
Parallel operation	Up to 10 units per set of CT (to 51 st order), any size combination Backward compatibility with AccuSine PCS operated in parallel. Contact your SE sales office for applications if more than 10 units required
Parallel operation options	Master/Master (masters receive mains CT) Master/Slave Multi-Master/multi-slave Same as AccuSine PCS for retrofits
Parallel sequence options	Cascade: Lead/lag with unit rotation; one unit operates to full capacity before next unit turns on; timed rotation. Load Share: All operating units function at the same output percentage.
Parallel redundancy	Any unit with CT connections will automatically become master if the controlling master is taken offline. Automatic increase in output of all units to make up capacity of any offline unit.
Parallel HMI control	Any unit permits viewing and changing parameter settings of complete system or any other unit in parallel system
Parallel communications	Proprietary COM Bus between operating units
Power factor correction	Optimized PF correction, leading (capacitive) or lagging (inductive) power factor (Cos ϕ) to target
Control response time	25 μ s
Harmonic correction time	2 cycles
Reactive correction time	1/4 cycle
Display	144 mm QVGA TFT 64k-color touchscreen
Operator interface	Magelis HMI STU touch panel screen
Display parameters	100's: includes THDi, THDv, oscilloscope for viewing many selected parameters, phasor diagrams, load power, measured currents for I _h , I _s , I _f , I neg seq, PF (Cos ϕ), injected currents for I _h , I reactive, I neg seq, etc.
Communications Capability	Modbus RTU, Modbus TCP/IP
Discrete input/outputs	4 input and 4 output dry contacts; assignable
Noise level (ISO3746)	< 70 db at one meter from unit surface
Earthing (Grounding) systems	Suitable for most earthing (grounding) systems: IT switch on EMC filter for IT earthing (ground), high resistance earthing (ground) or corner earthed (grounded) systems

Definition of Power Factor

- ❖ Power factor is the ratio between real power consumed by load and apparent power

$$PF = \cos(\theta) = \frac{P}{S}$$



- ❖ Power factor in case of nonlinear load

$$PF = \frac{\cos(\theta)}{\sqrt{1 + THD^2}}$$

Causes of low power factor

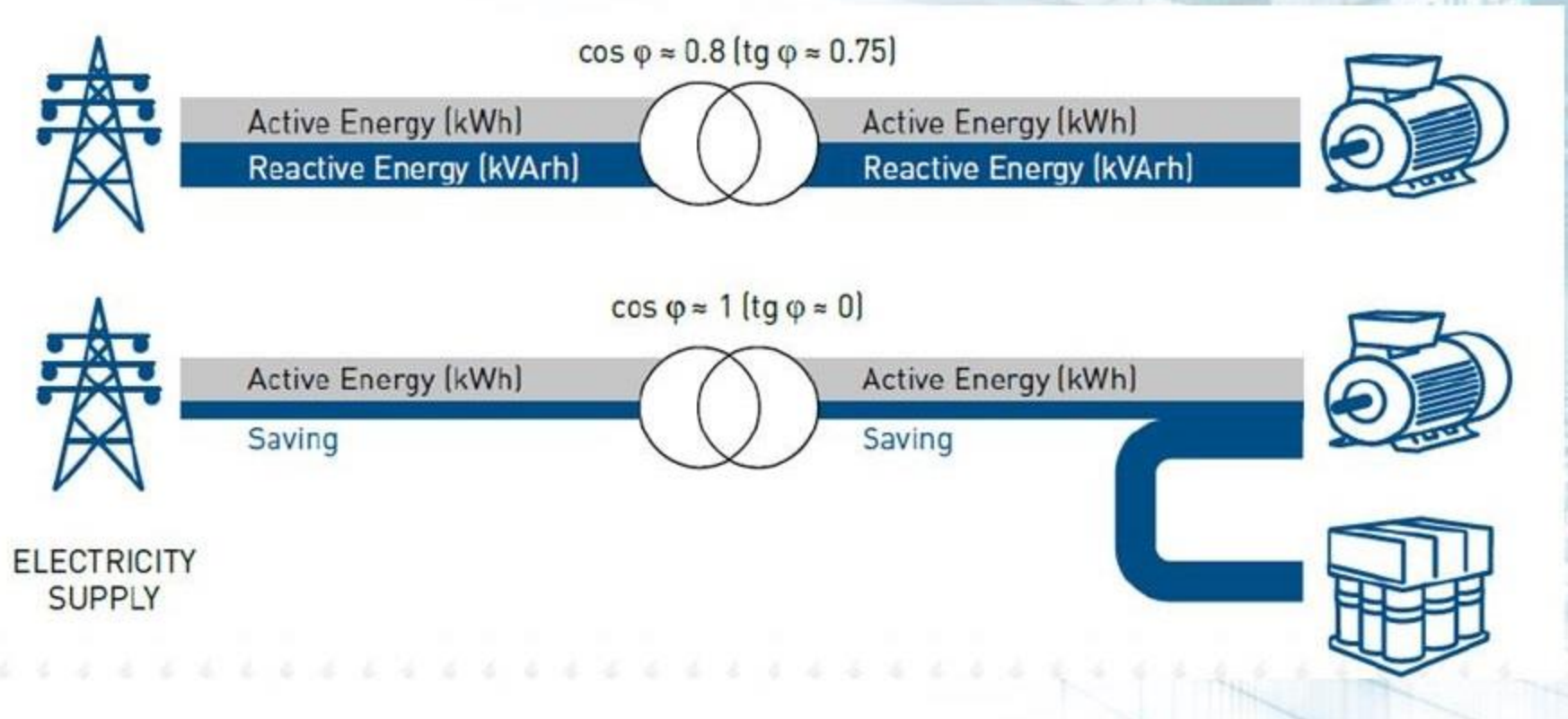
- ❖ Inductive load (motor,...)
- ❖ Fluocense lamp, arc welding machines, arc furnaces,...
- ❖ Nonlinear load (rectifier, switching power supply,....)



Effect of low power factor

- ❖ Higher power loss in transmission lines
- ❖ Electric equipment with higher rating power and larger size
- ❖ Larger cable size
- ❖ Higher voltage drop in transmission lines
- ❖ Reduce efficiency

Effect of low power factor





Power factor correction solutions

Power factor correction solutions

- ❖ Capacitor bank
- ❖ Static Var Generator (SVG)

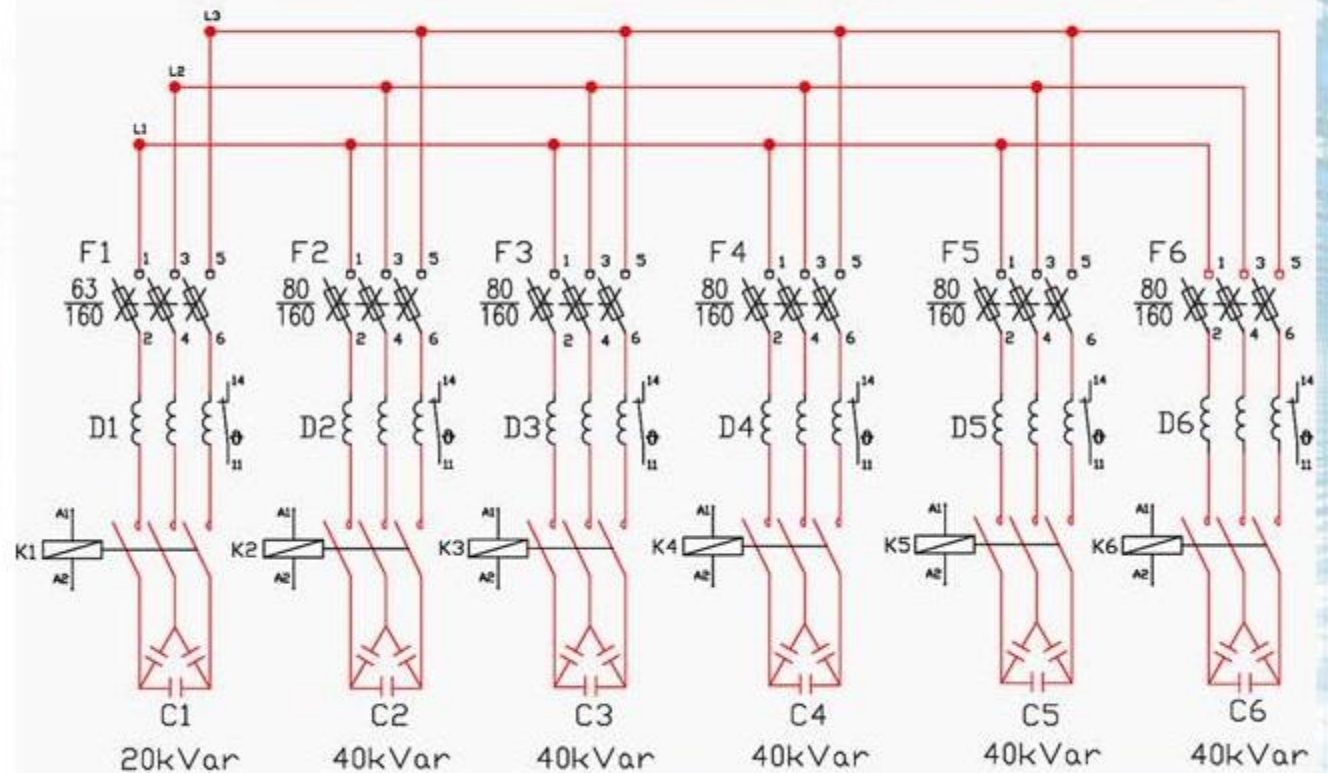


Capacitor bank



Static Var Generator

Capacitor bank

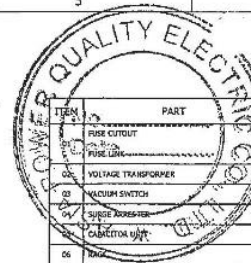
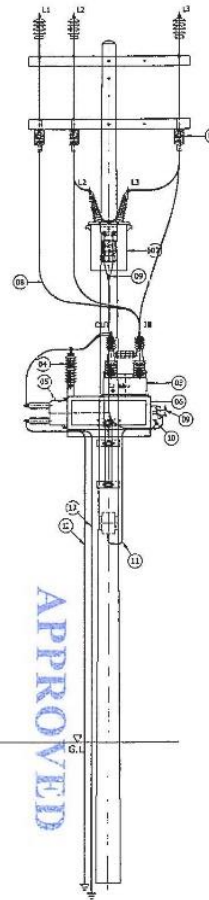
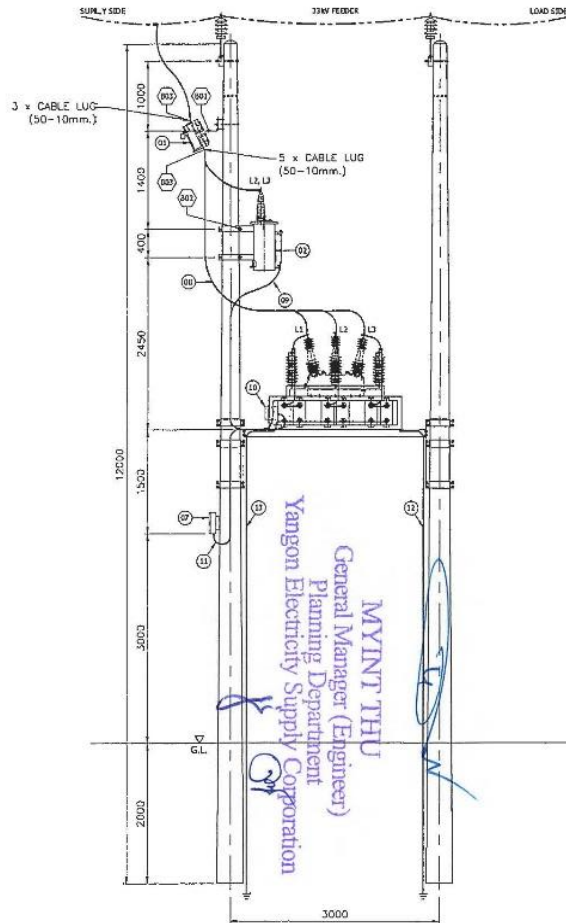


YESC ပိုင်ဆိုင်အားခွဲရုံများတွင် Capacitor Bank တပ်ဆင်ပြီးစီးမှုစာရင်းချုပ်

စဉ်	ဗို့အား	ခွဲရုံ အရေအတွက်	ဓာတ်အားလှိုင်း အရေအတွက်	တပ်ဆင်ပြီး စီးမှု (Mvar)
1	66kV	6		60
2	33kV	10	10	90
3	11kV	5	15	30
4	6.6kV	6	20	30
	Total	27	45	210

33kV Automatic Switching Capacitor Bank

© Copyright 2009 ABB. All rights reserved.



ITEM	PART	DESCRIPTION	QTY	TOTAL	REMARK
01	FUSE CUTOFF	ABB, OUTDOOR CUTOFF, RCK 38kV, 100A, 10kA, 8k, 200kV	3	3	
02	FUSE LINK	ABB, 100A, 10kA, 8k, 200kV	3	3	
03	VOLTAGE TRANSFORMER	THANATARAKIT TRANSFORMER, OUTDOOR OILFILLED 10kV, 220V/10kV, 20VA, 3kVA, 50kVA, 85, 70/0.7kV	1	1	
04	VACUUM SWITCH	ABB, P200 20kV, 100A, 15kA, 8k, 70/0.7kV, 3PHASE	1	1	
05	SURGE ARRESTER	ABB, POL-3H-5.7 10kV/27kV, U _m =33kV, CLASS 3	3	3	
06	CAPACITOR UNIT	ABB, BAH 20 10-400-10V, 2 DISCHARGES 600kvar, 15/20kV, 31.5kV, 50kV, 10kV, 50kV	6	6	DOWN TO 10kV WITHIN 600 Sec.
07	CONTROLLER	ABB, C2000 AUTOMATIC - MANUAL, 80 TO 264 VAC UNIVERSALS	1	1	
08	CABLE	POWER CABLE 50 Sq.mm	1 LOT	1 LOT	PROVIDED BY OTHERS
09	CABLE	CONTROL, VT TO JUNCTION BOX 2C x 4 Sq.mm	1 LOT	1 LOT	PROVIDED BY OTHERS
10	JUNCTION BOX (3PHASE SWITCH)	CONTROL CABLE MASH-HALLING BOX	1	1	
11	CABLE	CONTROL CABLE, JUNCTION BOX TO CONTROLLER	1 LOT	1 LOT	PROVIDED BY OTHERS
12	CABLE	BANK EARTHING 50 Sq.mm	1 LOT	1 LOT	PROVIDED BY OTHERS
13	CABLE	EARTHING 50 Sq.mm	1 LOT	1 LOT	PROVIDED BY OTHERS

EARTHING REQUIREMENTS

- VOLTAGE TRANSFORMER
- VACUUM SWITCH
- SURGE ARRESTER
- CAPACITOR UNIT
- CONTROLLER CASE
- GALVANIZED STEEL RACK
- MASH-HALLING BOX & CONTROL EARTH
- FOR GROUNDED BANK ONLY (CAPACITOR STAR POINT)

NOTES

POLES AND BANK EQUIPMENT TO BE EARTHED ACCORDING TO LOCAL RULES

BOLT & NUT LIST

ITEM No.	DESCRIPTION	BOLT SIZE (mm or inc.)	MATERIAL	SPRING WASHER	FLAT WASHER	TOOTH WASHER	NUT	QTY /BANK
B01	FOR FIXING FUSE CUTOFF WITH STEEL SUPPORT	M12 x 55	HG	1	2	-	1	6
B02	FOR FIXING VOLTAGE TRANSFORMER WITH STEEL SUPPORT	M16 x 60	HG	1	2	-	1	2
B03	FOR CONNECTING FUSE CUTOFF WITH CABLE LUG	M10 x 50	SS	1	2	-	1	6

NOTE

HG = HOT DIP GALVANIZED
SS = STAINLESS STEEL

00	For approval	24.06.2019	Prepared Nimit C.	Approved Prawat D.	Title
	Checked Anawat B.		Date 24.06.2019		
	Project name		IFB3-7 ODA LCB		
Rev. in.	Description	Date			

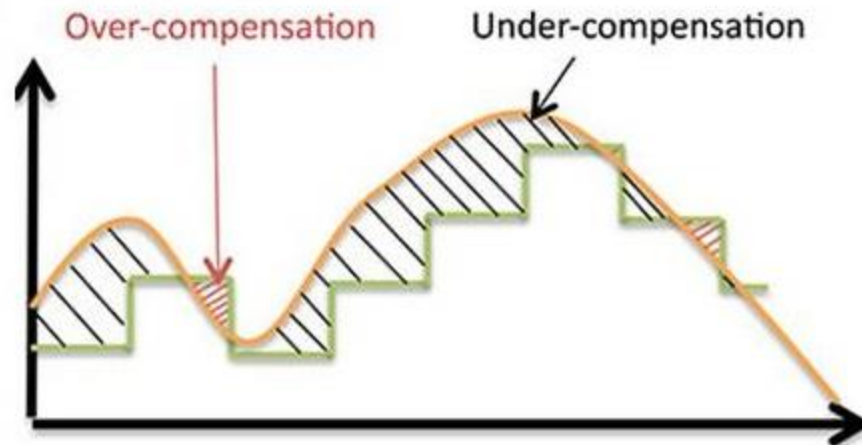
MV. POLE MOUNTED CAPACITOR BANK	3.6Mvar, 33kV, 50Hz, 3phase
---------------------------------	-----------------------------

Page Description	COMMON DRAWINGS & GENERAL ARRANGEMENT
Doc. No.	14C/2019
WBS No.:	TH-40319019
ABB I.O. No.:	3100099891
ABB	ABB LIMITED, PGHV

Lang.	EN
Page	G03
Pages	5

Disadvantages of capacitor bank

- ❖ Stepped correction
- ❖ Under-compensation or over-compensation
- ❖ High risk of explosion in high harmonic environment
- ❖ Slow response time

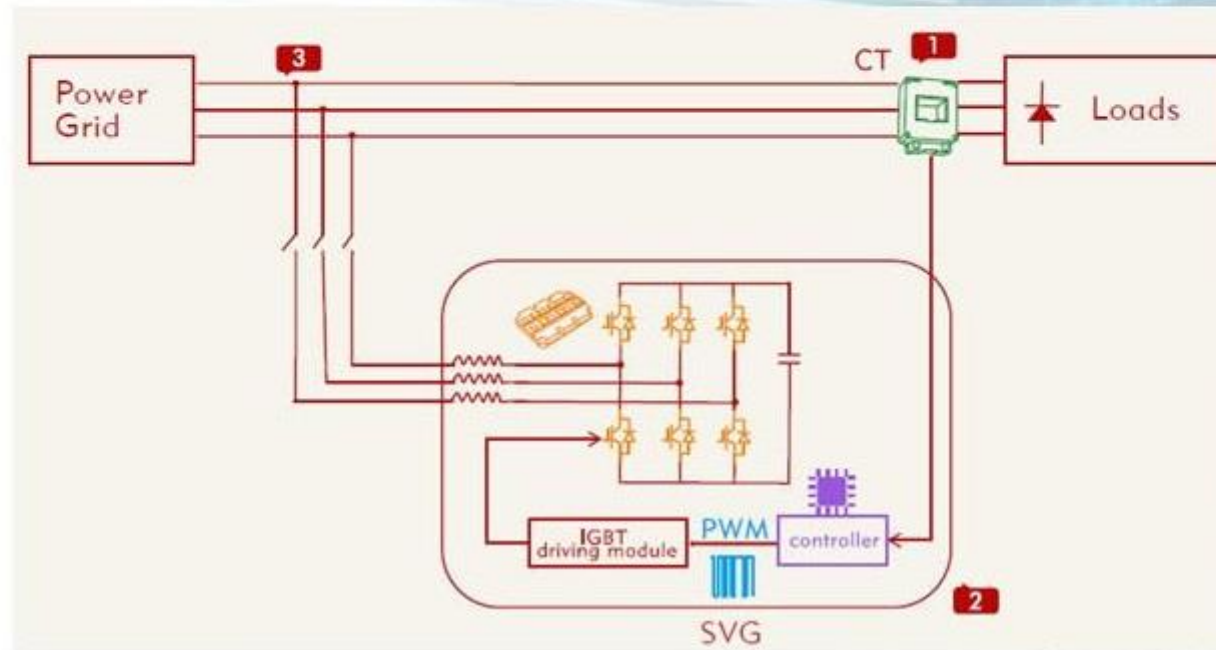


သင်္ချာနည်းဖြင့်၊ ကမာကြည်လမ်းတွင် 6.6kV Automatic Switching Capacitor Bank တပ်ဆင်ပြီးစီးပုံ



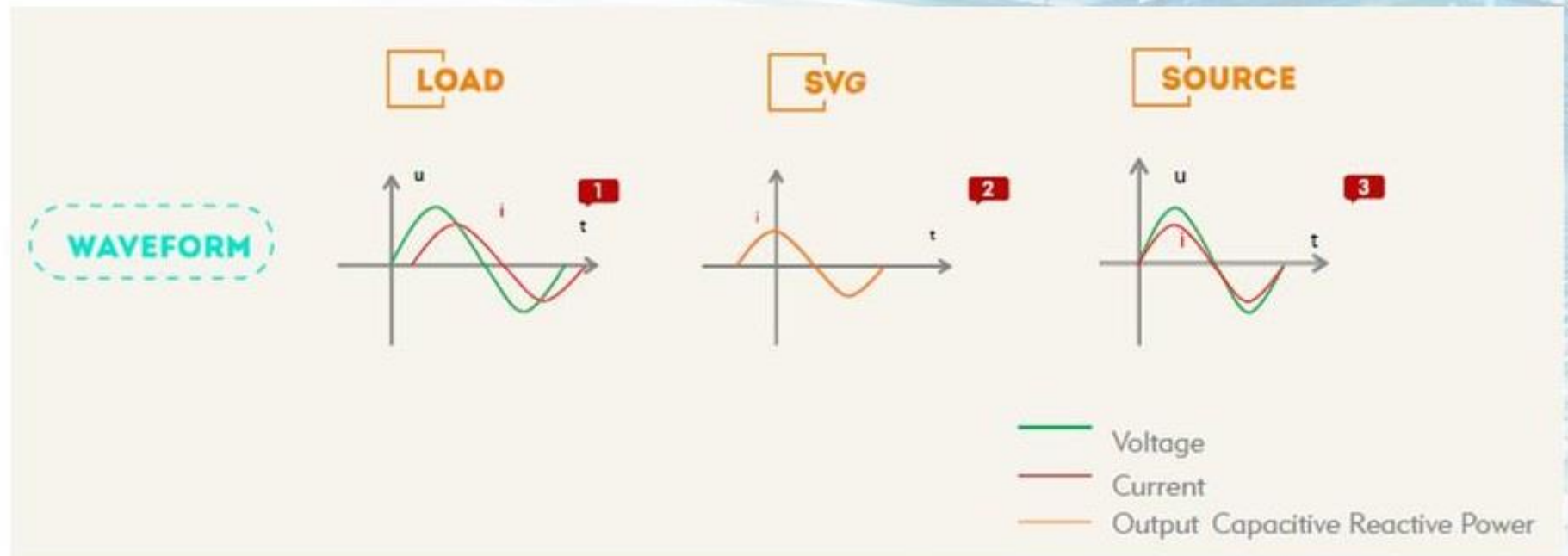
Static Var Generator

- ❖ Use DSP to control an inverter to generate compensation currents in such a way that the source currents are in the same phase as voltages.



Static Var Generator (SVG)

❖ Current and voltage waveform of SVG



Advantages of SVG

- ❖ PFC performance 0.99
- ❖ Stepless compensation without over-compensation and under-compensation, compensate specific capacity that system needs
- ❖ Fast response time within 15ms
- ❖ Compensation with inductive reactive power and capacitive reactive power
- ❖ SVG can also compensate unbalanced current because it is a current source.

SVG of Sinexcel

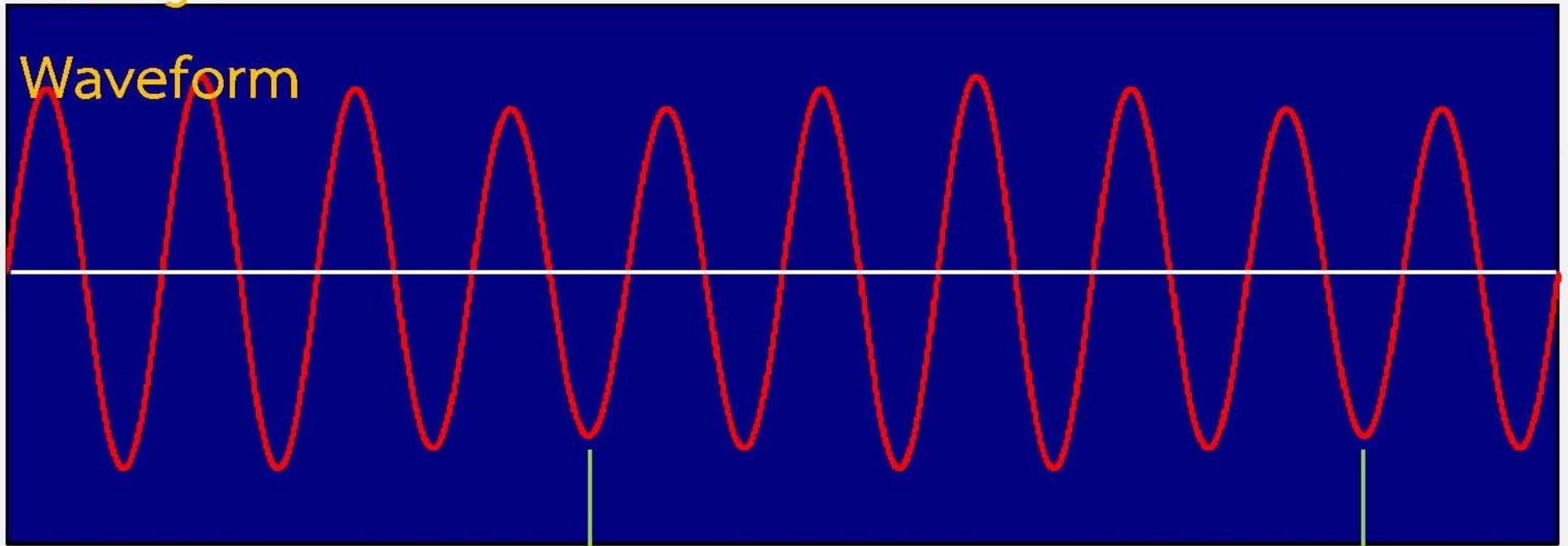
Items	SVG 400	SVG 480	SVG 690
Products			
Rated Voltage	400V (3P4W/ 3P3W)	480V (3P3W)	690V (3P3W)
Voltage range	-40% ~ +20%	-20% ~ +20%	-30% ~ +15%
Rated capacity	30kvar/50kvar/100kvar (30.50kvar Wall-Mount opt)	65kvar/130kvar/195kvar/260kvar	90kvar/180kvar/270kvar/360kvar
Modes of operation	Both inductive and capacitive PFC, 3-phase unbalance compensation	Both inductive and capacitive PFC, 3-phase unbalance compensation	Both inductive and capacitive PFC, 3-phase unbalance compensation
Response time	< 15ms	< 15ms	< 15ms
Mounting type	Wall-mounting/Rack-mounting	Compact Cabinet	Compact Cabinet

Voltage Fluctuation

- Voltage fluctuation is a condition that magnitude of voltage increase and decrease repetitively causing a change in luminance of the light bulb. The change in brightness can cause the irritation to people in that environment.
- Severity of voltage fluctuation can determine by the Amplitude of voltage change and Frequency of voltage change.

Voltage

Waveform

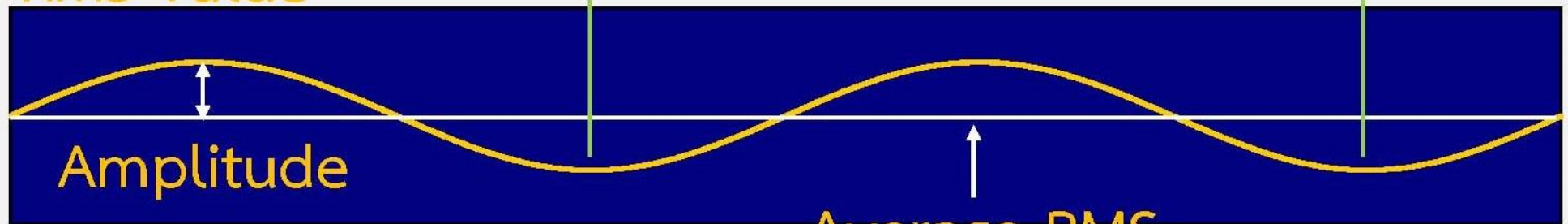


RMS Value

Period

Amplitude

Average RMS



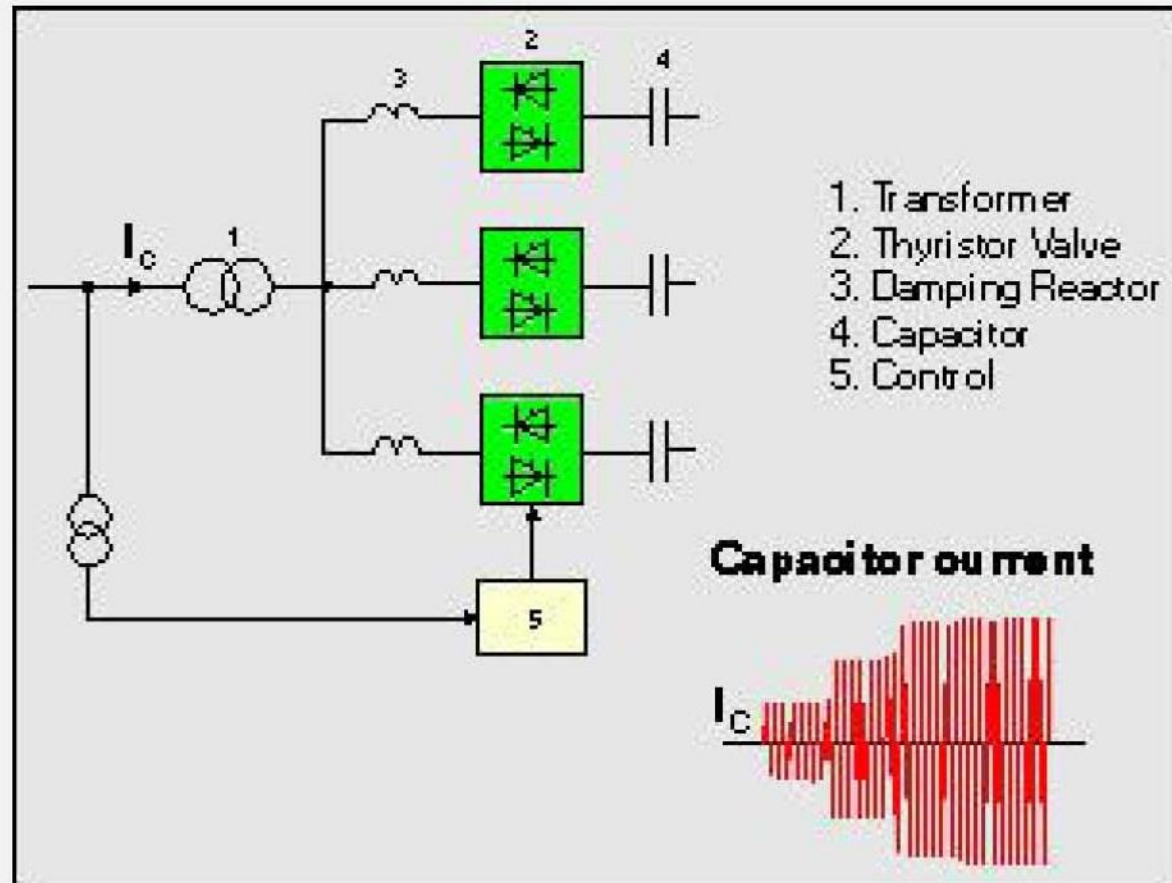
Cause of voltage fluctuation

- Produced from large fluctuating load which draw high current in short period or continuously vary. This make voltage drop in system impedance changing along with the fluctuating current and cause fluctuation in receiving voltage
- These loads are Arc Furnace or large motor which continuously start and stop

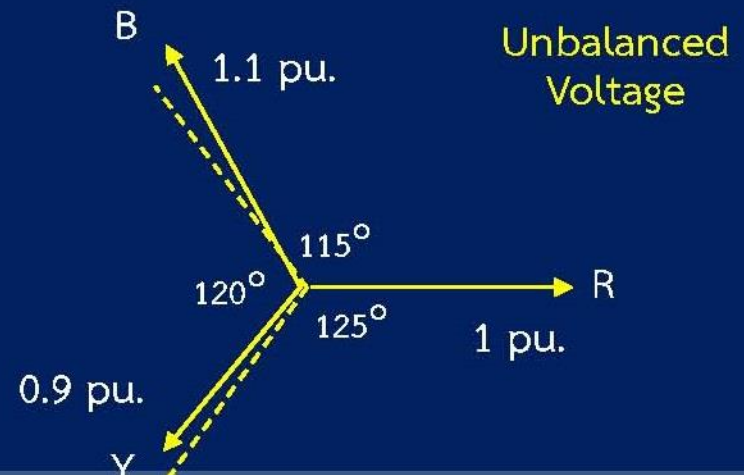
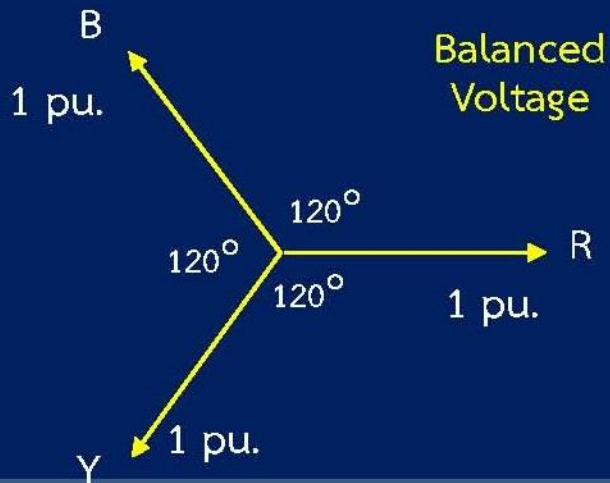
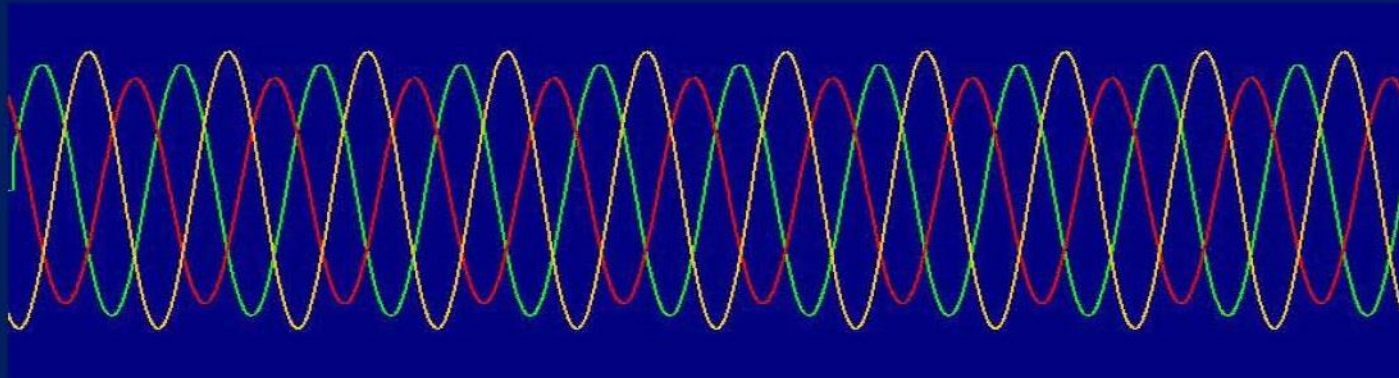
Solution for Voltage Fluctuation

- Fluctuating load must connect to higher voltage system since higher voltage system have higher fault level (lower system impedance) and the impact from voltage fluctuation can be reduced
- Install Static VAR Compensator to quickly response and compensate the change of load reactive current

SVC (Thyristor Controlled Capacitor)



- Voltage Unbalance occur when magnitude and/or phase angle of each voltages in three phase system are not equal



Voltage Unbalance

- Voltage unbalance can be analyzed by Symmetrical Component technique
- Any voltage unbalance can be separated in to Positive Sequence Component , Negative Sequence Component and Zero Sequence Component

Source of Voltage Unbalance

- In LV system, inappropriate single phase load allocation between each phase is the cause of voltage unbalance
- In HV system, single phase traction load (electric train) is the major source of voltage unbalance
- Non-transposed transmission line or feeder maybe produce voltage unbalance even in balanced load condition

Impact of Voltage Unbalance

- Undue voltage unbalance level in power system can affect the operation of three phase AC motor as followings:
 - Increase current, heat and vibration in motor
 - Reduce torque
 - At normal operating speed, degree of current unbalance is up to 6-10 times of degree of voltage unbalance

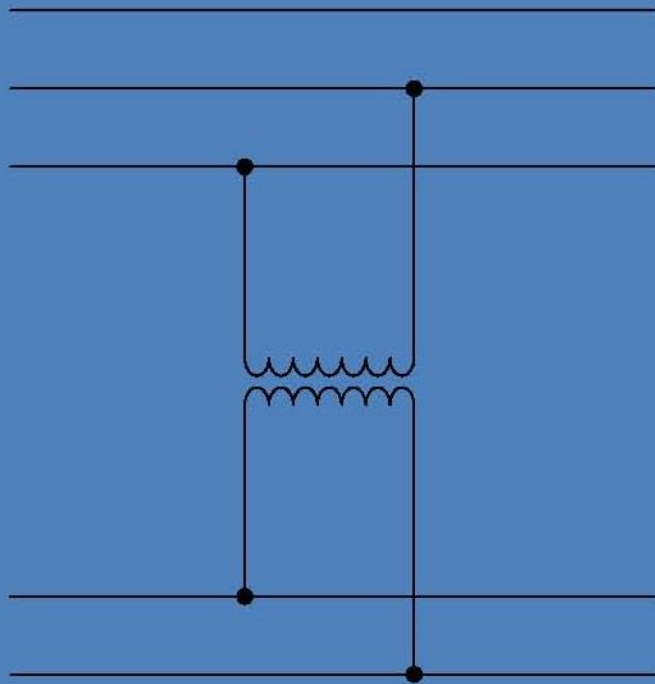
- IEC 60034-26 specify that Three Phase AC Motor should operate in environment having continuous voltage unbalance level **less than 1%** and allow **up to 1.5% in short period**
- If motor must operate in high Voltage Unbalance environment for a long time, the motor should be **derated** to protect the damage to motor

Voltage Unbalance Mitigation

- In LV system, solve by proper allocation of single phase load in three phase power system
- Voltage unbalance from traction load can be mitigated by special transformers which are Scott Transformer and V-connection Transformer

Special Transformer to Reduce Unbalance

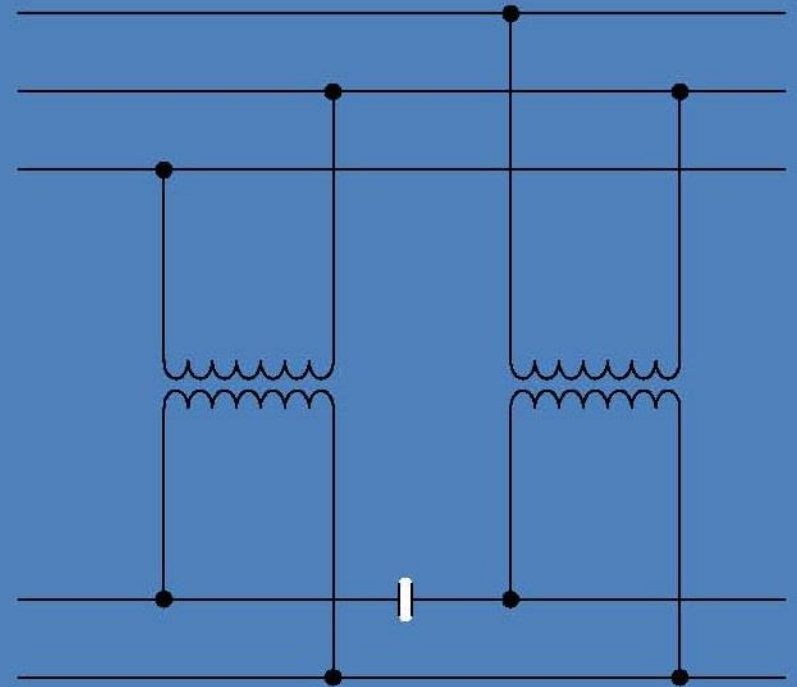
Single Phase Connection



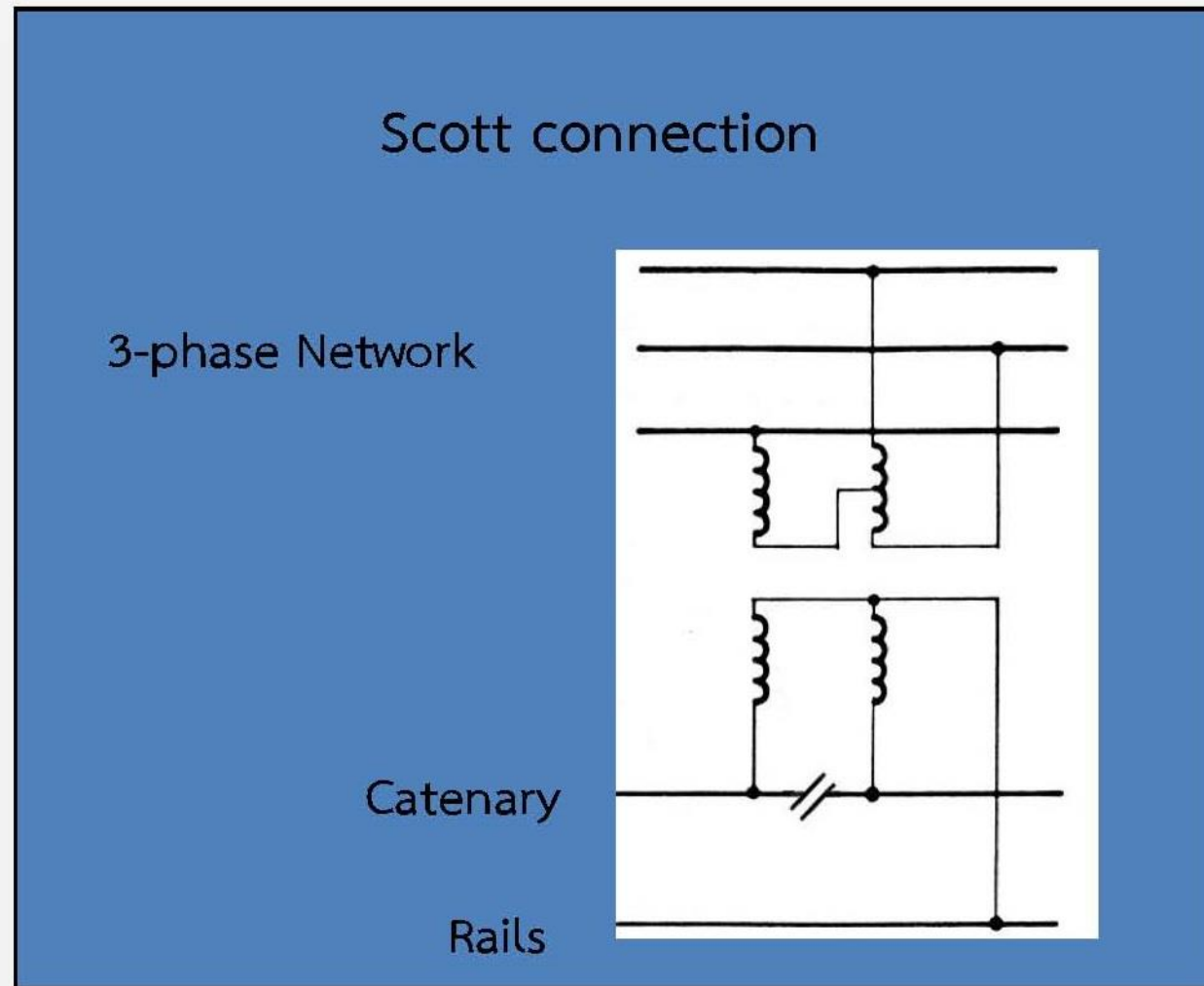
3 phase Network

Catenary
Rails

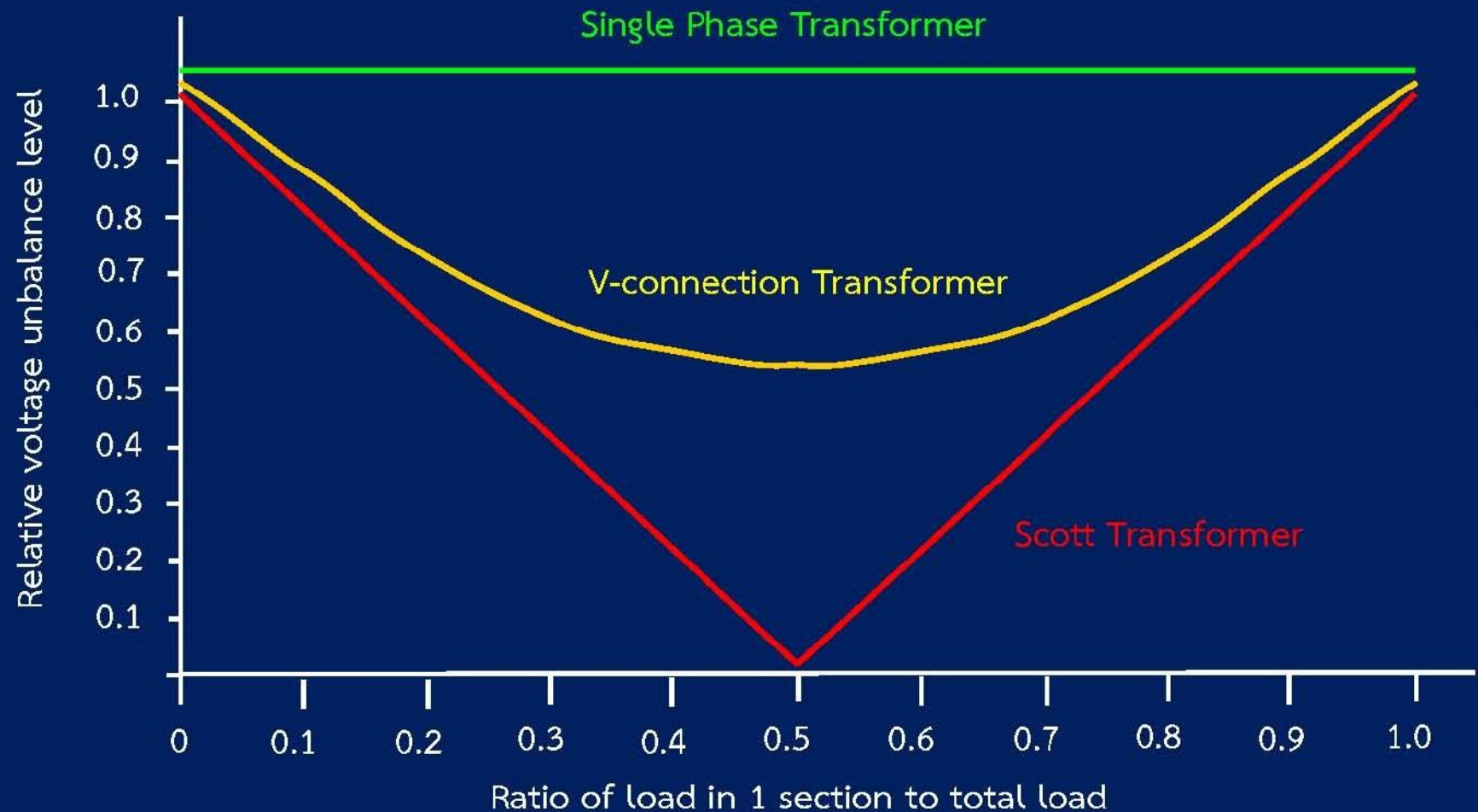
V - Connection



Special Transformer to Reduce Unbalance



Special Transformer to Reduce Unbalance



Reliability Indices

- Reliability Indices can be used to evaluate the performance of power system in ability to supply continuous and stable power. How often and how long does interruption occur? How fast does the system can restore the supply?

- General Reliability Indices

SAIDI (System Average Interruption Duration Index) is and average interruption duration that each customer receive in specific period of time (ex. 1 year)

SAIFI (System Average Interruption Frequency Index) is and average interruption frequency that each customer receive in specific period of time

- SAIDI and SAIFI are usually calculated base on only Permanent Fault (more than 1 minute interruption)

- Additional Reliability Index for evaluate system performance in Momentary Interruption is
MAIFI (Momentary Average Interruption Frequency Index) is and average momentary interruption frequency that each customer receive in specific period of time
- MAIFI can be used to evaluate power system performance in temporary fault prevention (less than 1 minute interruption) which much more frequently occur than permanent fault

Voltage Dip (Sag)

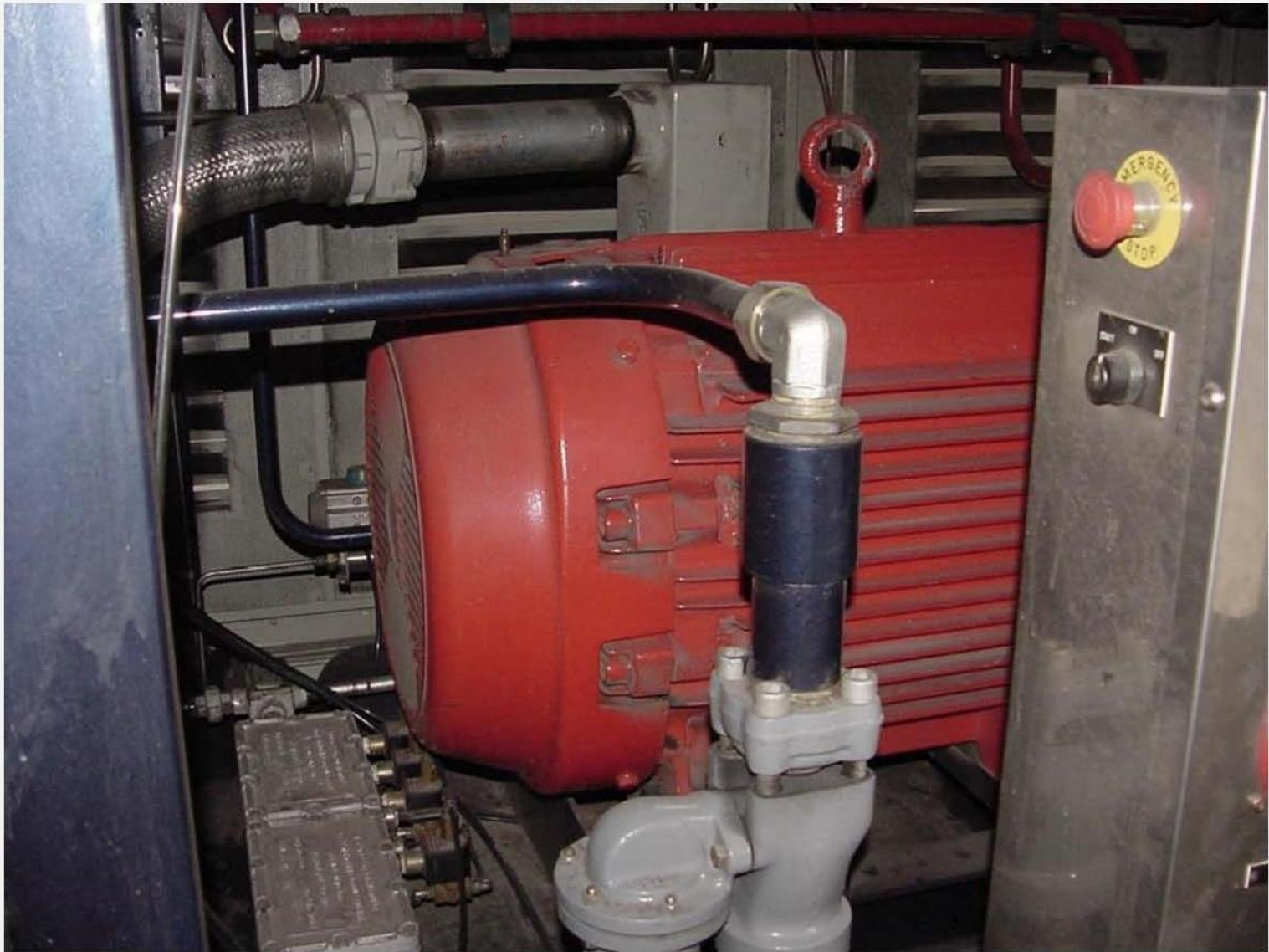
- Voltage Dip is an event which supplied voltage decrease below normal voltage range (ex. below 90%) in short period ($\frac{1}{2}$ cycle to 1 minute by IEEE definition)
- Severity of Voltage Dip can be specified by its **Magnitude and Duration**
- Furthermore, **Phase Shift of voltage phasor** when Voltage Dip occur can interfere some equipment operation

Cause of Voltage Dip

Cause by abnormal high current flowing in the system in a short period e.g.

- **Large motor starting current** which can draw about 5 - 8 times of full load current in short period (2 - 3 seconds)
- **Short circuit (Fault) current** which can draw several ten times of normal load current in very short period (3 - 5 cycle or 60 - 100 ms)

Voltage Dip form Motor Starting



Voltage Dip vs. Interruption (Cause)

- Voltage Dip is produced by fault in neighbor circuit which supplied from the same source with customer's supplied circuit
- Interruption cause by fault in customer's directly supplied circuit

Voltage Dip vs. Interruption (Characteristic)

- Voltage Dip impact less adversely effect to equipment (no effect in some equipment) but occur more frequently
- Interruption impact more adversely effect to equipment but occur less frequently

Voltage Dip

```
graph LR; A[Voltage Dip] --> B[cause jerk in motor, damage sensitive mechanic load]; A --> C[cause microprocessor to reset, interrupt the manufacturing process]; A --> D[cause adjustable speed drive (ASD) to trip out or damage in some severe case];
```

cause jerk in motor, damage sensitive
mechanic load

cause microprocessor to reset, interrupt the
manufacturing process

cause adjustable speed drive (ASD) to trip out or
damage in some severe case

Decrease Voltage Dip Severity

By reducing magnitude and/or duration of voltage dip

- Install Neutral Ground Resistor (NGR) in power transformer
- Apply Current Limiting Fuse instead of normal expulsion fuse
- Install Fault Current Limiter to limit magnitude of fault current

Voltage Dip Mitigation

Can be divided into 2 parts

1. **Utility Part** by reducing the number and severity of fault event which is the cause of voltage dip
2. **Customer Part** by improving their system and equipment's voltage dip ride-through capability

**** The effective voltage dip mitigation must derive from the cooperation of both utility and customer ****

Voltage Dip Mitigation for Utility

1. Decrease number of fault event in power system which is the cause of voltage dip
2. Decrease the severity of voltage dip by reduce magnitude and/or duration of fault current
3. Split supplied system into small part to reduce the impact from voltage dip
4. Install voltage dip compensated device

Decrease Number of Fault Event

Can be done by

- Tree maintenance
- Animal protection
- Equipment Preventive Maintenance

ရန်ကုန်တိုင်းဒေသကြီးအတွင်း ဓာတ်အားပြတ်တောက်ချိန်လျော့နည်းရေးနှင့်
အပြစ်ဖြစ်သောအပိုင်းအားဖယ်၍ ဓာတ်အားအမြန်ပေးနိုင်ရေးအတွက်
Auto Recloser တပ်ဆင်မှုစာရင်းချုပ်

စဉ်	အမျိုးအစား	တပ်ဆင်ပြီးစီးမှု (Nos)
1	ABB	3
2	SIEMANS	4
3	COOPER	7
4	NOJA POWER	93
	TOTAL	107

၃၃ကေဗီဓာတ်အားလိုင်းများတွင် Auto Recloser တပ်ဆင်မှုမှတ်တမ်းဓာတ်ပုံများ



Tree Problem and Fault



24 kV Aerial Space Cable

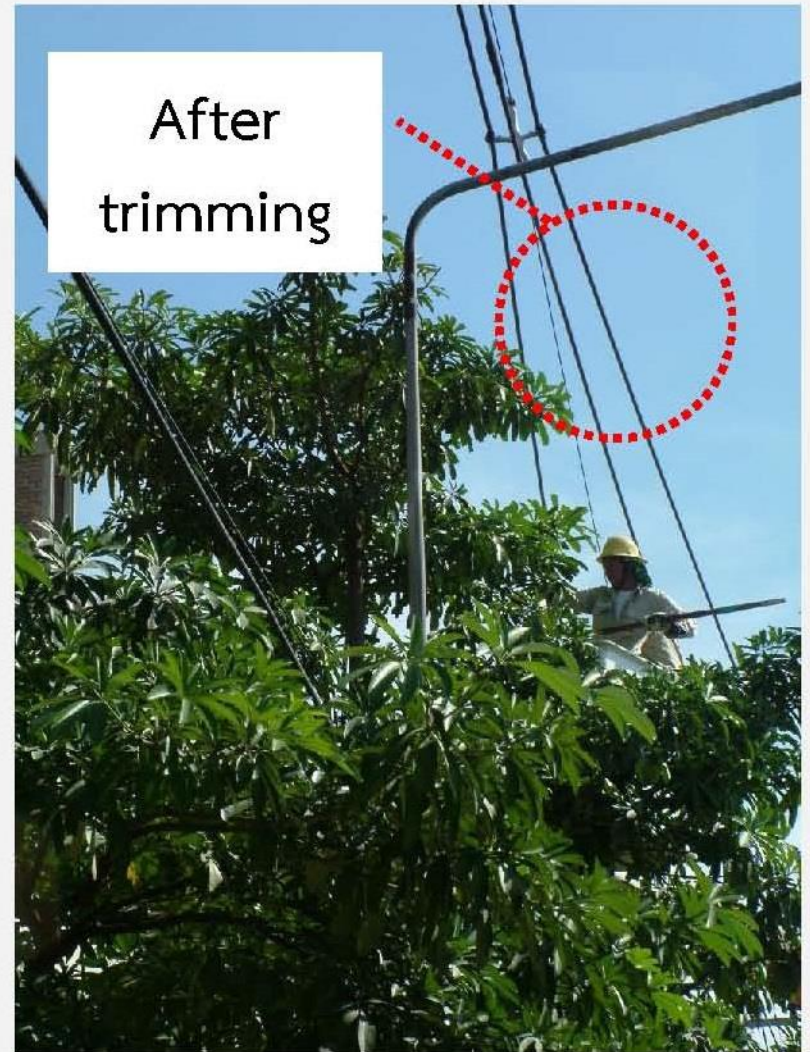
Tree Problem and Fault



Disconnecting Switch

Tree Problem Mitigation

1. Repeatedly cut and trim tree branch that close or touch the overhead HV equipment
2. Use plant hormone to control the growth rate and height of tree under feeder or transmission line



Tree trimming near 24 kV feeder

Tree Growth Control by Plant Hormone

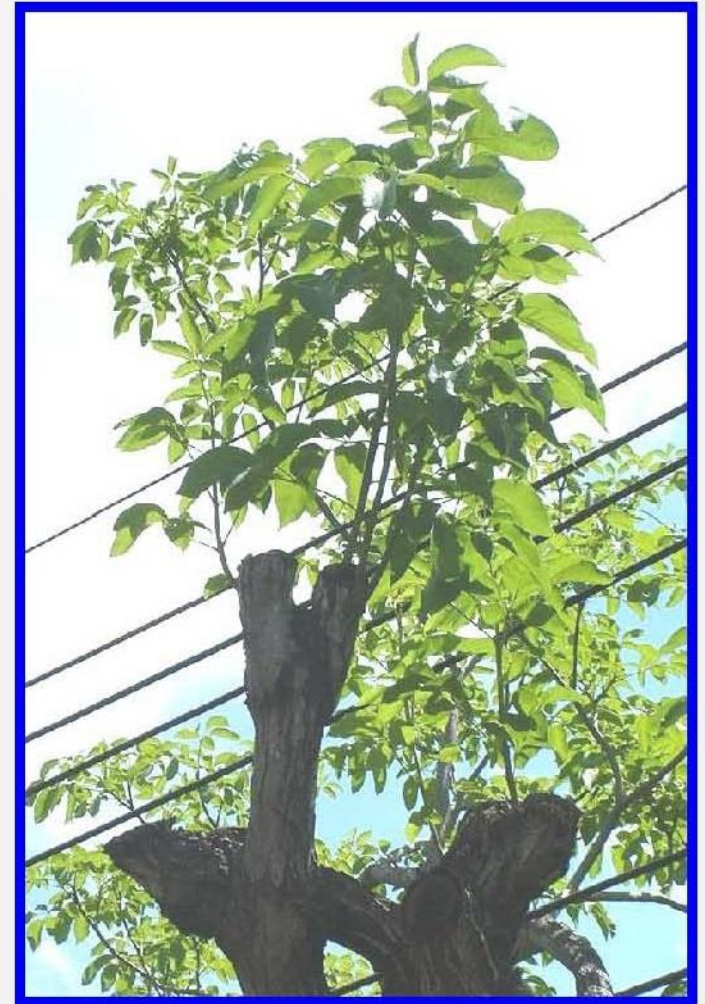




3 Months

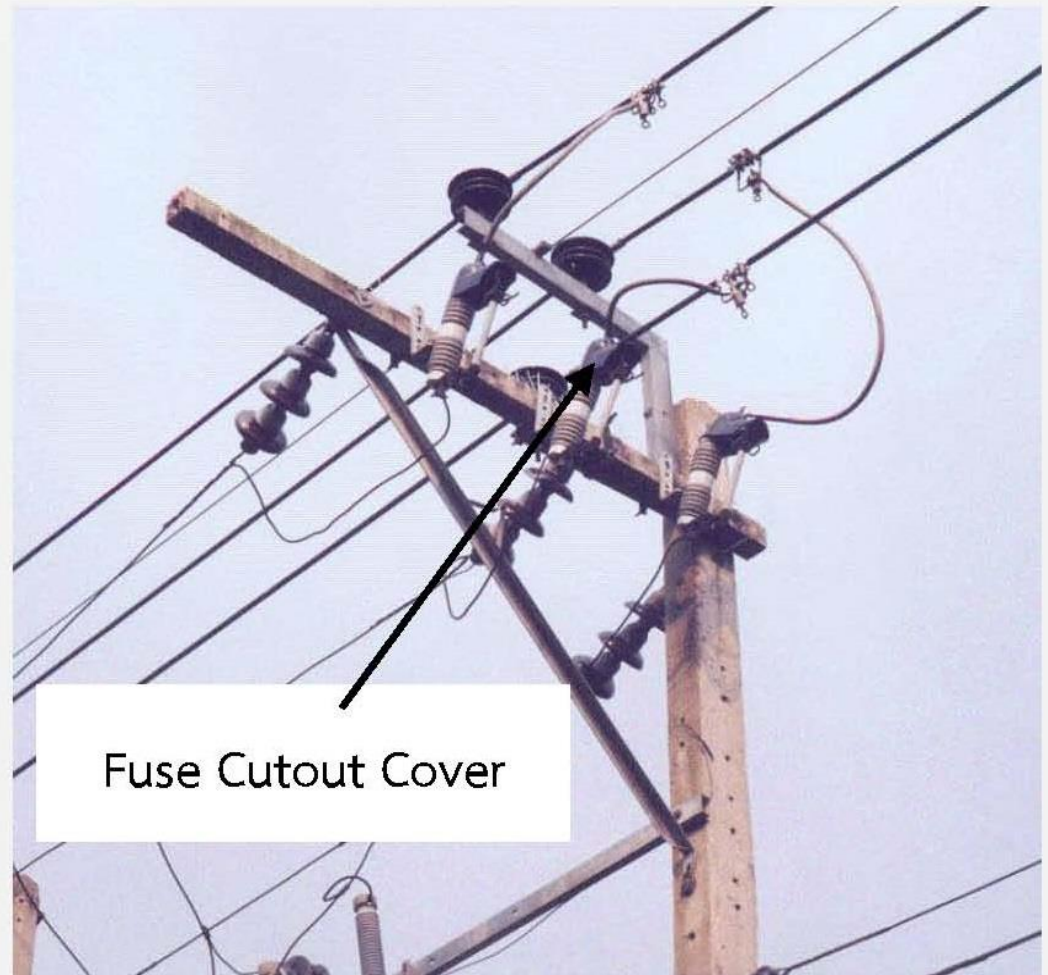


5 Months

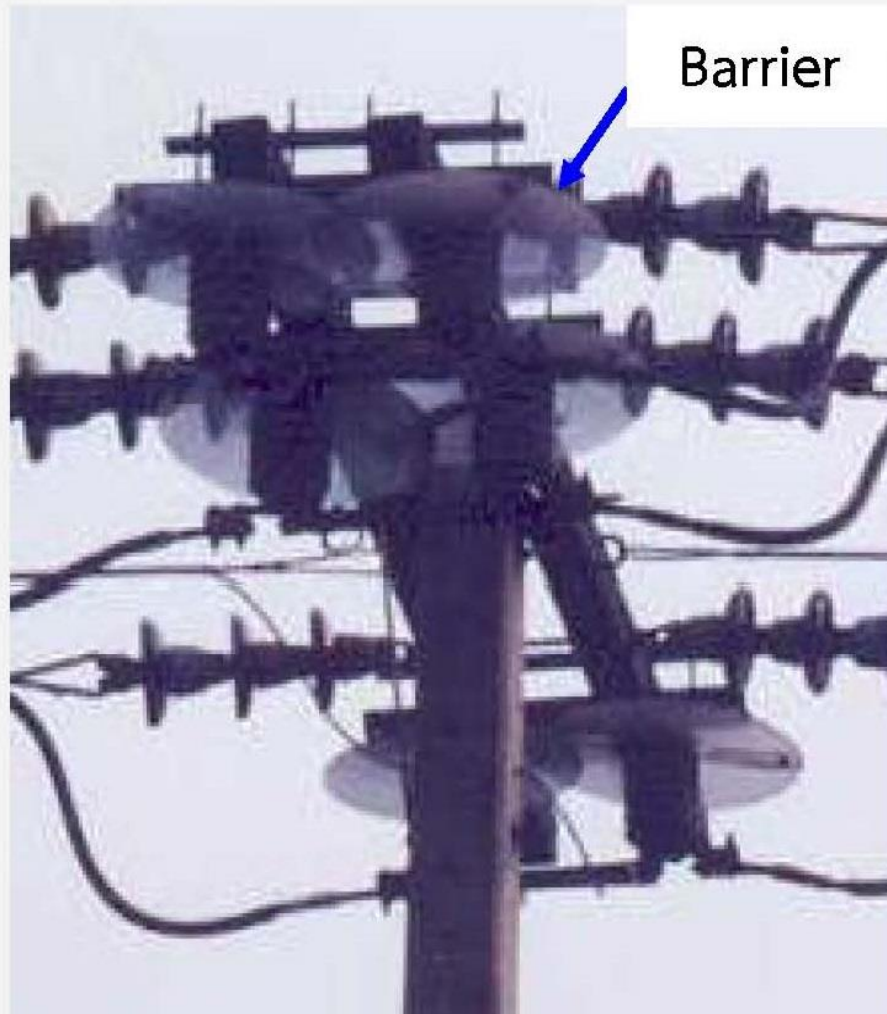


6 Months

Animal Problem Mitigation



Animal Problem Mitigation



Animal Problem Mitigation





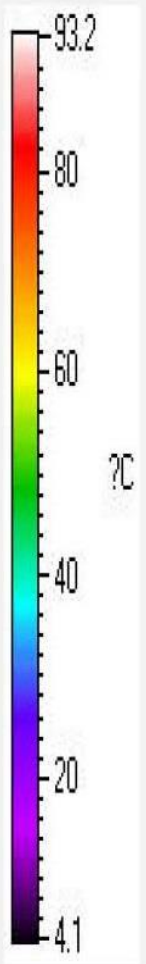
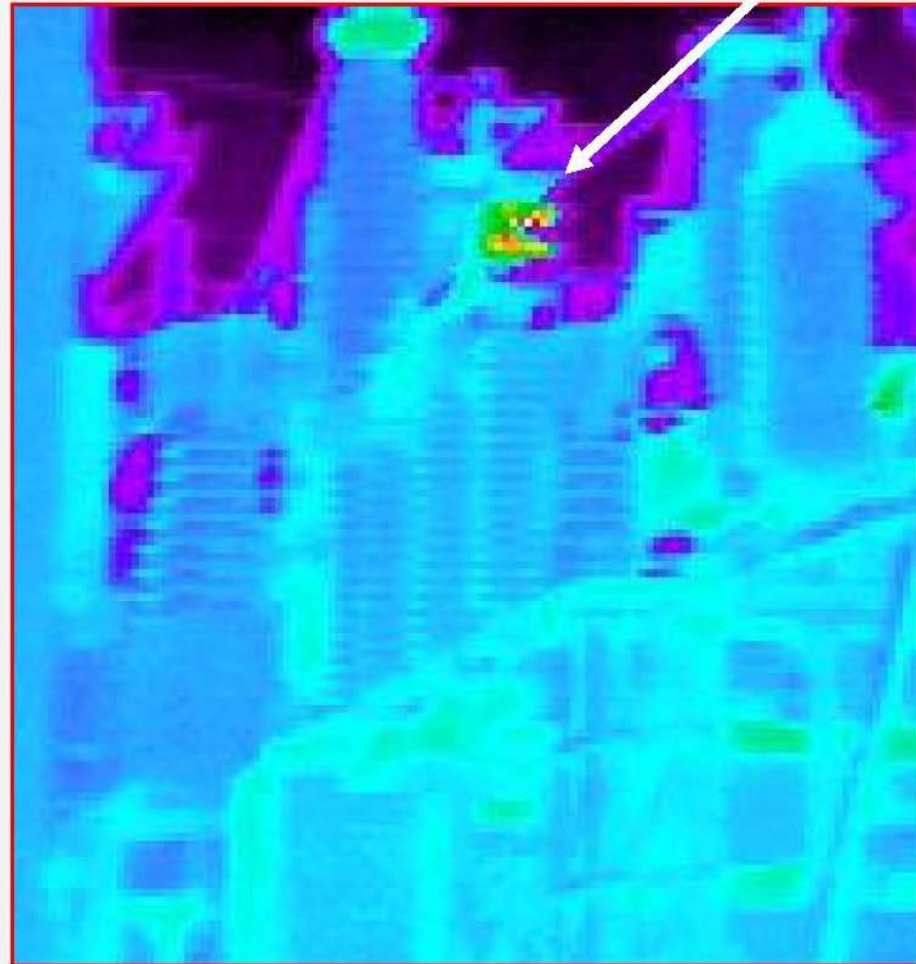
PM Survey by Inspection and Thermovision

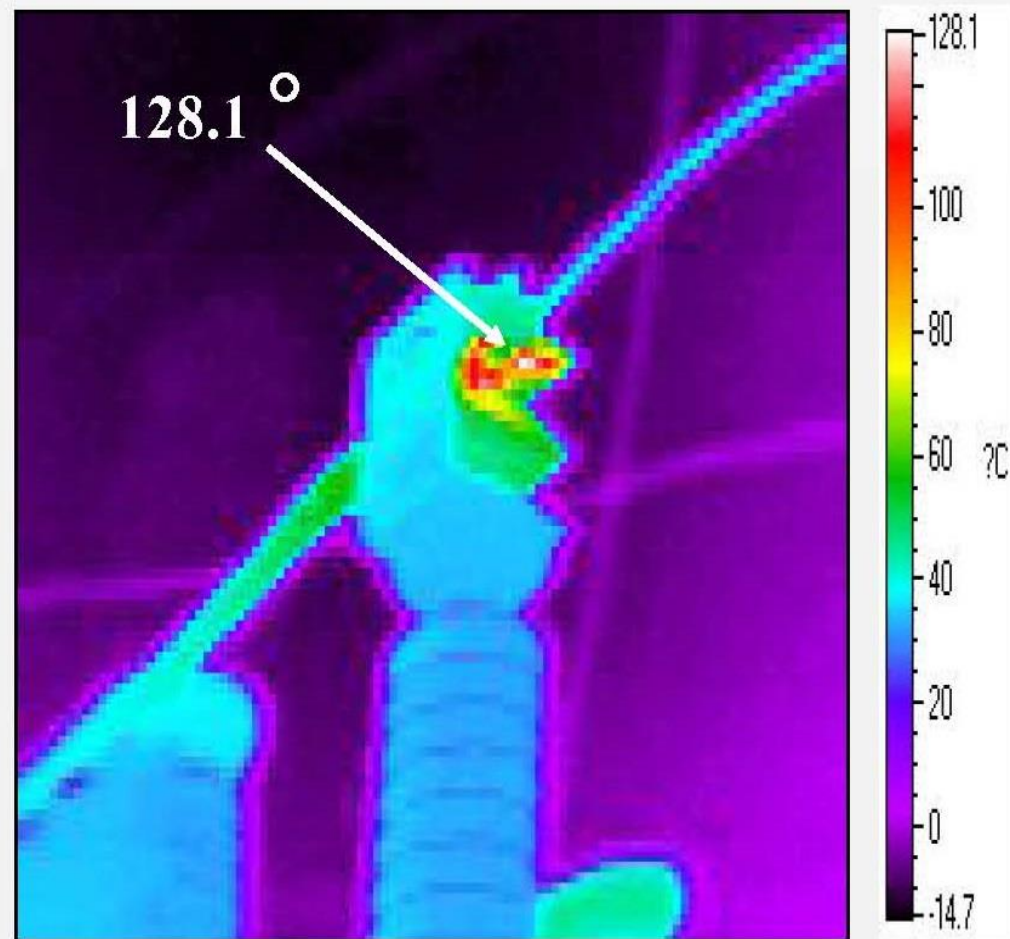


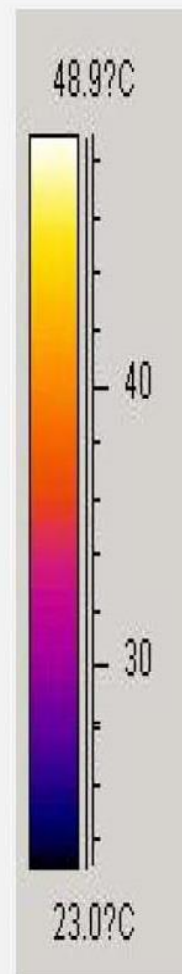
PM Survey by Thermovision and PD Detection



■ Hot Spot







- Partial Discharge (PD) disadvantages are
 - Create losses in the system
 - Gradually damage insulator -> finally breakdown
 - Damage Equipment
- What are the indicators of PD?
 - Ultrasonic
 - Ultraviolet (UV) light
 - Ozone

Preventive Maintenance by PD Detection

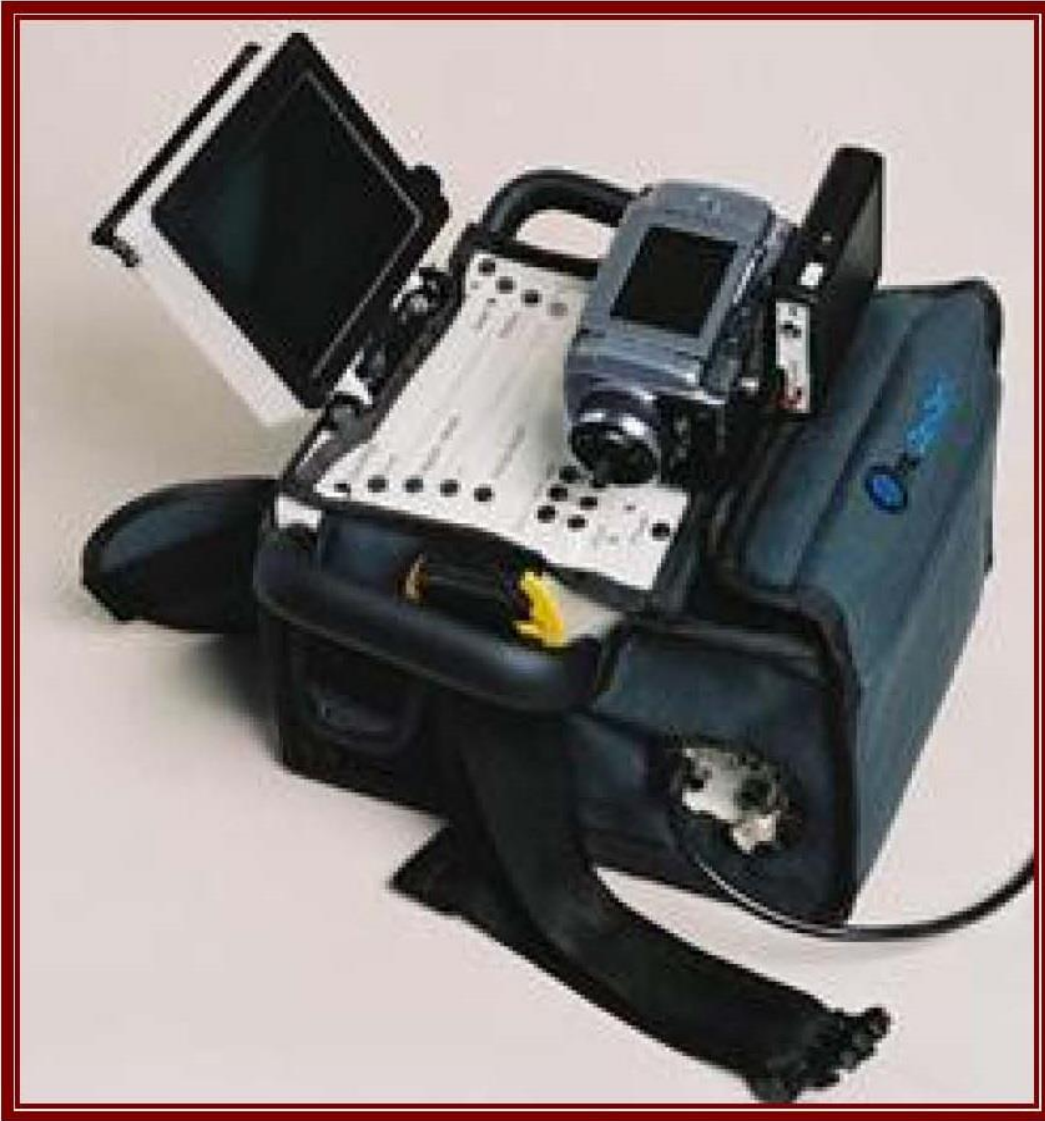
PD damaged Insulator are more likely to short circuit in high moisture environment or contact by animal





Ultrasonic Detector











Equipment Preventive Maintenance

33kV သယ်နီးကျွန်းမြောက် ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ဥက္ကံ ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ကွမ်းခြံကုန်း ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ဒဂုံဆပ်ကမ်း အမှတ်(၁) ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ဒဂုံမြို့သစ်(တောင်ပိုင်း)မြို့ရုံး ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင်ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV အင်းဝ ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV အင်းတိုင် ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV မူးလမန်း ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



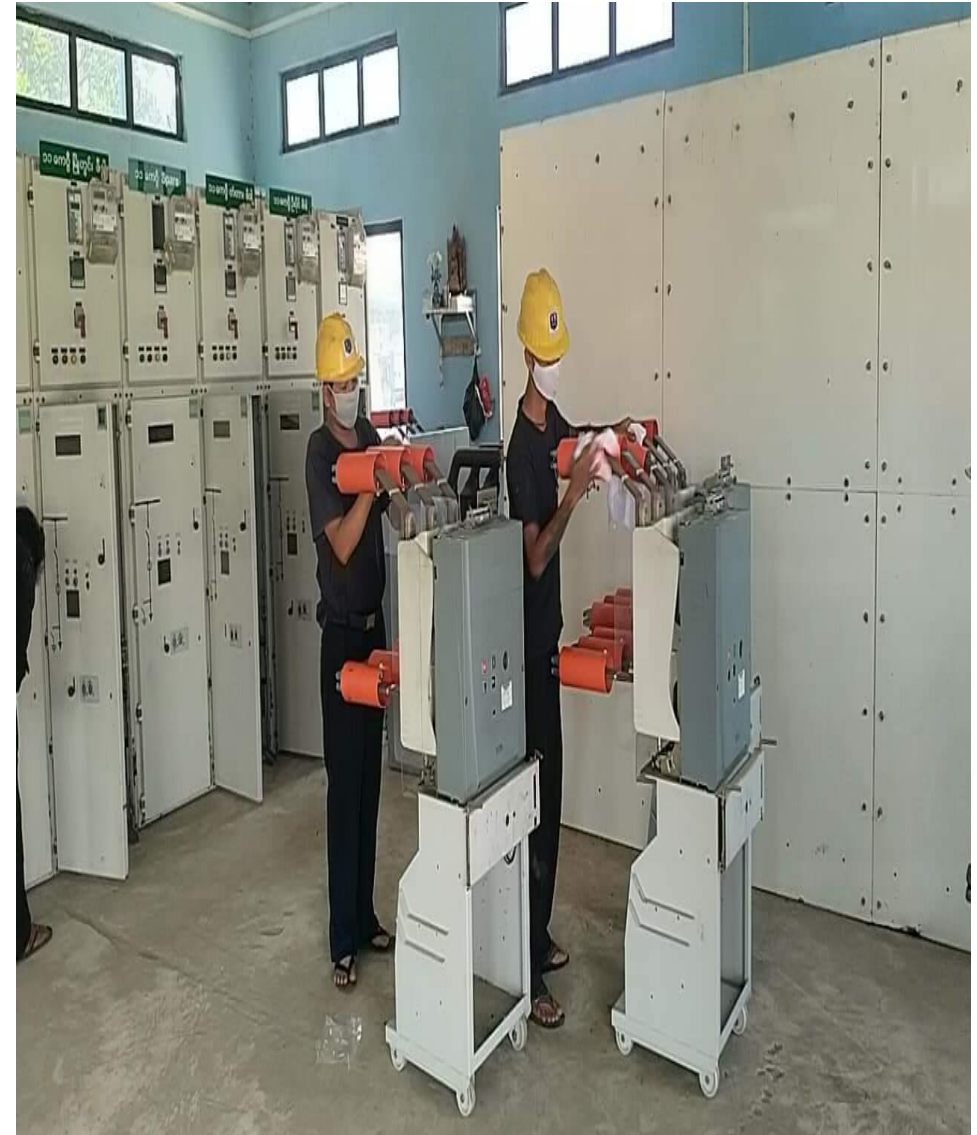
Equipment Preventive Maintenance

33kV လိုင်သာယာ ဇုန်(၁) ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



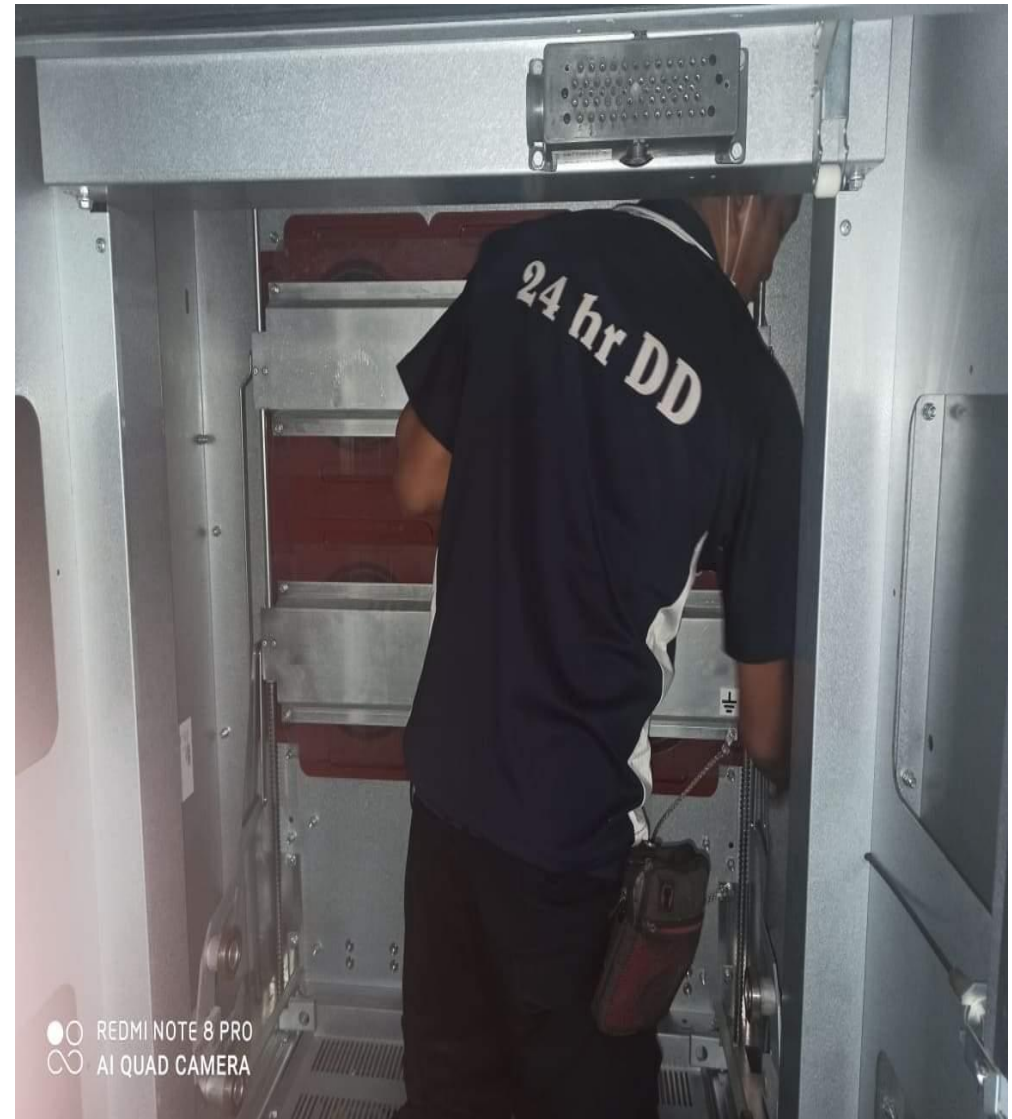
Equipment Preventive Maintenance

33kV ရွှေပြည်သာ စက်မှုဇုန်(၄) ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ရွှေအုန်းပင် ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



Equipment Preventive Maintenance

33kV ကြက်ဖြူကန် ဓာတ်အားခွဲရုံရှိ Switchgear Panel များအား ထိန်း/ပြင် ဆောင်ရွက်ခြင်း



THANK YOU

Q & A