Power Quality Evaluation on the Impact of Renewable Energy Generations in Thailand Power Grid

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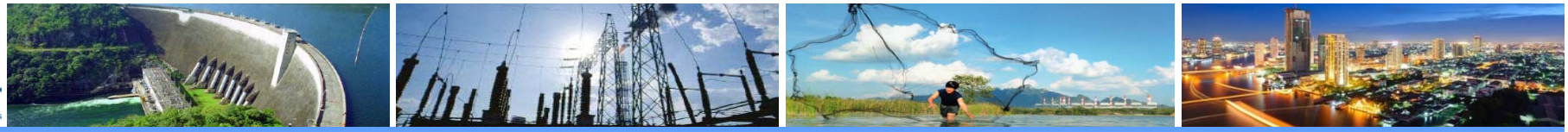
Control and Protection System Division

Electricity Generating Authority of Thailand

PQ SYNERGY 2015

EGAT
Power for Thai Happiness



OUTLINES

- Introduction
- Power Quality Guidelines of Thailand Power Grid
- PQ Evaluation at SPP Substation
- PQ Evaluation at Transmission Substation
- Problems and Challenges
- Conclusions




Introduction - Thailand Power Grid

Generation

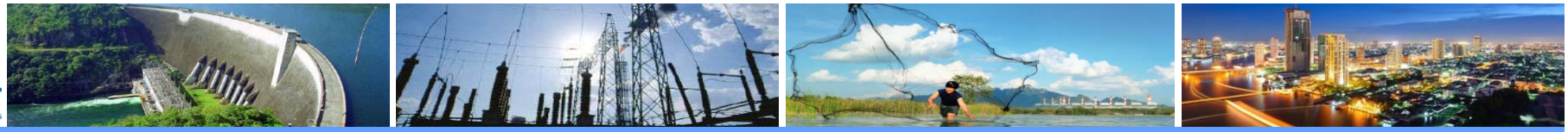
- EGAT
- IPP
- SPP, VSPP
- Neighboring Countries

Transmission

- EGAT

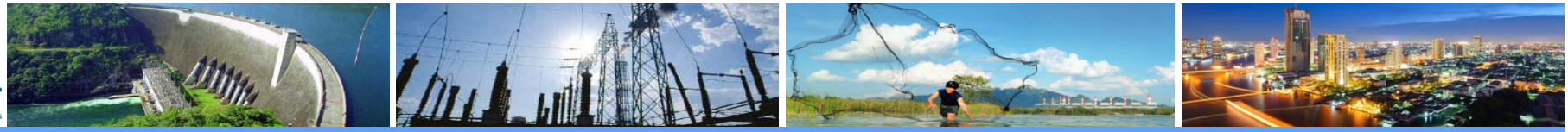
Distribution

- MEA
- PEA



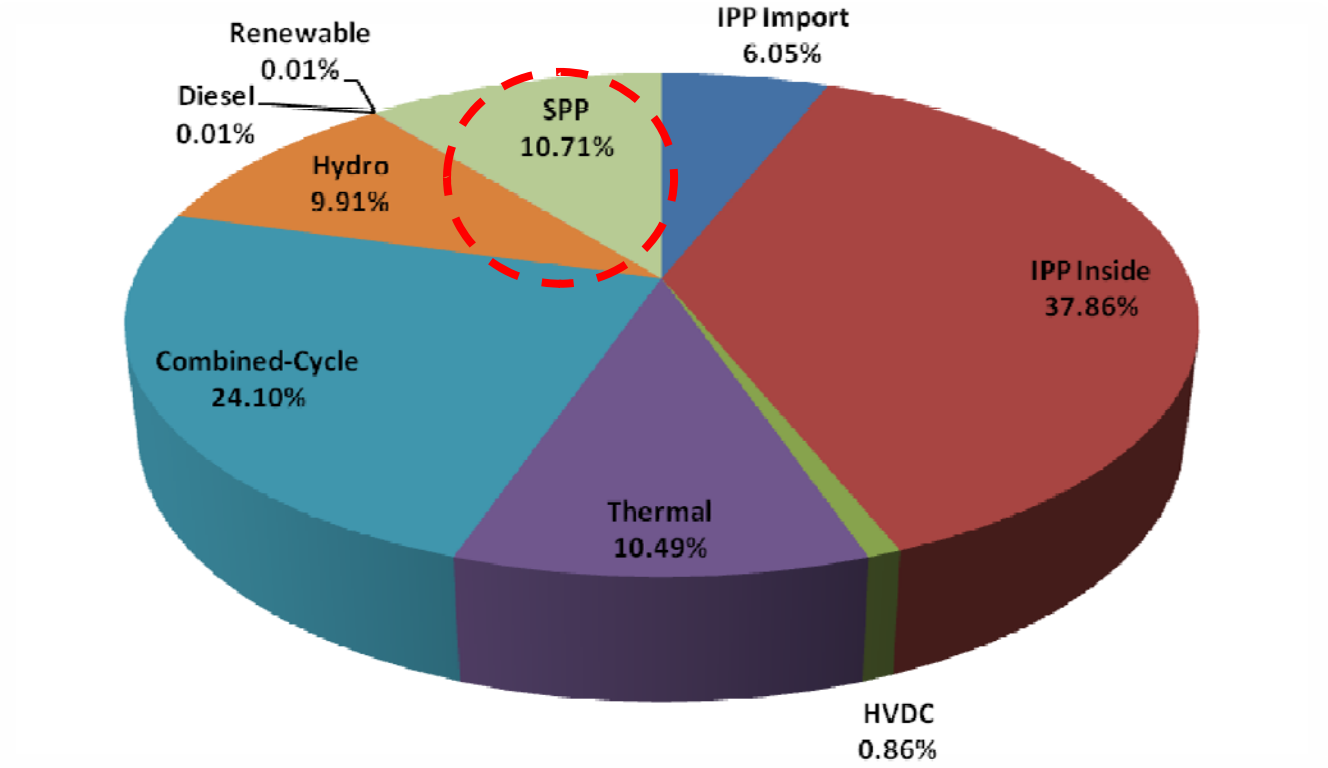
Introduction - Thailand Power Grid

- Renewable Energy Generations play as an important role of Thailand's power generation.
- Thailand's Government encourages the electricity suppliers to generate their electricity from renewable energy.



Introduction - Thailand Power Grid

Total Power Capacity 34,780.03 MW



Total Power Capacity of EGAT

Power System Control and Operation Division,

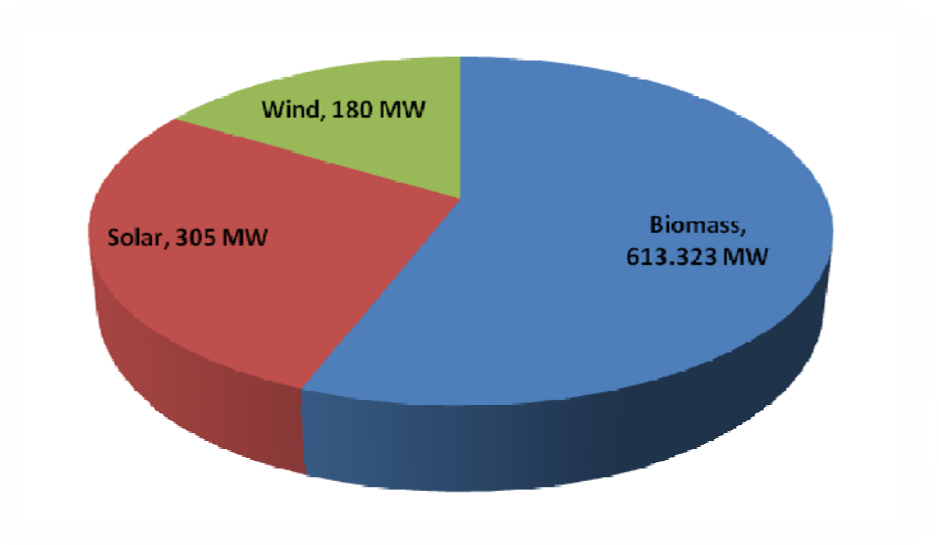
Electricity Generating Authority of Thailand (EGAT), March. 2015.

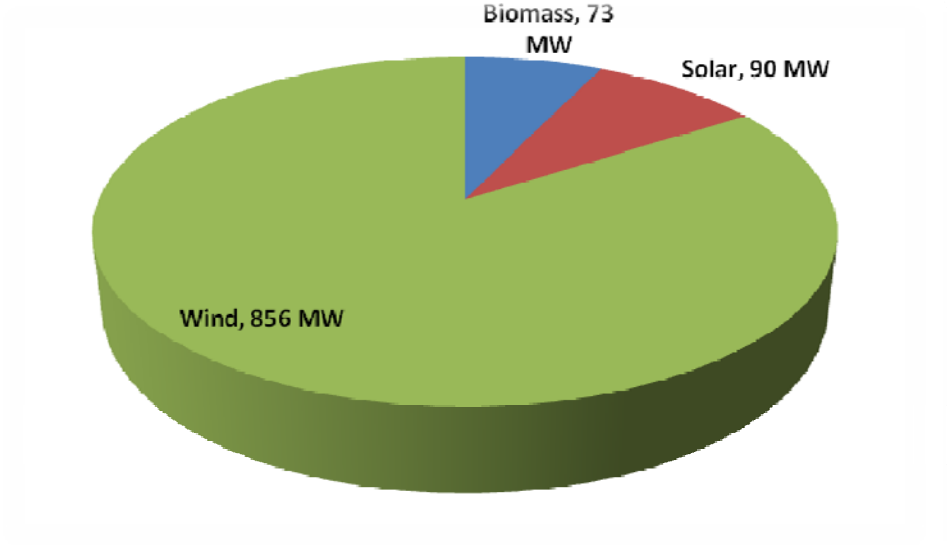



Introduction - Thailand Power Grid

SPP Renewable Energy Generation

Firm and Non-Firm Power Purchase Agreement





Started Commercial Operation

Total Power Purchase Agreement = 1,098.32 MW

Waiting for Commercial Operation

Total Power Purchase Agreement = 1,019.00 MW

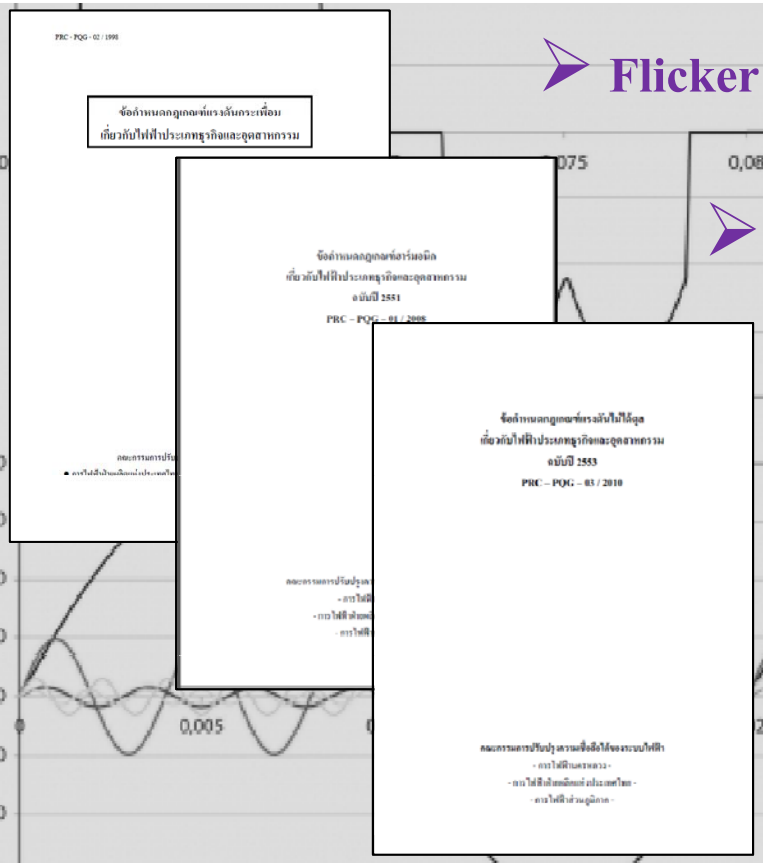
Power System Control and Operation Division,

Electricity Generating Authority of Thailand (EGAT), March. 2015.

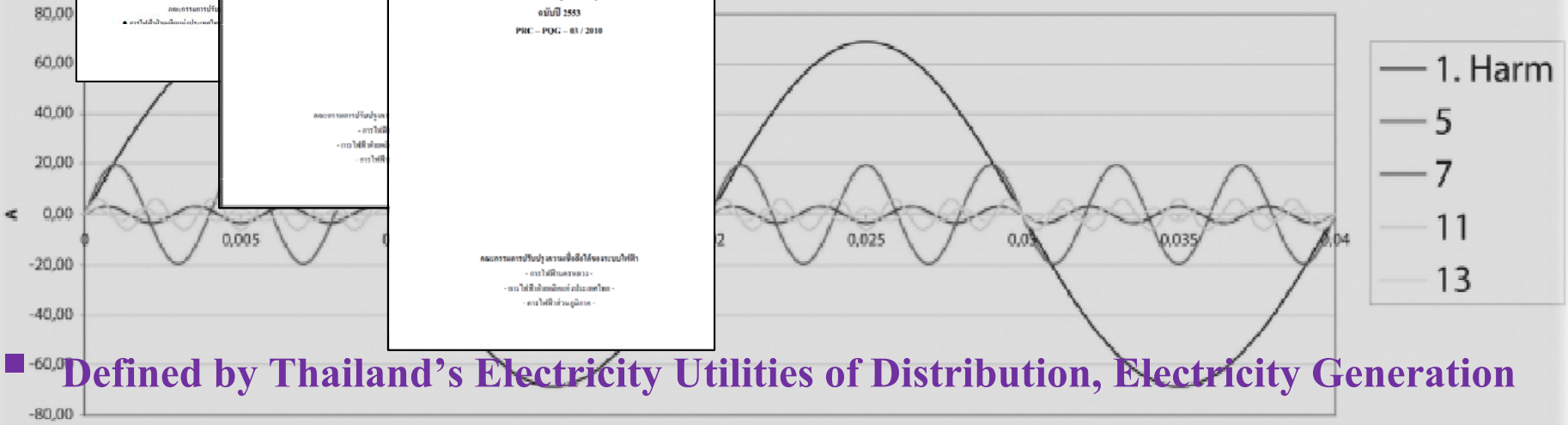



Thailand's Power Quality Guidelines

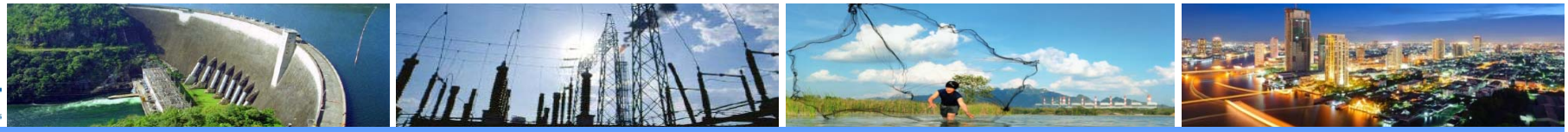
Power Quality Guidelines of Thailand Power Grid



- Flicker Guideline
- Harmonic Guideline
- Voltage Unbalance Guideline



- Defined by Thailand's Electricity Utilities of Distribution, Electricity Generation Authority of Thailand.



Thailand's Power Quality Guidelines

Limit of PQ Indexes from Thailand's Power Quality Guidelines

Supply System Voltage (kV) at PCC Point	Pst Limit
115 kV and below	1.0
above 115 kV	0.8

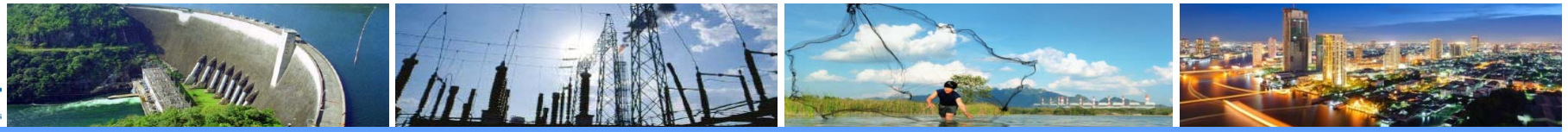
➢ **Short Term Flicker Severity Values**

Supply System Voltage (kV) at PCC Point	THDv Limit
400 V and below	5%
12, 22, 24 and 33 kV	4%
69, 115 kV and above	3%

➢ **Total Harmonic Voltage Distortion**

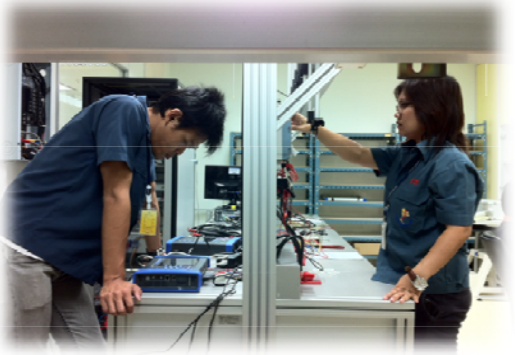
Supply System Voltage (kV) at PCC Point	Voltage Unbalance Factor (%u) Limit
500 kV	0.8
230 kV	0.8
69 and 115 kV	1.4
12, 22, 24 and 33 kV	1.8
400 V and below	2.0

➢ **Voltage Unbalance Factor**



Thailand's Power Quality Guidelines

Power Quality Monitoring according to EN50160 Standard



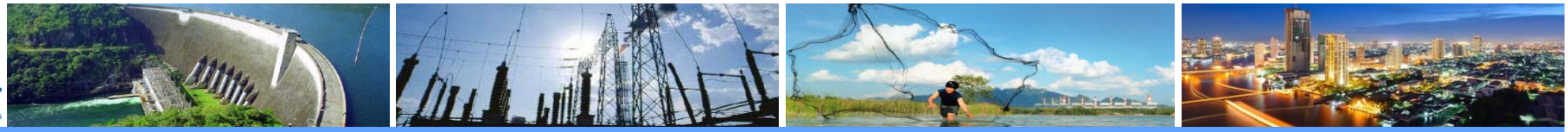
- Time interval 10 minutes
- Observation Period for 1 week or more
- Use the values at 95 Percentile for evaluation




PQ Evaluation at SPP Substation

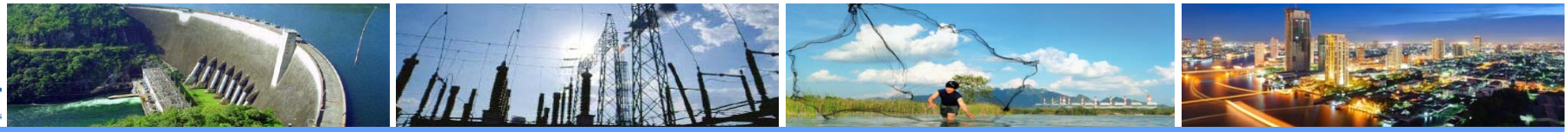
PQ Evaluation at SPP Substation. (SOLAR POWER PLANT)

- HUW Substation (90 MW)
- HC Substation (90 MW)



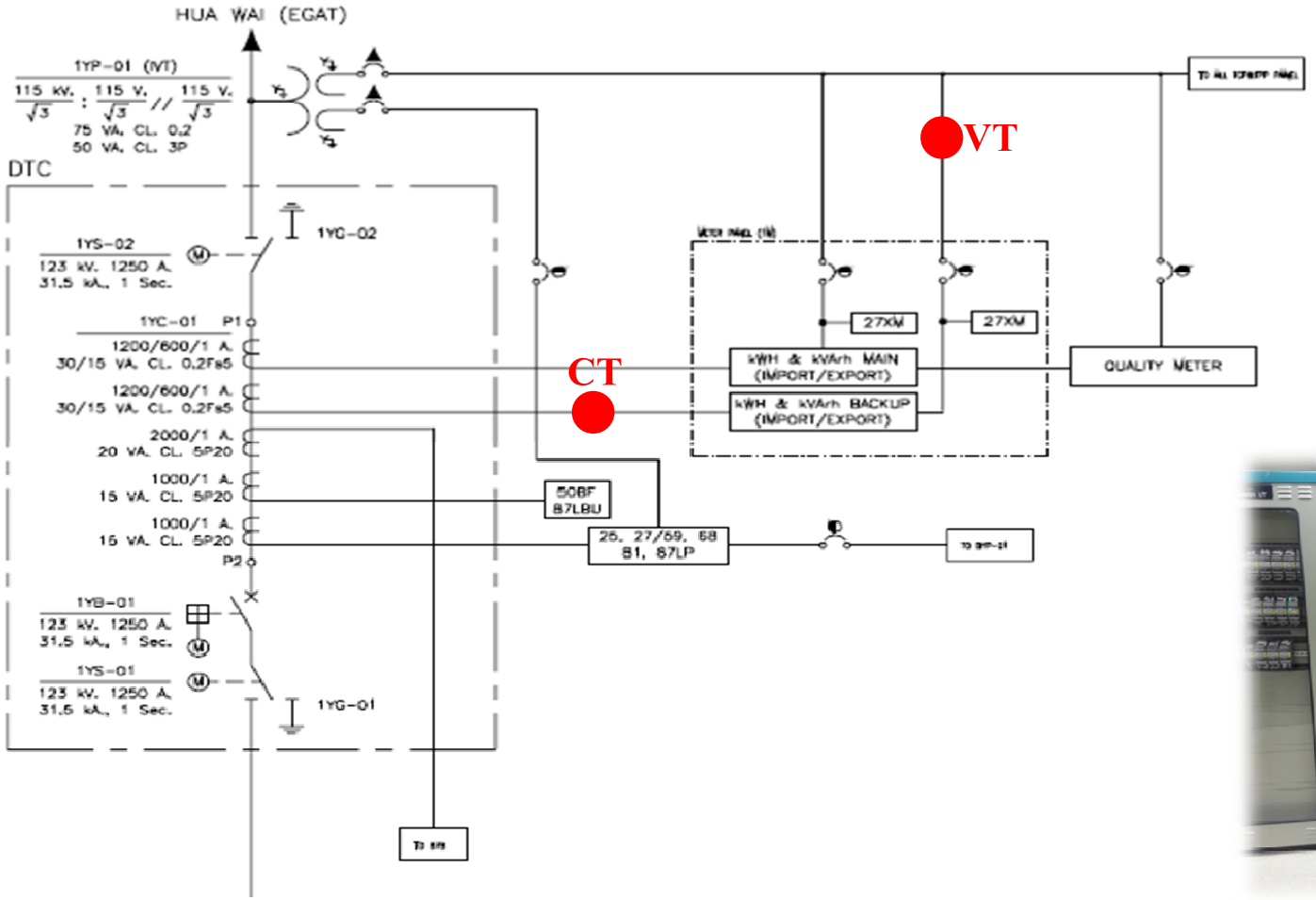
PQ Evaluation at SPP Substation - Proposed

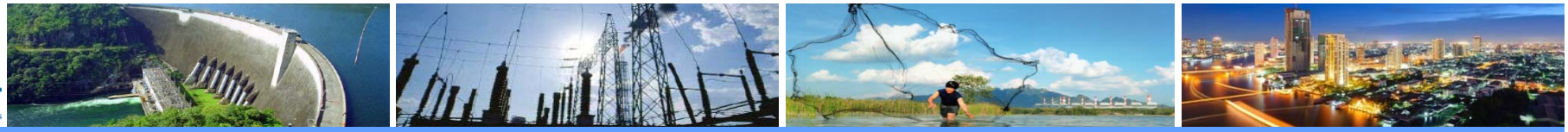
- To evaluate the impact of Renewable Energy Generations on Power Quality for their **First Synchronization to EGAT's system.**
- To provide PQ data for Grid Code **before their Commercial Operation Date.**



PQ Evaluation at SPP Substation - HUAWAI 115kV (HUW)

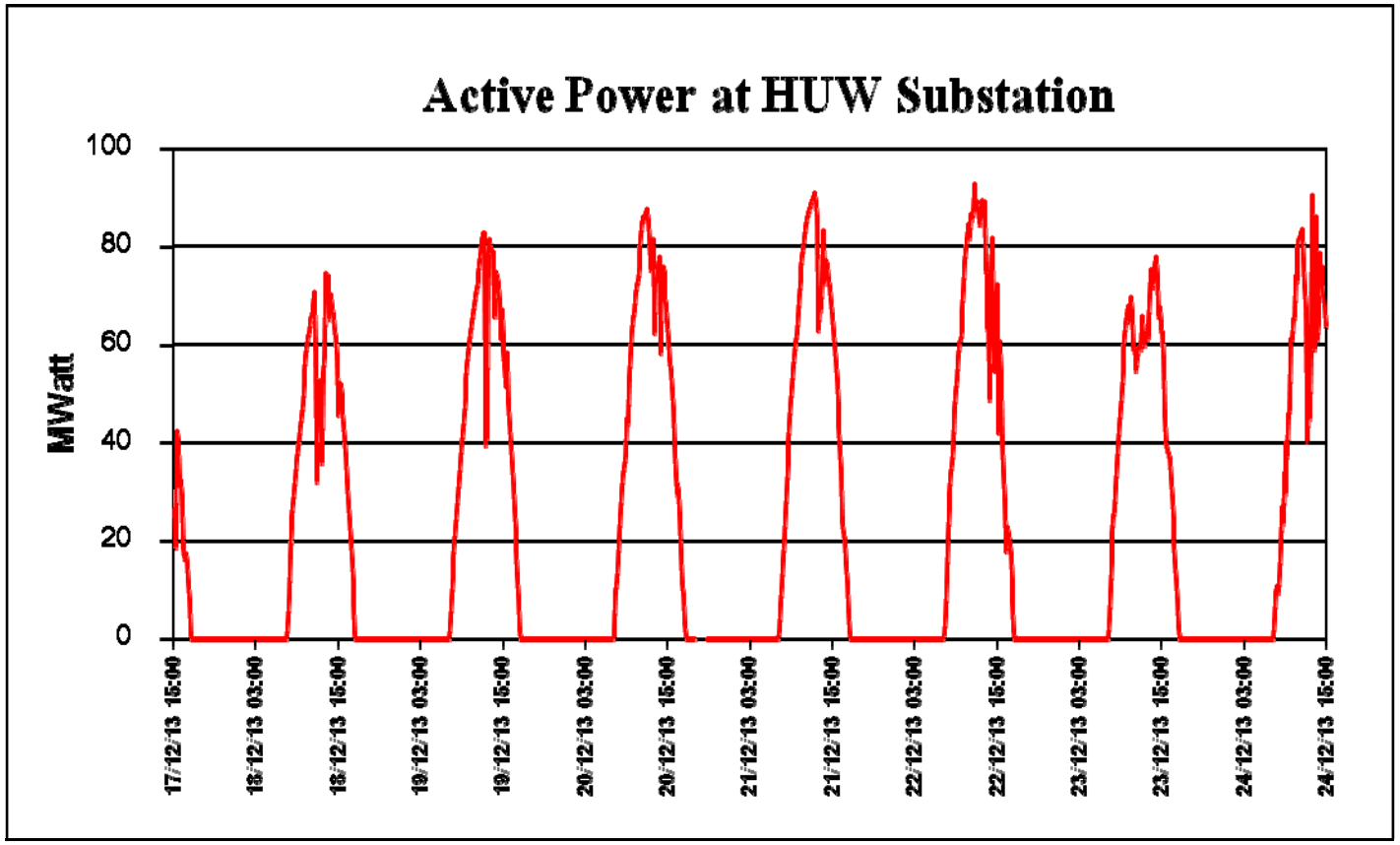
Installed PQ Meter at HUW Substation at Point of Common Coupling (PCC)



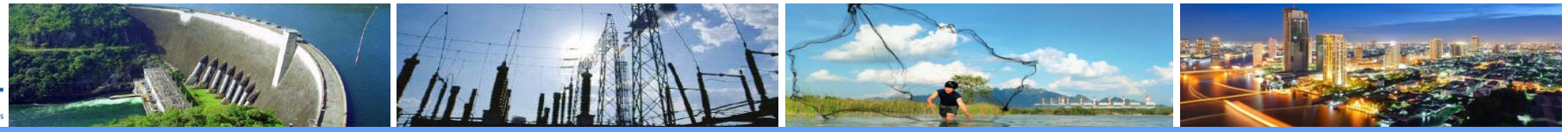


PQ Evaluation at SPP Substation - HUAWAI 115kV (HUW)

- Recording data every 10 minutes, during 17 - 24 December 2013 .



- The Solar Power Plant generated power 40 - 90 MW.



PQ Evaluation at SPP Substation - HUAWAI 115kV (HUW)

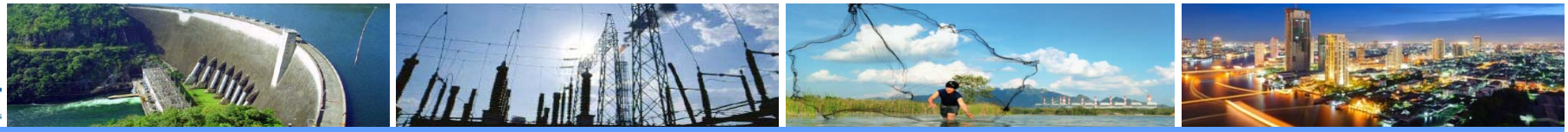
PQ Indexes compared with Limit of Guidelines.

Substation	Short Term Severity Values, Pst			
		Limit	As Found	Evaluated
HUW	Phase A	1.0	0.15 ✸	Passed
	Phase B	1.0	0.13	Passed
	Phase C	1.0	0.14	Passed

Substation	Total Harmonic Voltage Distortion , %THDv			
		Limit	As Found	Evaluated
HUW	Phase A	3%	1.40%	Passed
	Phase B	3%	1.32%	Passed
	Phase C	3%	1.47% ✸	Passed

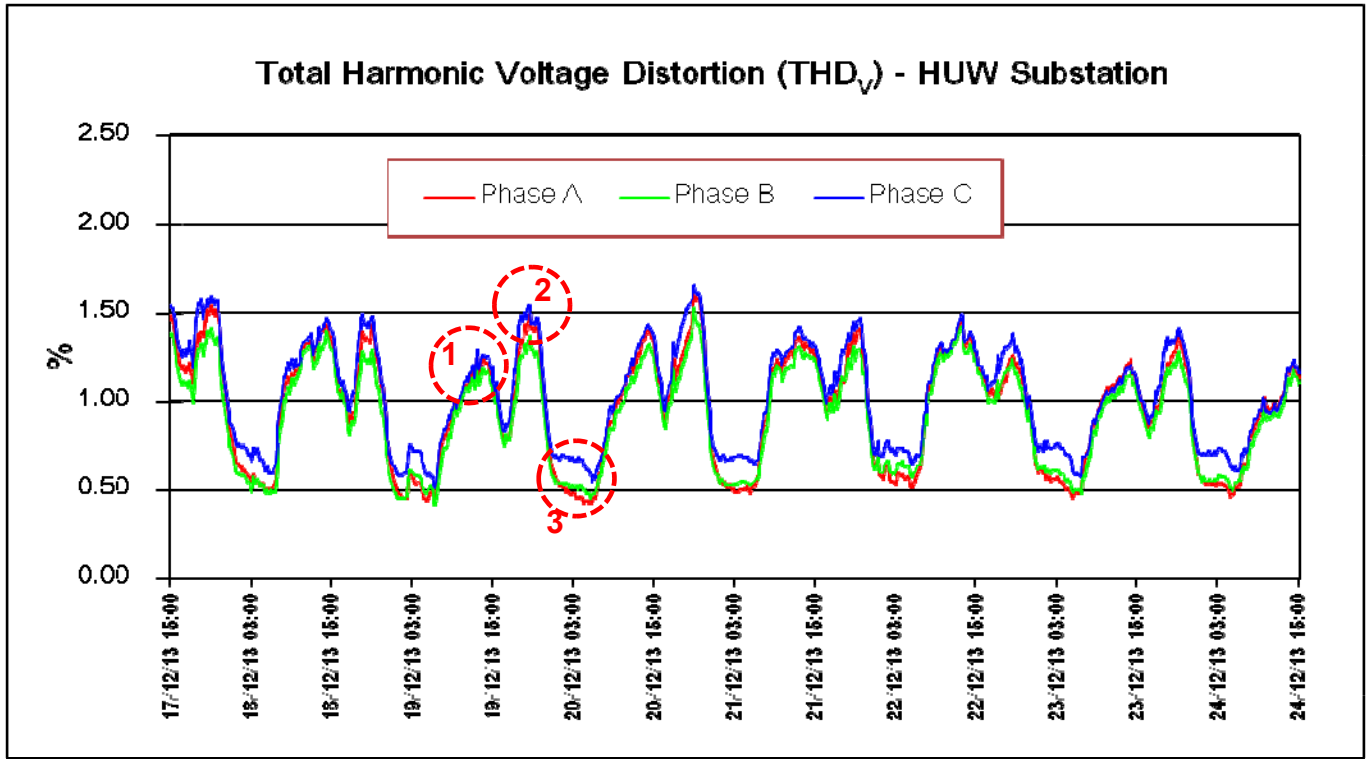
Substation	Voltage Unbalance Factor, %u		
	Limit	As Found	Evaluated
HUW	1.4%	0.77%	Passed

✸ Max Value



PQ Evaluation at SPP Substation - HUAWAI 115kV (HUW)

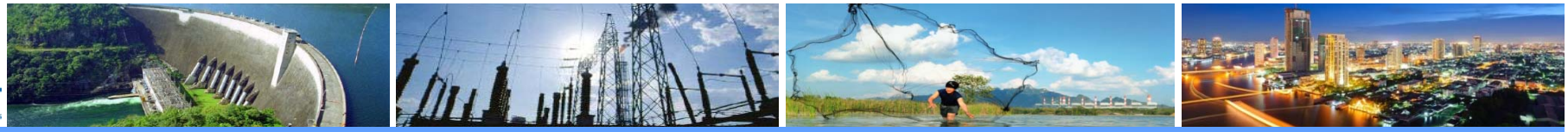
- The Background Harmonic of System is about 0.60% .



1 . 7.00 am - 6 .00 pm : THDv is 1.46% peak, caused by Generation and Load.

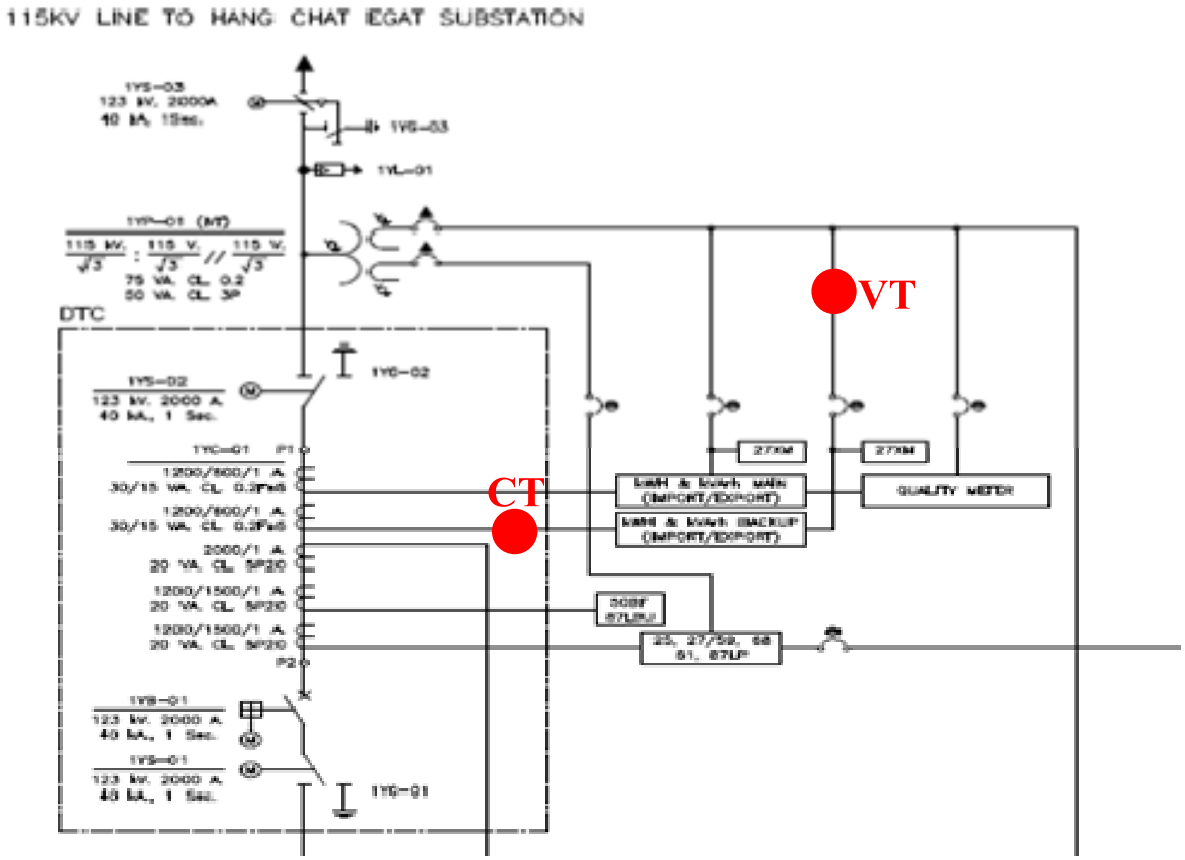
2 . 6.00 pm - 12.00 pm : THDv is 1.50% peak, caused by Load.

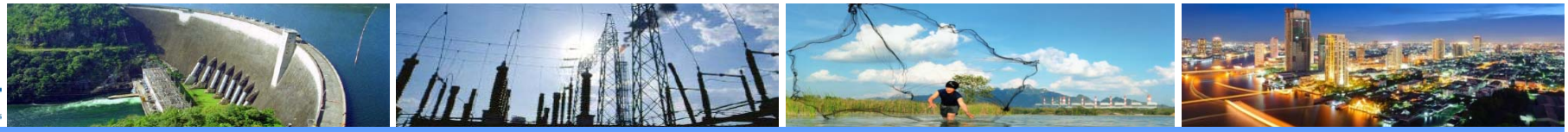
3 . 12.00 pm - 7.00 am : THDv is 0.60% peak, caused by Load.



PQ Evaluation at SPP Substation - HANG CHAT 115kV (HC)

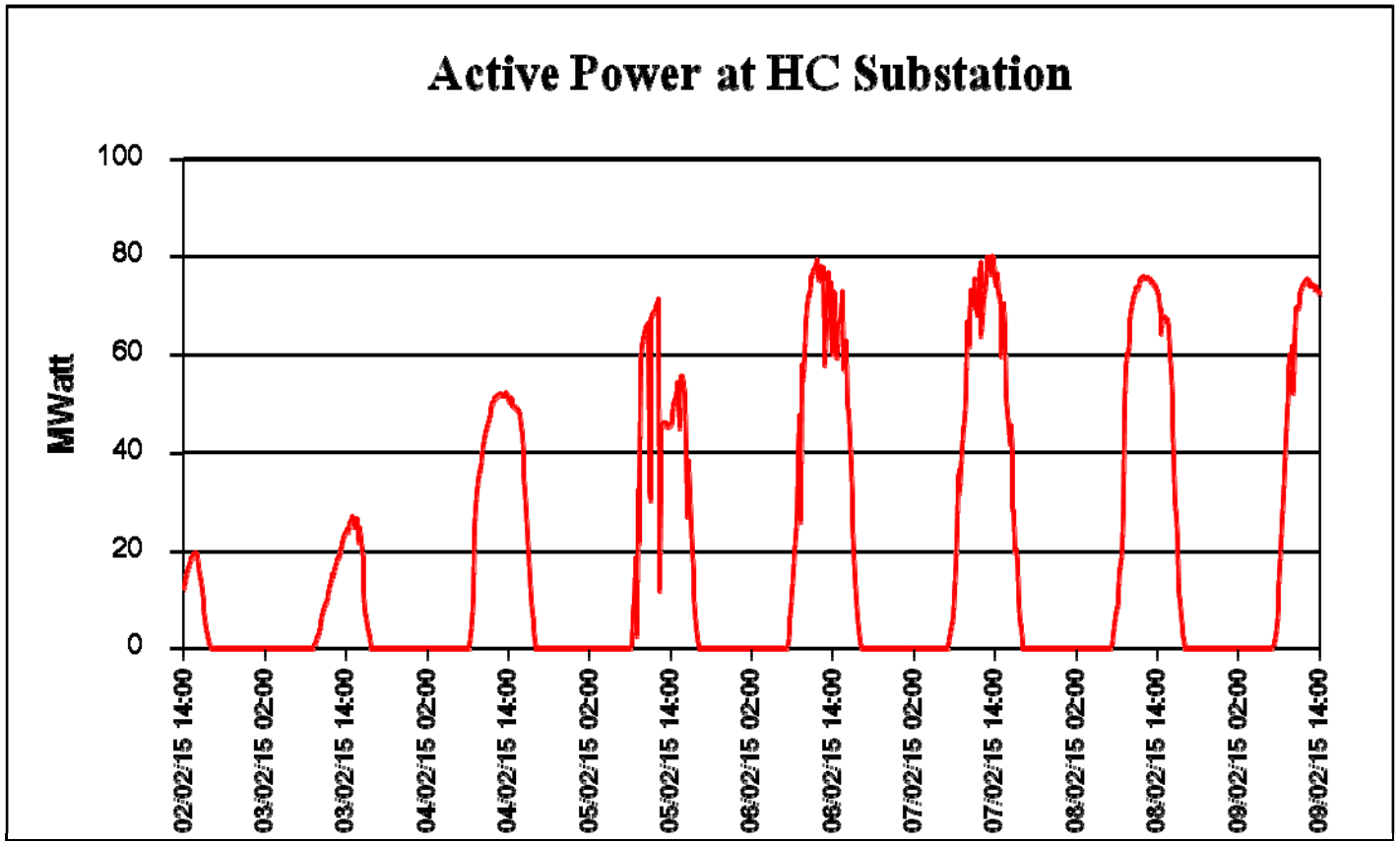
Installed PQ Meter at HC Substation at Point of Common Coupling (PCC)



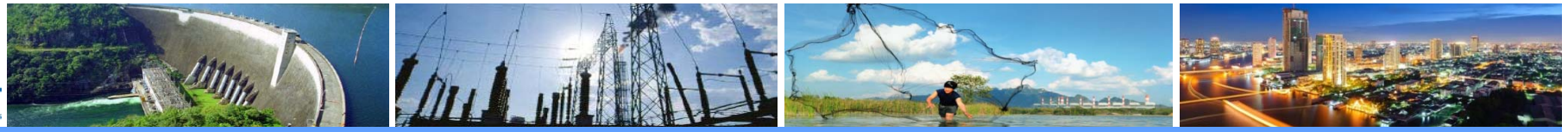


PQ Evaluation at SPP Substation - HANG CHAT 115kV (HC)

- Recording data every 10 minutes, during 2 - 9 February 2015 .



- The Solar Power Plant generated power 20 - 80 MW.



PQ Evaluation at SPP Substation - HANG CHAT 115kV (HC)

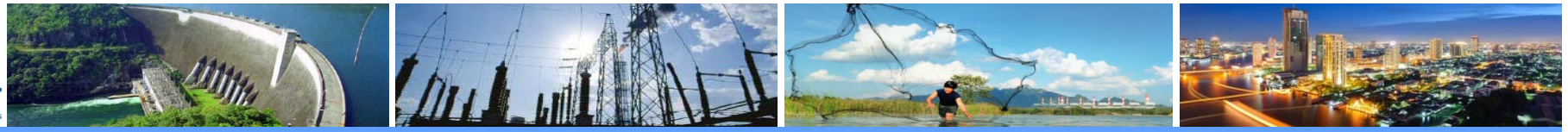
PQ Indexes compared with Limit of Guidelines

Substation	Short Term Severity Values, Pst			
		Limit	As Found	Evaluated
HC	Phase A	1.0	0.18 ✸	Passed
	Phase B	1.0	0.18	Passed
	Phase C	1.0	0.17	Passed

Substation	Total Harmonic Voltage Distortion , %THDv			
		Limit	As Found	Evaluated
HC	Phase A	3%	1.27% ✸	Passed
	Phase B	3%	1.14%	Passed
	Phase C	3%	1.22%	Passed

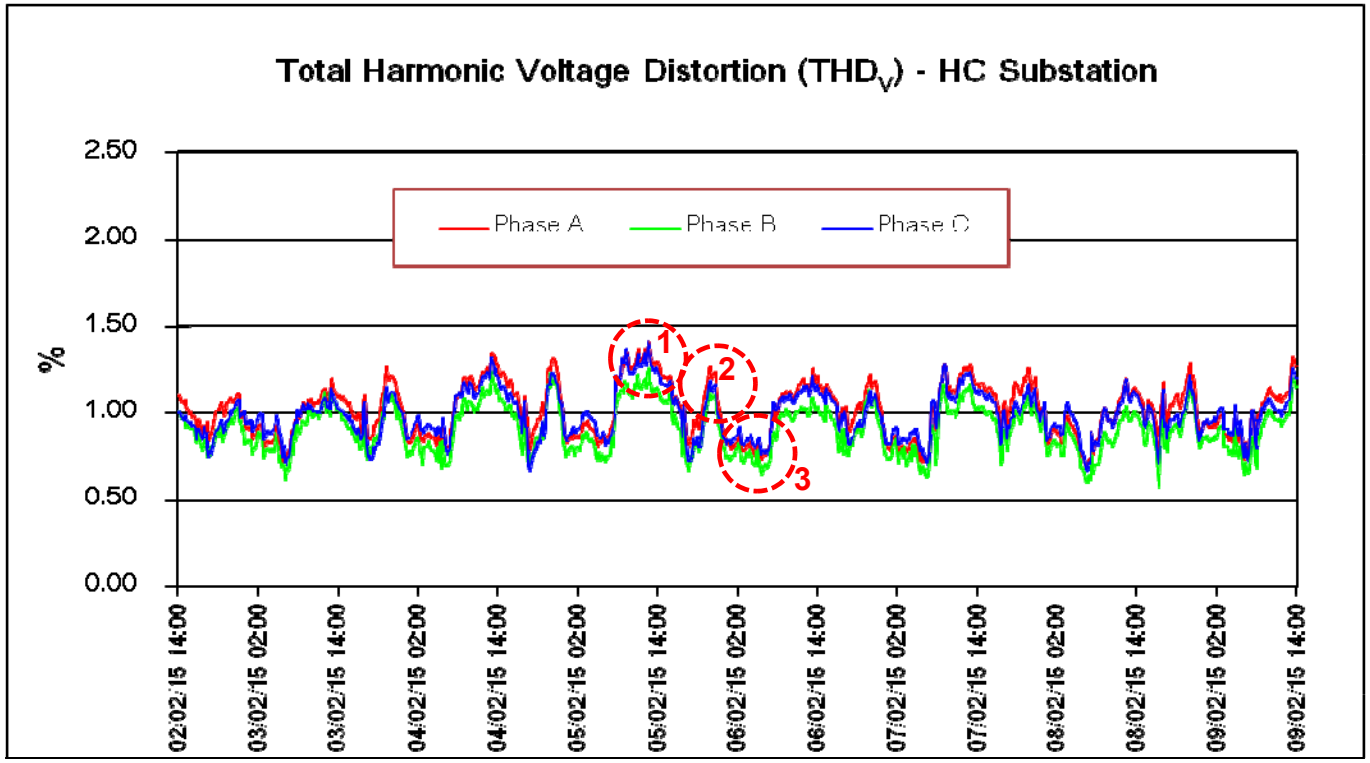
Substation	Voltage Unbalance Factor, %u		
	Limit	As Found	Evaluated
HC	1.4%	0.25%	Passed

✸ Max Value



PQ Evaluation at SPP Substation - HANG CHAT 115kV (HC)

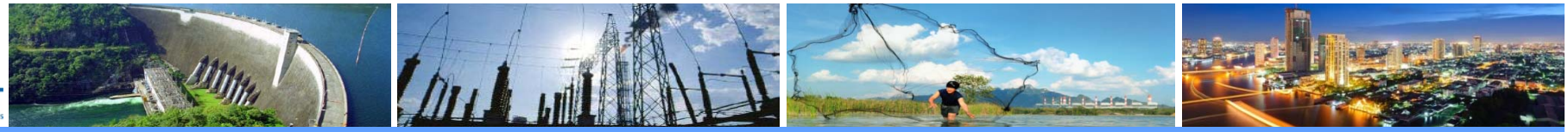
- The Background Harmonic of System is about 0.80% .



1 . 7.00 am - 6 .00 pm : THDv is 1.41% peak, caused by Generation and Load.

2 . 6.00 pm - 12.00 pm : THDv is 1.31% peak, caused by Load.

3 . 12.00 pm - 7.00 am : THDv is 0.80% peak, caused by Load.



PQ Evaluation at SPP Substation – Data Analysis

- HUW has index values of THDv and %u more than HC except Pst index.
- The maximum THDv of HUW and HC are increased by their Solar Plant and Distribution Load about 0.8% and 0.6% from Background THDv.
- The Power Quality Indexes at all interconnecting points are within the Guidelines.
- The Renewable Energy Generations do not contribute the impact on power quality in power system.

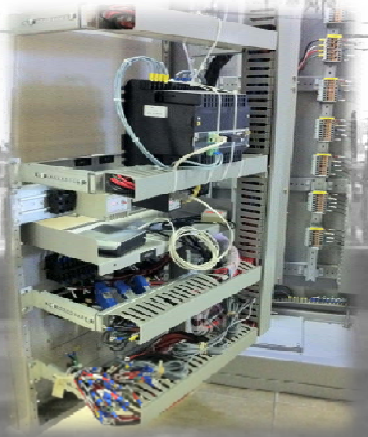
Substation	PQ Evaluation		
	Flicker	Harmonic	Unbalance
HUW	✓	✓	✓
HC	✓	✓	✓



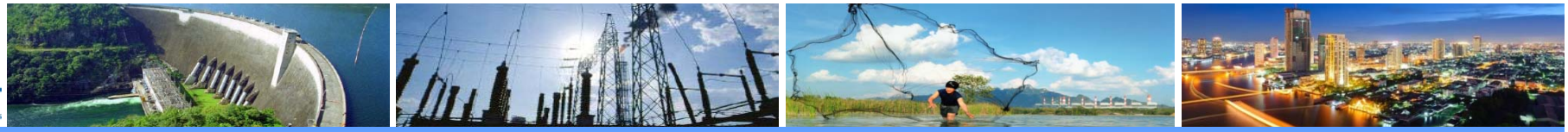

PQ Evaluation at Transmission Substation

PQ Evaluation at EGAT's Substations



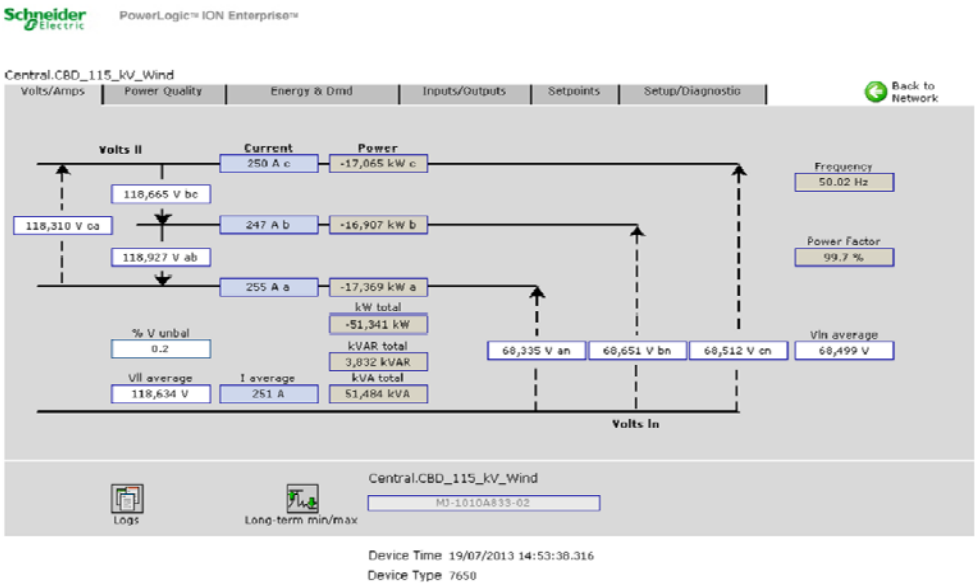



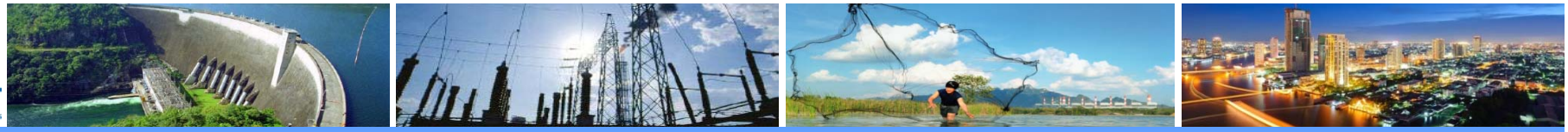
- CBD Substation 115 kV Line to SOLAR
- CBD Substation 115 kV Line to WIND1
- CBD Substation 115 kV Line to WIND2
- CPA Substation 115 kV Line to BIOMASS



PQ Evaluation at Transmission Substation - Proposed

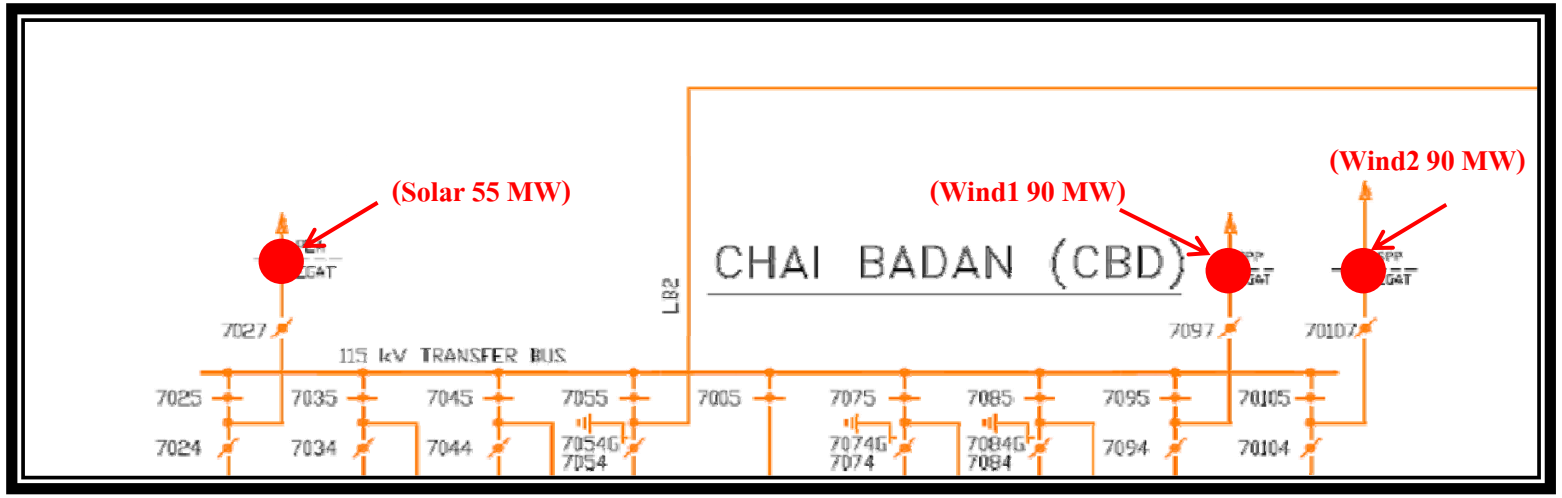
- To evaluate the impact of Renewable Energy Generations on Power Quality after their connected to EGAT's system.
- To get real time PQ data while Renewable Energy Generations are connected to EGAT's system.

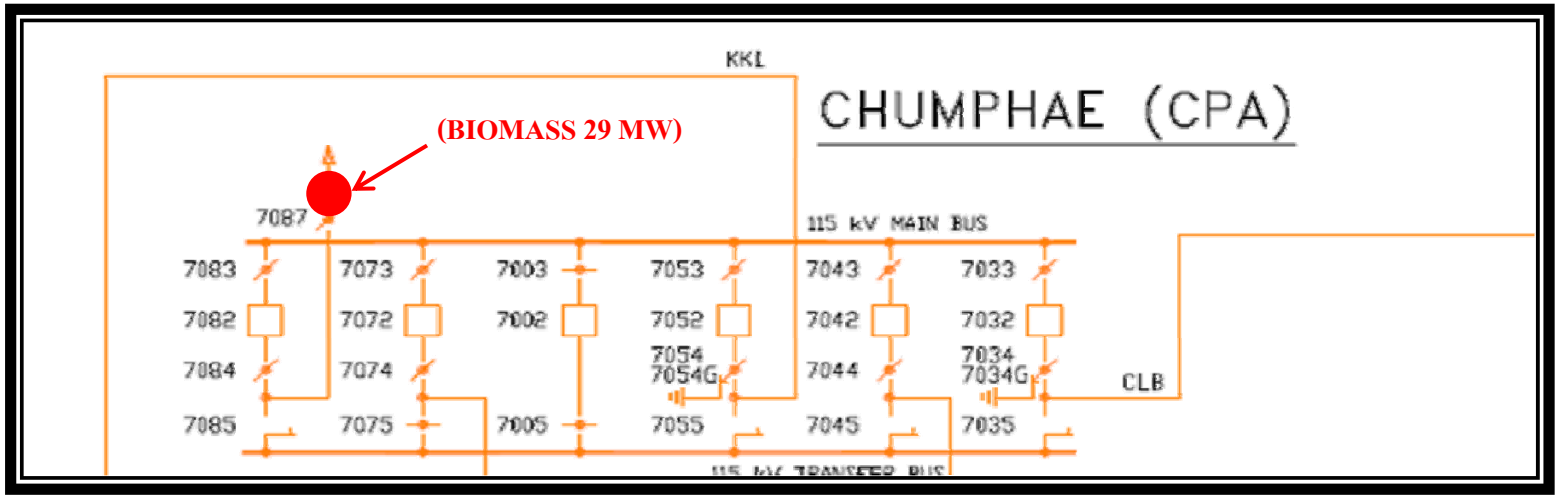




PQ Evaluation at Transmission Substation

Installed PQ Meter at EGAT's Substation at Point of Common Coupling (PCC)







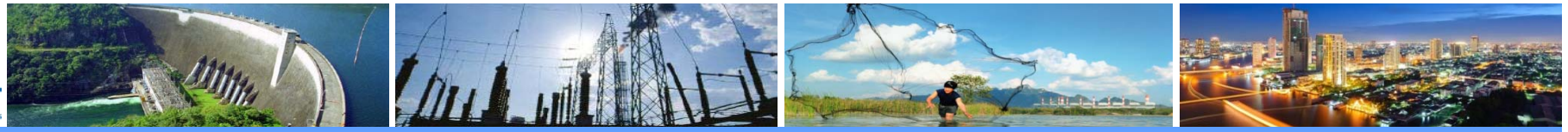

PQ Evaluation at Transmission Substation

PQ Indexes compared with Limit of Guidelines.

			Limit	As Found				Evaluated
				CBD(Solar) 55 MW	CBD(Wind1) 90 MW	CBD(Wind2) 90 MW	CPA(BIO) 29 MW	
Pst	JAN	Phase A	1.00	**0.17**	**0.18**	**0.17**	**0.16**	Passed
		Phase B	1.00	**0.16**	**0.19**	**0.16**	**0.17**	Passed
		Phase C	1.00	**0.17**	**0.19**	**0.17**	**0.18**	Passed
	FEB	Phase A	1.00	**0.17**	**0.18**	**0.17**	**0.17**	Passed
		Phase B	1.00	**0.16**	**0.18**	**0.16**	**0.18**	Passed
		Phase C	1.00	**0.17**	**0.18**	**0.17**	**0.18**	Passed
	MAR	Phase A	1.00	**0.23** ✸	**0.23** ✸	**0.23** ✸	**0.18**	Passed
		Phase B	1.00	**0.22**	**0.22**	**0.22**	**0.19** ✸	Passed
		Phase C	1.00	**0.21**	**0.21**	**0.21**	**0.18**	Passed

		Limit	As Found				Evaluated
			CBD(Solar) 55 MW	CBD(Wind1) 90 MW	CBD(Wind2) 90 MW	CPA(BIO) 29 MW	
%u	JAN	1.4	**0.76** ✸	**0.68** ✸	**0.68** ✸	**0.49** ✸	Passed
	FEB	1.4	**0.75**	**0.68**	**0.67**	**0.40**	Passed
	MAR	1.4	**0.70**	**0.63**	**0.63**	**0.28**	Passed

✸ Max Value



PQ Evaluation at Transmission Substation

PQ Indexes compared with Limit of Guidelines.

			Limit	As Found				Evaluated
				CBD(Solar) 55 MW	CBD(Wind1) 90 MW	CBD(Wind2) 90 MW	CPA(BIO) 29 MW	
%THDv	JAN	Phase A	3%	2.23% ✸	3.61%	3.77%	1.37%	Passed
		Phase B	3%	1.92%	3.24%	3.22%	1.53% ✸	Passed
		Phase C	3%	2.18%	3.31%	3.37%	1.27%	Passed
	FEB	Phase A	3%	2.09%	3.67% ✸	3.84% ✸	1.25%	Passed
		Phase B	3%	1.76%	3.30%	3.29%	1.36%	Passed
		Phase C	3%	2.03%	3.39%	3.41%	1.21%	Passed
	MAR	Phase A	3%	1.91%	3.08%	3.23%	1.24%	Passed
		Phase B	3%	1.62%	2.83%	2.80%	1.34%	Passed
		Phase C	3%	1.83%	2.76%	2.83%	1.26%	Passed

✸ Max Value

- Although THDv of Wind Energy Generations are exceed the limit, the result of evaluation are accepted due to Capacitive Voltage Transformer (CVT) characteristic. (CVT can get the exactly data only at fundamental frequency- 50 Hz) **Hence, the Harmonic Current must be concerned.**



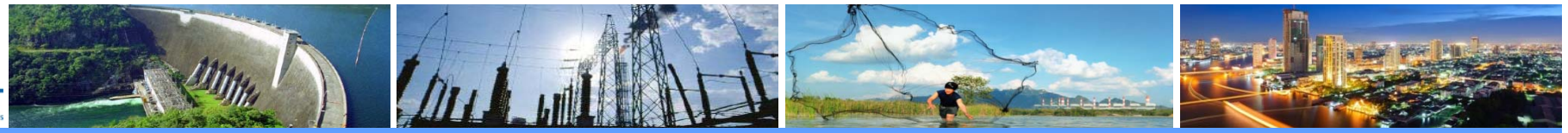

PQ Evaluation at Transmission Substation

- **The Harmonic Current Limit is calculated by program which is defined by Thailand's Electricity Utilities of Distribution and Generation.**

	Input Data
System Voltage[1] (kV)	1
Total Available Power[2] (MW)	1
Agreed Power[3] (MW)	1
Min. Short Circuit Power[4] (MVA)	1
Coincidence Factor[5]	1
Transfer Factor[6]	1

Planning Level			Summation Exponent	Global Contribution	Harmonic Order	Current Limit (A)
HV	MV	LV				
1	1.5	1.6	1	0.1	2	0.29
2	3	4	1	1	3	1.92
0.8	1	1	1	0	4	0.14
2	3	4	1.4	1.81790322	5	2.10
0.5	0.5	0.5	1.4	0	6	0.10
2	3	4	1.4	1.81790322	7	1.50
0.4	0.4	0.4	1.4	0	8	0.07
1	1.2	1.2	1.4	0	9	0.06
0.4	0.4	0.4	1.4	0	10	0.06
1.5	2	3	2	2.23606798	11	1.17
0.2	0.2	0.2	2	0	12	0.05
1.5	2	2.5	2	1.5	13	0.67

- **Calculation of the limit is derived from IEC 61000-3-6 (1996) Standard.**



PQ Evaluation at Transmission Substation

IEC 61000-3-6 (1996) Standard.

"Assessment of Emission limits for distorting loads in MV and HV Power Systems"

Emission Limits in HV System : $$E_{Uhi} \leq L_{hHV} \cdot \sqrt[\alpha]{\frac{S_i}{S_t} \cdot \frac{1}{F_{HV}}}$$

E_{Uhi} = Harmonic voltage emission Order h for Customer i

L_{hHV} = HV system planning level

Si = Agreed power of Customer i

St = Total Available Power in HV system

α = Harmonic Summation Exponent

F_{HV} = Coincidence factor for HV loads distorting simultaneously, typical value are between 0.4 and 1

PQ Evaluation at Transmission Substation

- **IEC 61000-3-6 (1996) Standard.**

"Assessment of Emission limits for distorting loads in MV and HV Power Systems"

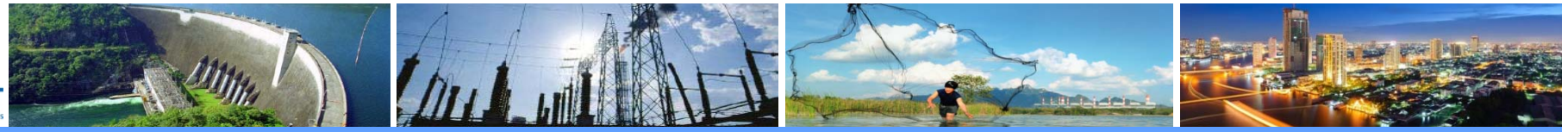
Harmonic Current Emission Limits : $$E_{Ihi} = \frac{E_{Uhi}(\%) \times (V_{LN} / 100)}{Z_h}$$

E_{Ihi} = Harmonic current emission Order h for Customer i

E_{Uhi} = Harmonic voltage emission Order h for Customer I

V_{LN} = System Voltage (Phase-Ground) of Customer

Z_h = Frequency-dependent impedance at PCC



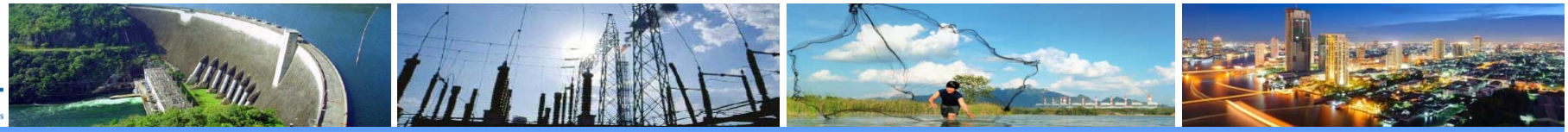
PQ Evaluation at Transmission Substation

- The Harmonic Current Limit is calculated by program.

	Input Data
System Voltage[1] (kV)	115
Total Available Power[2] (MW)	445.37
Agreed Power[3] (MW)	90
Min. Short Circuit Power[4] (MVA)	911.8859
Coincidence Factor[5]	1
Transfer Factor[6]	1

Planning Level			Summation Exponent	Global Contribution	Harmonic Order	Current Limit (A)
HV	MV	LV				
1	1.5	1.6	1	1	2	4.63
2	3	4	1	2	3	6.17
0.8	1	1	1	0.8	4	1.85
2	3	4	1.4	2	5	5.84
0.5	0.5	0.5	1.4	0.5	6	1.22
2	3	4	1.4	2	7	4.17
0.4	0.4	0.4	1.4	0.4	8	0.73
1	1.2	1.2	1.4	1	9	1.62
0.4	0.4	0.4	1.4	0.4	10	0.58
1.5	2	3	2	1.5	11	2.81
0.2	0.2	0.2	2	0.2	12	0.38
1.5	2	2.5	2	1.5	13	2.37

- Input Data
  - System Voltage V_{L-L} = 115 kV
  - Total Avaliable Power = 445.37 MW
  - Agreed Power = 90 MW
  - Minimum Short Circuit Power = 911.89 MVA
  - Coincidence and Transfer Factor are constant .



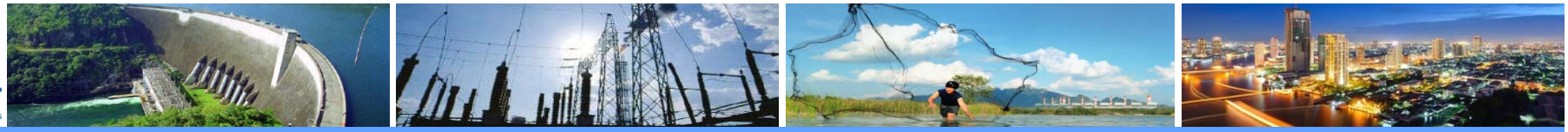
PQ Evaluation at Transmission Substation

Harmonic Current compared with the Harmonic Guideline.

Harmonic Current (A)	Limit	As Found						Evaluated
		JAN		FEB		MAR		
		CBD(Wind1)	CBD(Wind2)	CBD(Wind1)	CBD(Wind2)	CBD(Wind1)	CBD(Wind2)	
Order 3	6.17	1.18 ✸	1.13 ✸	0.59	0.53	0.62	0.58	Passed
Order 5	5.84	3.44 ✸	3.43 ✸	2.66	2.56	2.09	2.04	Passed
Order 7	4.17	1.36	0.79	1.47 ✸	0.90 ✸	0.96	0.71	Passed
Order 9	1.62	0.25	0.12	0.26 ✸	0.13 ✸	0.22	0.11	Passed
Order 11	2.81	1.58	0.74	1.73	0.79	1.75 ✸	0.85 ✸	Passed
Order 13	2.37	0.63 ✸	0.60 ✸	0.63	0.56	0.59	0.53	Passed

✸ Max Value

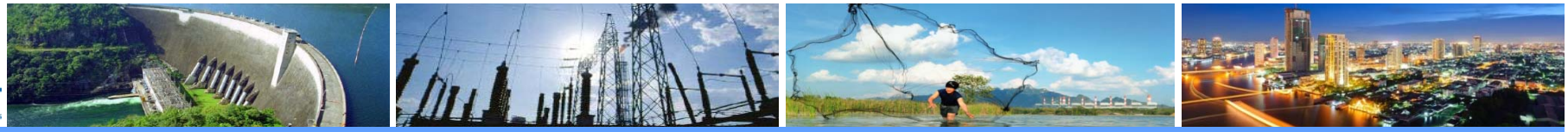
- Normally, the Wind Energy Generation produced significant levels of 3^{rd}, 5^{th}, 7^{th}, 9^{th}, 11^{th}, and 13^{th} Harmonic Current.



PQ Evaluation at Transmission Substation – Data Analysis

- The Power Quality Indexes of all Renewable Energy Generations are within Guidelines although THDv of Wind Energy Gennerations are exceed a limit. After considering Harmonic current, the harmonic distortion of Wind energy generation are accepted.
- The impact of power quality in the power system will be increased by Power Generation of Renewable Energy.
- The Renewable Energy Generations do not contribute the impact on power quality in power system.

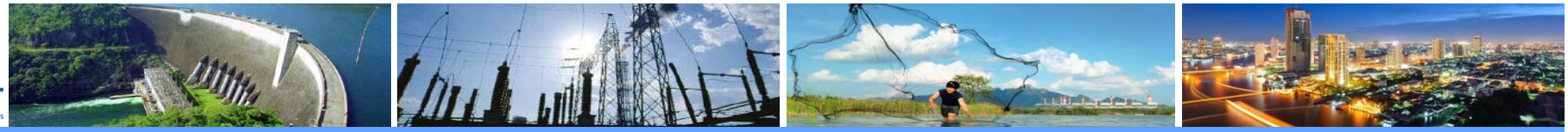
Substation	PQ Evaluation		
	Flicker	Harmonic	Unbalance
CBD (Solar)	✓	✓	✓
CBD (Wind1)	✓	✓	✓
CBD (Wind2)	✓	✓	✓
CPA (BIOMASS)	✓	✓	✓



Problems and Challenges

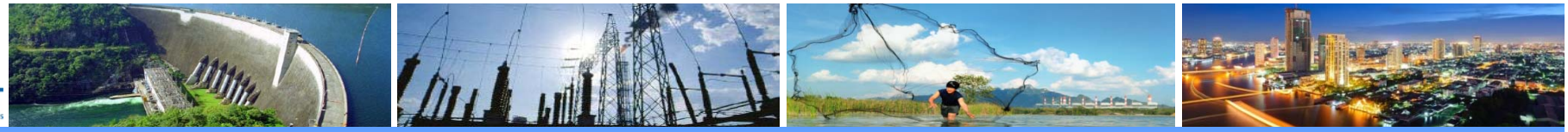
- Most of 115 kV EGAT's substations use Capacitive Voltage Transformer (CVT) as measurement instrument. Therefore, harmonic voltage data from PQ meters that always has harmonic voltage value more than its should be.

- Wind Energy Generations have high generation rate in Light Load Period, during 10.00 pm - 6.00 am. Hence, the energy storages and energy management should be more concerned.



Conclusions

- The impact of power quality will be more severe due to the increasing of Renewable Energy Generations.
- In the future, For many types of the new Renewable Energy Generation must be evaluated before they connect to power system and after they connected. The PQ data still collect for monitoring the impact of Renewable Energy Generations on power quality as well.
- The power quality evaluation method and data will be used to be the benchmark on Thailand's grid code for control the impact of Renewable Energy Generations on power quality.



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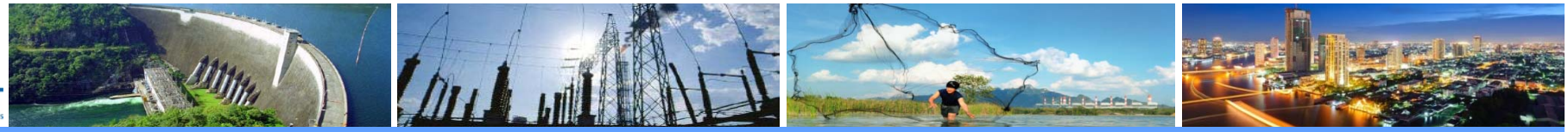

THANK YOU